C. Douglas copy
NPWS

Clara / Raheenmore Bogs
PHD 1995

Laura Kelly

Text only

IRISH - DUTCH RAISED BOG STUDY
GEOHYDROLOGY AND ECOLOGY

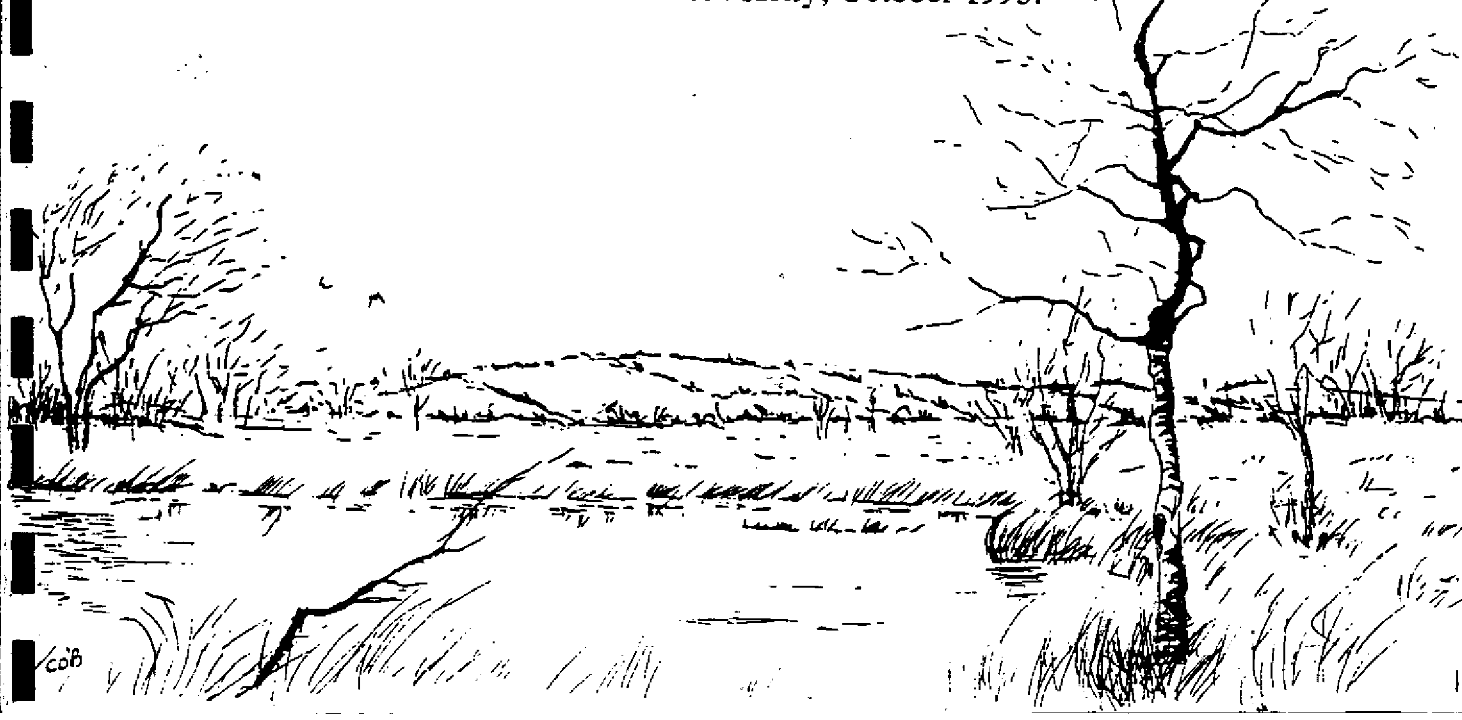
- National Parks and Wildlife Service of the Office of Public Works, Dublin
- Department of Nature Conservation, Environmental Protection and Wildlife Management, The Hague
- Geological Survey of Ireland, Dublin
- National Forest Service, Driebergen

Hydrology, Hydrochemistry and Vegetation of Two Raised Bogs in County Offaly.

A thesis submitted for the Degree of Doctor of Philosophy
University of Dublin, Trinity College.

By

M. Larissa Kelly, October 1993.



I declare:

(a) That this thesis has not been previously submitted for a degree at Trinity College Dublin, or any other university.

(b) That this thesis is entirely my own work, unless otherwise stated.

(c) That the library may lend or copy this thesis on request.

M. Larissa Kelly

M. Larissa Kelly.

TABLE OF CONTENTS.

Summary.		i
Acknowledgements.		ii
List of Figures.		iv
List of Plates.		viii
List of Tables.		x
		Page No.
Chapter 1. Introduction.		**1**
1.1	Raised bogs.	1
1.2	Raised Bog Distribution in Ireland.	1
1.3	The Importance of Raised bogs.	1
1.4	Background to The Project.	3
1.4.1	The aims of The Ecology Research.	4
1.5	Hydrology and Hydrochemistry.	4
1.5.1	Hydrology.	4
1.5.2	Hydrochemistry.	5
Chapter 2. Site descriptions and Environment.		**8**
2.1	Geology and Geomorphology.	8
2.2	Situation.	9
2.2.1	Clara Bog	9
2.2.2	Raheenmore Bog.	9
2.3	Climate.	9
2.4	Past Management, Drainage and Peat Cutting.	11
Chapter 3. Vegetation.		**13**
3.1	Introduction.	13
3.2	Methods.	13
3.3	Computer processing.	14
3.4	Mire vegetation classification.	14
3.5	Synoptic tables.	15
3.6	Vegetation classification and community descriptions.	16
Chapter 4. Hydrological and Hydrochemical Methods.		**52**
4.1	Hydrochemistry.	52
4.1.1	Methods.	52
4.1.2	Precipitation chemistry.	54
4.1.3	Water Classification.	54
4.2	Hydrology.	55
4.2.1	Methods.	55
4.2.2	Duration Lines.	55
4.3	Computer Methods.	56
4.3.1	CANOCO.	56
4.3.2	Data Transformation.	57

SUMMARY

The vegetation communities of Clara and Raheenmore raised bogs were examined in relation to their hydrological and hydrochemical regimes. This was undertaken with a view to the conservation and management of both sites.

The water table heights and hydrochemistry of the main plant communities at both sites were monitored over a period of two years. Canonical Correspondence Analysis was used to detect the patterns in vegetation that are correlated to trends in environmental variables.

Three main divisions in community types were recognised: high bog communities, soak communities and marginal communities.

The most important factors influencing the distribution of community types on the high bog were average water table depth and fluctuation. The chemistry of interstitial water from within the various intact communities of the high bog did not differ significantly. The hydrochemistry of the disturbed communities indicated a certain amount of increased peat mineralisation with elevated levels of Nitrogen and Phosphorus.

The marginal communities are of three main types, wet cut-away sites with indications of peat mineralisation, dry cut-away sites with indications of peat mineralisation and communities with hydrochemical analyses suggesting upwelling ground water.

Two soak types were identified: 1) the Lough Roe type, colonised by mesotrophic fen plant species with hydrochemical analyses indicating an input of ions from ground water: 2) the Shanley's Lough type, colonised by plant species indicating some mineral enrichment. This is derived from focussed flow rather than from ground water inputs.

Vegetation mapping of the two bogs, using aerial photography, highlighted the level of damage and degradation that has occurred at both sites, caused by drainage and peat extraction. Approximately 50% of the vegetation complexes on Raheenmore and Clara Bog West indicate degradation of the system and approximately 75% of the community complexes on Clara East indicate degradation.

The main problems facing the intact plant communities on Clara and Raheenmore are drainage and subsequent lowering of the water table. If these sites are to be conserved their hydrology must be protected.

ACKNOWLEDGEMENTS

I would sincerely like to thank the following people and organisations:

My supervisor Dr. David Jeffrey for his guidance and support during this project, particularly towards the end.

Dr Matthijs Schouten for an insight into his knowledge of Irish bogs and for his many suggestions and corrections.

Jan Streefkerk, who managed to keep me on my toes and without whom the Irish-Dutch project would not have functioned.

Dr. John Cross of the The National Parks and Wildlife Service, who started off as my technical supervisor but handed me over to the equally capable and helpful Jim Ryan and Catriona Douglas.

To the other supervisors involved in this project who at one time or other helped me in some way.

Ms. Debbie Hackett, Wildlife Service Laboratory, for her untiring water analyses and help.

Ms. Louise Scally, Evironmental Science Unit, T.C.D. for ion chromatography analyses.

Ray Flynn, Richard Henderson and Mary Smyth, my co-workers and compatriots!

All the Dutch students, who if I named them would fill several pages.

Monieke Noreen for her help and advice on CANOCO.

Drs. Jan van Dijk for his help with vegetation work during the first field work season.

My friends and co-laboratory workers who helped in various ways.

The Photographic section of the Irish Air Corps, in particular Tony and Willie, for providing excellent colour photographs of both bogs.

The Meteorological Service, in particular Tom Keane. for providing me with meteorological data.

Staff and technical staff of the School of Botany, Trinity College Dublin.

The National Parks and Wildlife Service (Office of Public Works) for financing this project and EOLAS for additional financial support.

My Mother for her excellent proof reading and for allowing me use her Macintosh computer once again.

My Mother, my sister Rachel and Eugene for helping to collect water samples, when I really needed assistance.

Eugene for suffering me during the first months of our married life. This was the true test.

But most of all heartfelt gratitude to my parents, Patrick and Jean, without whose support, care and much understanding my academic career would never have happened.

Chapter 5. High Bog Hydrochemistry and Hydrology. **58**

5.1 Precipitation Chemistry. 58
5.1.1 Conclusions. 62
5.2 Hydrology, Hydrochemistry and Bog Vegetation. 62
5.2.1 Hydrology. 64
5.2.2 Specific conductivity and pH of peat waters. 69
5.3 Bog Hydrochemistry. 72
5.4 Canonical Correspondence Analysis. 73
5.5 Bog and Marginal Hydrochemistry and Hydrology. 74

Chapter 6. Marginal and Cut-Away Hydrology and Hydrochemistry. **75**

6.1 Introduction. 75
6.2 Hydrology. 76
6.3 K_{corr} and pH Measurements. 79
6.4 Hydrochemistry and CCA of the Marginal and Cut-away sites. 81
6.5 Conclusions. 83
6.6 Relationships between Bog, Marginal and Soak communities. 83

Chapter 7. Soak Systems. **85**

7.1 Introduction. 85
7.2 Soaks on Clara Bog. 85
7.2.1 Lough Roe. 85
7.2.2 Shanley's Lough. 90
7.3 Other small soaks. 93
7.4 Minor investigations. 94
7.5 Soak Community Hydrology and Hydrochemistry. 97
7.6 Conclusions. 100

Chapter 8. Vegetation and Combined Mapping. **101**

8.1 Introduction. 101
8.2 Mapping Methods. 101
8.3 Vegetation Complex Maps. 102
8.3.1 Conclusions 108
8.4 Desiccation Maps. 108
8.5 Discharge Maps. 108
8.6 Ecotope Maps. 109
8.7 Acrotelm and Vegetation Complex. 109
8.8 Conclusions. 111

Chapter 9. Final Conclusions and Recommendations. **112**

9.1 Overview. 112
9.2 The Main Problems to Vegetation and Possible Solutions. 113
9.2.1 Surface Drainage. 113
9.2.1.1 Clara. 113
9.2.1.2 Raheenmore. 114
9.2.2 Deep Peripheral Drainage. 114
9.2.2.1 Raheenmore. 114
9.2.2.2 Clara. 115
9.2.3 Peat Cutting. 115
9.3 Restoration of Lagg Communities. 116
9.4 Conservation of the Soak Systems. 116
9.5 Restoration Monitoring. 117
9.6 Site Access. 117

9.7 Main Management Objectives. 118
9.8 In Conclusion. 118

References.

Appendices.

LIST OF FIGURES.

		PAGE NO.
Fig. 1.1	A schematic cross-section through a raised bog (Mitchell, 1990).	1
Fig. 1.2	The distribution of Raised Bogs in Ireland (Ryan and Cross, 1984).	2
Fig. 1.3	Conceptual model of the inter-relationships of hydrology and hydrochemistry on a raised bog.	7
Fig. 2.1	Borehole data showing the lithologies of Clara and Raheenmore. Derived from data from The Geological Survey of Ireland.	8
Fig. 2.2	Stratigraphy of Clara Bog (Bloetjes and Van der Meer, 1992).	8
Fig. 2.3	Section of a map of the former and present extent of raised bogs in Ireland, showing Clara and Raheenmore (Cross, 1990).	8
Fig. 2.4	Map of Ireland showing the situation of Clara and Raheenmore.	9
Fig. 2.5	Mean monthly precipitation at Birr and Mullingar meteorological stations (Meteorological Service of Ireland).	10
Fig. 2.6	Monthly precipitation from Clara, Raheenmore, Birr and Mullingar for 1990.	10
Fig. 2.7	Evapotranspiration and precipitation at Birr and Mullingar for 1990.(Meteorological Service of Ireland).	11
Fig. 4.1	Design of phreatic tubes used for water table measurements and hydrochemical sampling.	52
Fig. 4.2	Diagram showing hydrochemical sampling hierarchy.	53
Fig. 4.3	Design of collecting vessel for precipitation.	54
Fig. 4.4	Sample graph of duration line preparation.	55
Fig. 4.5	Sample duration line.	55
Fig. 5.1	Precipitation chemistry from Birr, Kinitty, Clara and Raheenmore.	58
Fig. 5.2	Relationship between SO_4 and precipitation at Raheenmore.	59
Fig. 5.3	Mg, Cl and Na in precipitation at Clara and Raheenmore.	60
Fig. 5.4	Relationship between Na and Cl in precipitation from Clara and Raheenmore.	60
Fig. 5.5a	Percentage input of elements from precipitation to Clara (kg ha^{-1} yr^{-1}).	61
Fig. 5.5b	Percentage input of elements from precipitation to Raheenmore (kg ha^{-1} yr^{-1}).	62

9

Fig. 5.6	The structure of pool. hollows. lawns. flats and hummocks.	63
Fig. 5.7	Average annual mean, maximum and minimum water table depths of the high bog communities.	64
Fig. 5.8	Monthly mean water table heights of the pool communities.	65
Fig. 5.9	Monthly mean water table heights of the lawn communities.	65
Fig. 5.10	Monthly mean water table heights of the hollow communities.	66
Fig. 5.11	Monthly mean water table heights of the flat communities.	66
Fig. 5.12	Monthly mean water table heights of the burnt/disturbed communities.	67
Fig. 5.13	Duration lines of the burnt/disturbed and hollow communities.	67
Fig. 5.14	Monthly mean water table heights of the hummock communities.	67
Fig. 5.15	Monthly mean water table heights of the face-bank community.	68
Fig. 5.16	Summary tables of ANOVA of mean, maximum and minimum water table heights of the bog communities.	68
Fig. 5.17	Average annual mean, maximum and minimum K_{corr} values of the high bog communities.	70
Fig. 5.18	Summary tables of ANOVA of mean, maximum and minimum K_{corr} values of the bog communities.	71
Fig. 5.19	Monthly mean K_{corr} values of the pool and hummock communities.	71
Fig. 5.20	Average annual mean, maximum and minimum pH values of the high bog communities.	72
Fig. 5.21	Typical hydrochemistry from a high bog community.	73
Fig. 5.22	CCA ordination plot of the bog sites using mean values of abiotic data from 1990-1991.	73
Fig. 5.23	CCA ordination plot of the bog sites using mean values of abiotic data from 1991-1992.	73
Fig. 5.24	CCA ordination plot of the bog and marginal sites using mean values of abiotic data from 1990-1991.	74
Fig. 5.25	CCA ordination plot of the bog sites using mean values of abiotic data from 1991-1992.	74
Fig. 6.1	Diagram showing the area of mixing of ground water and surface water run-off at the margins of a raised bog.	75
Fig. 6.2	The annual average mean, maximum and minimum water table heights of the marginal communities.	76

Fig. 6.3	ANOVA summary tables of average mean. maximum and minimum water table heights of the marginal communities.	77
Fig. 6.4	Average monthly water table heights of the wet cut-away communities.	78
Fig. 6.5	Average monthly water table heights of the dry cut-away communities.	78
Fig. 6.6	Average monthly water table heights of the desiccated cut-away communities.	78
Fig. 6.7	Average monthly water table heights of the group 15 communities.	79
Fig. 6.8	Average monthly water table heights of the group 16 communities.	79
Fig. 6.9	Duration lines of variants 16A and 16B.	79
Fig. 6.10	The annual average mean, maximum and minimum K_{corr} values of the marginal communities.	80
Fig. 6.11	The annual average mean, maximum and minimum pH values of the marginal communities.	80
Fig. 6.12	CCA ordination plot of the marginal sites using hydrological and hydrochemical data from 1990-1991.	81
Fig. 6.13	Monthly average Ca values from the cut-away communities.	81
Fig. 6.14	Monthly average Ca values from the two typical high bog communities.	82
Fig. 6.15	Monthly average Ca values from the intermediate communities.	82
Fig. 6.16	Monthly average Ca values from the lagg communities.	83
Fig. 6.17	CCA ordination plot of the bog, marginal and soak sites.	83
Fig. 7.1	Situation of the soak sites on Clara bog	85
Fig. 7.2	Stratigraphic section through the east-west axis of Lough Roe Source: Connolly (1992).	85
Fig. 7.3	The 1838 and 1910 Ordnance Survey maps of Clara bog showing Lough Roe and Shanley's Lough.	85
Fig. 7.4	Map showing the Bord na Móna drains on Clara East.	85
Fig. 7.5	Vegetation map of Lough Roe.	86
Fig. 7.6	Sampling points in Lough Roe.	86
Fig. 7.7	Average monthly K_{corr} values for the Lough Roe sites.	87
Fig. 7.8	Van Wirdum diagram of water samples from Lough Roe.	89
Fig. 7.9	Aerial photographs of Shanley's Lough-type soaks.	91

Fig. 7.10	Sampling sites in Shanley's Lough.	92
Fig. 7.11	Van Wirdum diagram of water samples from Shanley's Lough.	93
Fig.7.12	Tissue concentrations of N, P, K, Ca and Mg in *Moliniacaerulea*, from various studies.	96
Fig. 7.13	CCA ordination of soak site data from August and October, 1992.	97
Fig. 7.14	CCA ordination of soak site of the means of one year's data.	97
Fig. 7.15	Water table, K_{corr} and pH transect across Lough Roe.	99
Fig. 7.16	Ca transect across Lough Roe.	100
Fig. 8.1.1	Desiccation map of Raheenmore.	108
Fig. 8.1.2	Desiccation map of Clara West.	108
Fig. 8.1.3	Desiccation map of Clara East.	108
Fig. 8.2.1	Map of possible discharge sites on Raheenmore.	109
Fig. 8.2.2	Map of possible discharge sites on Clara West.	109
Fig. 8.2.3	Map of possible discharge sites on Clara East.	109
Fig. 8.3.1	Ecotope map of Raheenmore.	110
Fig. 8.3.2	Ecotope map of Clara West.	110
Fig. 8.3.3	Ecotope map of Clara East.	110
Fig. 8.4	Percentage of vegetation cover on Raheenmore, Clara West and Clara East associated with particular acrotelm thickness.	110
Fig. 8.5	Percentage of moribund and healthy acrotelm on Clara and Raheenmore	110
Fig. 8.6	Possible succession of the main vegetation complexes on Clara and Raheenmore.	111
Fig. 9.1	The links between hydrology, hydrochemistry and the vegetation communities of Clara and Raheenmore raised bogs.	112

12

LIST OF PLATES.

		PAGE NO.
Plate 1.	*Sphagnum cuspidatum* pool (2A) with *Rhynchospora alba* and *Menyanthes trifoliata.*	18
Plate 2.	*Sphagnum cuspidatum* pool (2A) with *Droseraanglica.*	18
Plate 3.	*Narthecium ossifragum* hollow (3A).	19
Plate 4.	*Sphagnum magellanicum* low hummock (3Bb) topped with *Calluna vulgaris* and *Ericatetralix.*	19
Plate 5.	*Carex panicea* hollow/flat (4B).	24
Plate 6.	*Leucobryum glaucum* low hummock (4C) covered with *Droserarotundifolia.*	24
Plate 7.	*Sphagnum imbricatum* hummock topped with *Calluna vulgaris*, *Ericatetralix* and *Eriophorum vaginatum* (4F).	26
Plate 8.	Community of *Carexacuta* and *Carexhirta* (22) with grassland community in the foreground (23).	26
Plate 9.	Lough Roe showing central quaking scragh.	86
Plate 10.	Central community in Lough Roe of *Carex rostrata* and *Drepanocladus fluitans* with *Nuphar lutea.* (5B).	86
Plate 11.	Community of *Menyanthes trifoliata* and *Sphagnum squarrosum* in Lough Roe (6B).	86
Plate 12.	Community of *Sphagnum recurvum* lawns with *Potentilla palustris* (8Ab) in Lough Roe.	86
Plate 13.	Community of *Sphagnum palustre* (8B) with *Hydrocotyle vulgaris* and *Menyanthes trifoliata* in Lough Roe.	86

Plate 14. Community of *Aulacomnium palustre* (8C) lawns in Lough Roe. 86

Plate 15. Edge of Lough Roe showing community of scrub *Betula pubescens* (12Ab). 91

Plate 16. Open water pool at Shanley's Lough. Fringed by *Juncus effusus*, *Carex rostrata* and *Eriophorum angustifolium*. 91

Plate 17. *Betula pubescens* wood with *Molinia caerulea* south of the open water pool at Shanley's Lough. 91

Plate 18. *Molinia caerulea* tussock communities (14A and 14B) south of the Betula woodland at Shanley's Lough. Note the sharp boundary between the *Molinia* community and the *Myrica* and *Sphagnum magellanicum* community (3F). 91

Plate 19. Tall *Betula pubescens* tree at Addergoole soak. Note high water table conditions, June 1993. 91

Plate 20. *Betula pubescens* wood at Addergoole soak with an understorey of *Juncus effusus*, *Osmunda regalis* and *Dryopteris*. 91

Plate 21. The lower section of the long N/S soak on Clara West, showing the wettest area with *Typha latifolia* surrounded by *Juncus effusus* and *Menyanthes trifoliata*. 93

Plate 22. Shows the face-bank complex, dominated by *Calluna vulgaris* and the *Trichophorum* complex in the foreground. 103

Plate 23. The marginal *Rhynchospora alba* complex. 103

Plate 24. The *Narthecium* complex. Note the abundance of *Narthecium* hollows (orange fruiting heads). 103

Plate 25. *Cladonia floerkeana* colonising the spoil from the drains on Clara East. 103

LIST OF TABLES.

		PAGE NO.
Table 1.1	Main characteristics of the acrotelm and catotelm.	5
Table 1.2	Previous hydrochemical sampling methods.	6
Table 2.1	Average maximum, minimum and daily temperatures for Birr and Mullingar (1990).	11
Table 5.1	Precipitation chemistry from Clara and Raheenmore (mg l^{-1}).	58
Table 5.2	Calculations to estimate the amount of SO_4 derived from sources other than seawater.	59
Table 5.3	Precipitation chemistry from Clara and Raheenmore (kg ha^{-1} yr^{-1}).	60
Table 5.4	Comparison between precipitation inputs (kg ha^{-1} yr^{-1}) at Clara, Raheenmore and Chartley Moss.	61
Table 5.5	Summary of the hydrological and some hydrochemical characteristics of the high bog communities.	64
Table 6.1	Summary of the hydrological and some hydrochemical characteristics of the marginal (lagg) communities.	76
Table 7.1	Summary of the hydrological and some hydrochemical characteristics of the soak communities.	86
Table 7.2	Hydrochemical data from Lough Roe for the period August, 1991 to June, 1992 at two monthly intervals.	88
Table 7.3	Hydrochemical data from Shanley's Lough for the period August, 1991 to June, 1992 at two monthly intervals.	92

Table 7.4	Addergoole and Shanley's Lough hydrochemistry.	93
Table 7.5	Soak community water type classification.	98
Table 8.1	Area (ha) covered by the different community complexes on Raheenmore, Clara West and Clara East.	107
Table 8.2	Summary of the hydrological and hydrochemical characteristics of the ecotopes.	109
Table 8.3	Relationship between vegetation complexes and acrotelm depth.	109

CHAPTER I: INTRODUCTION.

1.1 RAISED BOGS.

The development of Irish raised bogs has been well documented in the past and the conventional explanations for their origins may be quickly stated (Praeger, 1969; Whittow, 1974; Mitchell, 1981; Cross, 1990). They are bodies of peat, chiefly formed in basins or shallow lakes which remained after the last glaciation, 10,000 years BP. These lakes developed due to impeded drainage, caused by the thick deposits of glacial drift over the lower Carboniferous limestones of the central plain. Fen vegetation, composed mainly of sedges and reeds, invaded the edges of these lakes. The lakes became more shallow, as muds and decayed plant material were deposited and the fen vegetation slowly in-filled the lake, depositing layers of fen peat as they advanced. Plant roots in areas such as these would still have been under the influence of minerotrophic ground water. If environmental conditions were suitable, the layers of fen peat eventually became poorer, as they grew thicker, so that less inorganic nutrients were available for plant growth, since the plant roots were no longer in contact with ground water. This provided an ideal habitat for the establishment of *Sphagnum* mosses, which are able to survive in a totally rain-fed or ombrotrophic situation (Clymo and Hayward, 1982). The formation of *Sphagnum* peat at these sites began at least 7,000 years BP (Mitchell, 1990). Stratigraphic investigations show the different layers of deposits that occur in a raised bog Fig. 1.1.

The properties of Sphagna are such that they provide ideal conditions for peat accumulation. Anaerobic, water logged conditions are created due to the presence of large dead cells in their leaves (hyaline cells), which enable these species to absorb many times their own weight in water. In addition, capillary action coupled with their extra-cellular water storage capacity ensures that the water table follows the growth of the raised bog dome (Ingram, 1983). *Sphagnum* species can also modify the pH of their surroundings, through the release of hydrogen ions (Clymo, 1963). Aerobic microbial activity is thus reduced to a minimum, plant decay is slow and peat accumulates (Clymo, 1970). Typically, a raised bog is dome shaped, owing to the greater accumulation of peat in the wetter anaerobic centre. Decay of plant material is faster towards the edges of the bog, where water table levels are lower and the environment is more aerobic. However, as will be discussed later, this domed shape may be altered due to the effects of drainage.

1.2 RAISED BOG DISTRIBUTION IN IRELAND.

In Ireland, raised bogs are concentrated in the Midlands (Midland sub-type) though some occur in the West of the country forming a 'Western sub-type' (Schouten, 1984). See Figure 1.2 for the distribution of Midland raised bogs in Ireland.

Midland raised bogs once covered 5%, approximately 350,000 ha. of Ireland (Cross, 1989), forming large complexes as the *Sphagnum* peat grew deeper and basins of peat coalesced. The exploitation of these originally vast areas, by privately hand and machine cutting and commercially by Bord na Móna and private peat developers, has left very few examples of these raised bogs remaining today. A survey carried out by the Wildlife Service, during the period 1985 to 1989, discovered that only 23,000 ha of relatively intact raised bog remained and only 12,000 ha were of the highest scientific interest (Cross, 1990). Today the figure is even less, as the destruction continues. The situation is even more acute in Northern Ireland, where a survey completed in 1987 showed that only four raised bog sites, with intact areas of more than 100 ha, remained (Leach and Corbett, 1987).

1.3 THE IMPORTANCE OF RAISED BOGS.

Global

Irish raised bogs are important on a global scale as they represent, in relative terms, the least modified examples of temperate oceanic raised bogs in Europe. Britain and Ireland together form the major distribution zone for the oceanic raised bog type (Goodwillie, 1980). Britain (excluding Northern Ireland) has approximately 3,327 ha of active (peat forming) raised bog remaining at present. Over half of these raised bog sites are less than 10 ha in size (Lindsay et al., in press). The hydrological viability of these small sites is very much in question. Raised bogs also occur in parts of the rest of Europe, but the continental influence means that many are wooded and are therefore classified differently. Those places where oceanic type raised bogs do occur are restricted to small areas in The Netherlands, Germany and Denmark (Cross, 1990). The Scandinavian raised bogs are also classified differently, as their flora and morphology differs from that of Irish bogs. Ireland is therefore in a privileged position as it possesses a large proportion of an extremely rare habitat type. An important international conservation obligation must therefore be fulfilled.

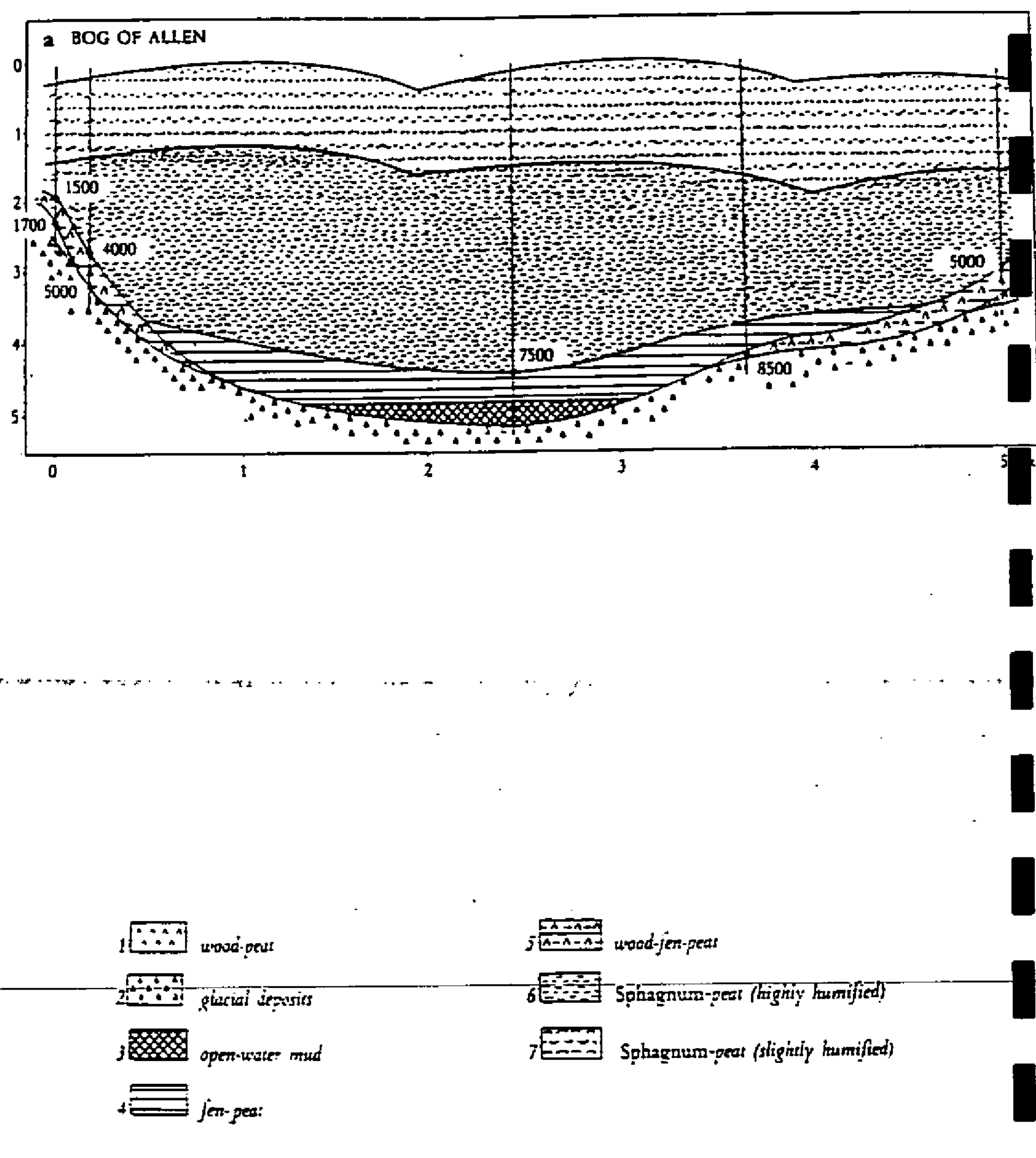


Fig. 1.1 Schematic representation of the stratigraphy of a Midlands Raised Bog.
Source: Mitchell (1990).

Flora and Fauna.
Raised bogs are important areas for wildlife. Due to the extreme environmental conditions that prevail, raised bogs have a range of specialist plant and animal species, many of which are not found elsewhere. Specialist plants such as the *Drosera* species are not found in other habitats in Ireland, as it is only here that they can compete with other species due to their ability to supplement their nutrition with the practice of insectivory. The *Sphagnum* mosses are abundant in this system and do not reach such importance in any other habitat type.

Invertebrates are fewer in acid mires than in fens, but again they can be specialists, for example the Large Heath butterfly (*Coenonympha tullia*), which is confined to peatlands in Ireland (Speight and Madden, 1987). For this reason they are very vulnerable to changes in their habitat (Key, 1989).

Amphibians are represented by an abundance of frogs (*Rana rana*) and reptiles by an occasional common lizard (*Lacerta vivipara*).

The bird life on a raised bog is probably the most noticeable wildlife aspect on a casual visit. Many species use the bog for breeding, roosting or over-wintering purposes, while a number remain all year round (Madden, 1987). Hydrological changes in a raised bog have a dramatic effect on the bird population. Raised bogs are known to be of considerable importance as wintering sites for Snipe (*Gallinago gallinago*) and Greenland white-fronted geese (*Anser albifrons*) (Hutchinson, 1989). If drainage occurs, and pools and hollows disappear, species such as Snipe will cease to frequent the site, as these are their main feeding areas. Raised bog systems in Ireland are particularly important for the Irish Red Grouse (*Lapogus lapogus hibernicus*), which feeds almost solely on Heather (*Calluna vulgaris*) shoots. They are shy birds and can only survive on larger sites, as a reduction in territory size decreases their breeding success (Lawton, 1990). Grouse also require wet areas on a raised bog as grouse chicks need a diet of protein rich insects in the first few weeks of life. If drainage of the system occurs, larval habitats for these insects will be reduced (Coulson and Butterfield, 1985).

There are few mammals on a raised bog the most significant species being the Irish hare (*Lepus timidus hibernicus*) which can be numerous on some sites. Foxes (*Vulpes vulpes*) are the only other mammals which are commonly seen.

It can not be emphasised enough that the species that do occur on raised bogs are often specialists and, for that reason, if the habitat disappears so do they. Restoration of sites after peat removal is not a solution as re-introduction of species, particularly invertebrates, from other sites is almost impossible (Key, 1989). It is essential therefore to conserve intact intra-site areas which could also act as re-colonisation refugia if conditions on other sections of the site were improved.

The point has often been made that the genetic resource of peatlands may become more important in the future. Some peatland species, such as *Drosera rotundifolia* and *Menyanthes trifoliata*, are already used in the manufacture of medicines (Stary and Jiràsek, 1978) and as natural remedies become more popular and desirable, the importance of this genetic reserve will undoubtedly increase.

Education Resource.
Raised bogs provide an education and research resource for all levels. They can be useful for introducing young children to the concept of nature conservation and could help to make them more environmentally aware from an early age. The projects which can be undertaken are numerous and can be incorporated into school syllabi (Wymer, 1987; O'Connell, 1991; O'Connell, 1992).

As research sites, the possibilities for using raised bogs are manifold. One important botanical use of an intact site is the ability to take cores through the depth of peat, which allows one to recreate vegetational records after pollen or macrofossil analysis has been carried out. This ability can be important for investigations into climate and vegetation history, as well as yielding information on past human activities. In addition, studies of plant and animal interactions, plant and animal specialisations and nutrient cycling investigations may be carried out in this well defined system.

Tourism and Recreation.
When so little peatland now remains in this country, particularly very few raised bog sites, their importance has increased.Although many people view peatlands as wastelands, places with no practical use to mankind until they are cut away, they are one of the few near-natural ecosystems remaining in Ireland and their wilderness value is immeasurable. They are an important part of our heritage as a landscape feature.

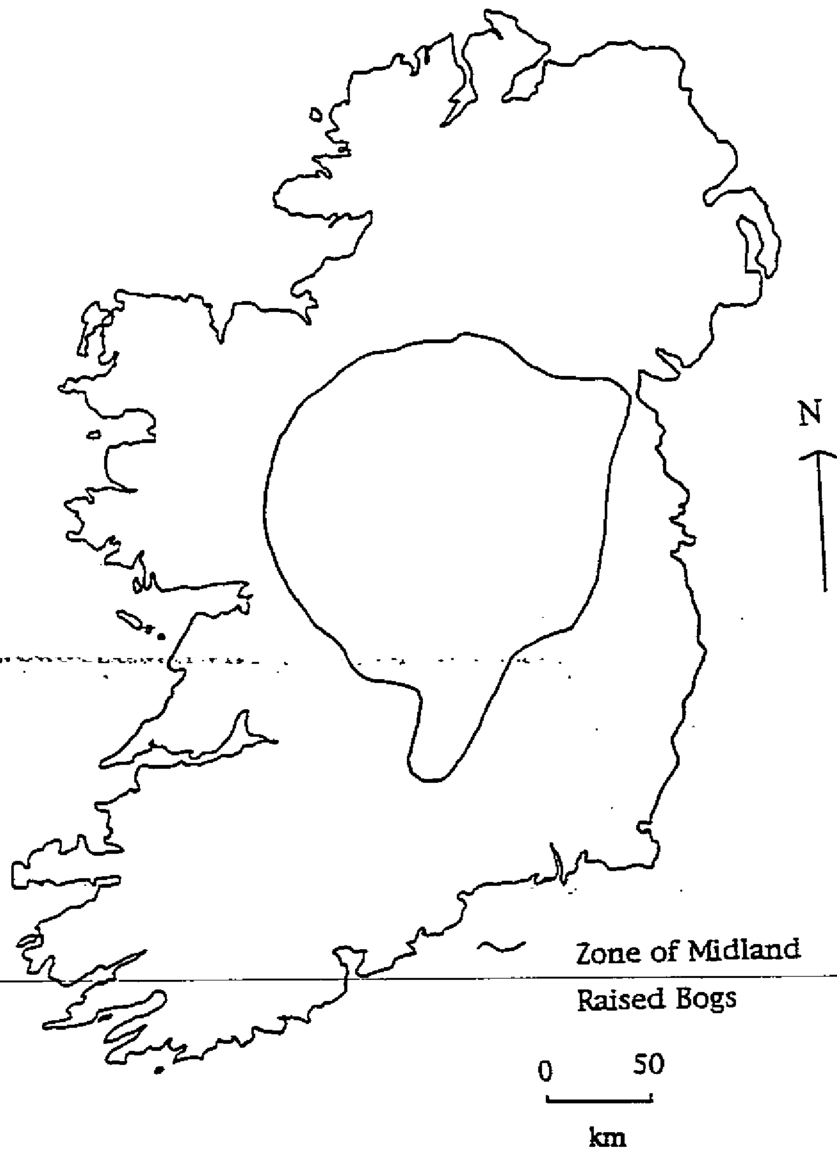


Fig. 1.2 The Distribution of Midland Raised Bogs in Ireland.
Source: Ryan and Cross (1984).

The Midlands were once covered by huge tracts of raised bog and it is desirable that some should remain in order that future generations may have an idea of what the landscape was like before the major impact of humans on it. The tourism potential of raised bogs and blanket bogs, as part of the landscape, is enormous. Our European neighbours too have few wilderness areas remaining, and Ireland provides them with the unique chance to see a bog in a relatively intact state.

Mankind as a destructive force is part of the natural system, but mankind can also be a conserver. In this role decisions must be made as to what is most desirable to conserve. It does not make economic sense to destroy these wilderness areas. At a time when agricultural surpluses are common in Europe and land is being set-aside, it is not wise to create more possible agricultural land. The tourism potential of these sites is almost certainly far greater if they remain as examples of relatively intact bog, rather than if they were developed in any other way. With rising unemployment, with the effect of increased recreation time and the subsequent need for recreational sites, it is not sensible to remove these wilderness areas.

1.4 BACKGROUND TO THE PROJECT.

The commercial exploitation of peatlands began in The Netherlands in the twelfth century and by the end of the sixteenth century most bogs had already been cut-away. The remaining areas were all hydrologically damaged and by the time the conservation value of peatlands was recognised in The Netherlands, extensive work was required to protect the areas remaining. The Dutch therefore have expertise in the construction of dams and the hydrology of damaged bog systems. As peatlands in The Netherlands consist only of damaged bogs there was much Dutch interest in Irish bog systems as examples of relatively intact sites. In 1983, this interest and concern that all Irish sites would also be exploited, prompted the establishment of The Dutch Foundation for the Conservation of Irish Bogs. This organisation was set up to raise funds for the purchase of Irish Bogs in order that they would be conserved.

This project arose because the Irish Government had acquired several raised bog sites, for conservation as National Nature Reserves, following the findings of a National raised bog survey completed by the Wildlife Service in 1987. It was realised that there was a need to understand the relationship between the hydrology, geology and ecology of the whole system in order to be able to conserve them effectively. The Irish Government requested the technical help of the Dutch Government to try to conserve their protected sites.

The Dutch Government and Dutch academic institutions were interested in being involved in any research work on Irish raised bogs, due to the lack of relatively intact sites in The Netherlands and the deficit of information on the hydrological regimes of relatively intact sites. This information they need for the continued restoration of their remaining raised bog remnants. The Irish data gathered would hopefully provide reference data for their work.

There are no completely intact raised bogs remaining in Ireland (Cross, 1990), but two relatively intact sites had been purchased by the Irish Government and had been declared National Nature Reserves. These were Clara and Raheenmore bogs in Co. Offaly. Both Clara and Raheenmore Bogs have experienced and are experiencing the major problems facing other raised bogs in Ireland and the rest of Europe. These are: peat extraction, surface drainage and deep peripheral drainage.

The main questions, to be answered by the project, were what are the effects of the above factors and how might they be remedied. In addition it was necessary to investigate whether disturbed raised bog sites could be conserved as incomplete hydrological units, a point which was highlighted by Newbould (1989).

To achieve these aims, a joint Irish-Dutch project commenced research in October 1989. Several Dutch and Irish Government departments and academic institutions were involved. The Dutch bodies included Staatsbosbeheer (The National Forestry Service) and the Department of Agriculture, Nature Conservation and Fisheries. The Irish Government departments involved were The National Parks and Wildlife Service (Office of Public Works) and The Geological Survey of Ireland.

A multi-disciplinary project was considered to be the best approach to tackle the aims, encompassing geology, geo-hydrology, geography, hydrology, ecology and engineering. Three Irish students were enlisted: a geologist (University College, Galway), a botanist (University of Dublin, Trinity College) and an hydrologist (Sligo Regional College). Approximately twenty Dutch hydrology students (Agricultural University of Wageningen), four Dutch geography students (University of Amsterdam), four engineering students (Imperial College, London) and two Irish engineering students (University College, Dublin) also took part, making this the largest raised bog research project ever undertaken in Ireland.

The exchange of knowledge between management, technical staff, academic staff and students was considered to be of paramount importance to integrate the separate studies successfully. In 1992, to highlight the co-operation which was taking place, Clara Bog was twinned with the largest area of raised bog remaining in The Netherlands, The Bargerveen.

To achieve the aims of the project within a three to four year period, it was necessary to set up a hydrological net-work of piezometers over the two bogs to examine their hydrological regimes (a hydrological transect had been established on Raheenmore soon after its purchase, so some data were already available for analysis). Geo-hydrochemical work was also carried out by the hydrologists and investigations were made into the properties of peat. The bedrock and quaternary geology was examined, using coring equipment and ground survey, including geophysical techniques. This resulted in a description of the regional and local geology of both sites. The engineers were mainly involved in investigating the impact on the bog of the road which bisects Clara Bog.

1.4.1 The Aims of The Ecological Research.

The main aims of the ecologist were to describe fully the vegetation communities of the mire expanse and marginal areas of both bogs and the soak systems on Clara. Then, following this, to attempt to establish a link between these community types and important environmental factors. The final aim was to map community complexes on both bogs and to predict, from a knowledge of related environmental factors, the vegetation changes which may occur in the future, depending on management regimes. Where management action is deemed necessary to conserve particular plant communities, the aim would be to recommend what action is most desirable. An examination of the hydrological and hydrochemical regimes of the plant communities of the two bogs was considered to be the most important link to be made in order to try to interpret plant community distribution.

1.5 HYDROLOGY AND HYDROCHEMISTRY.

In mire ecosystems the depth and movement of the watertable and the chemistry of the water have been recognised as important factors in controlling the distribution of plant communities (Green and Pearson, 1968). However it would be more true to say that differing watertable depths and hydrochemistry are known to be strongly correlated with, rather than that they control, vegetation patterns on the mire surface.

1.5.1 Hydrology.

If one considers that peat is normally composed of approximately 88-97% water (Ivanov, 1981) and that this water forms part of its structure, obviously a study of hydrological characteristics within a community is essential when investigating the vegetation of a raised bog system.
The hydrologic balance of an ombrotrophic bog can be summarised as follows (Chapman, 1965; Eber, 1982).

$P = E + R \pm \partial S$
where
P = Precipitation.
E = Evapotranspiration.
R = Runoff.
$\pm \partial S$= Changes in storage capacity.

This equation does not account for any vertical seepage that may occur. Streefkerk and Casparie (1989) suggest the following equation which includes a vertical seepage component.

$$P - E - R - L - D = \partial S$$

Where L = Lateral seepage (included in runoff in the previous equation) and D = Downward (vertical) seepage.

In either case the most important factors to note are that raised bogs depend totally on precipitation for inputs into the system and that the storage capacity of the system is vital. If the storage capacity is reduced the bog will start to dry out. During summer months evaporation exceeds rainfall and the water table level falls. Thus aeration of the upper layer is increased during periods of maximum plant growth. Although some shrinkage of the upper peat layer occurs, so that the bog surface follows water table levels (Ivanov, 1981), water table levels will still be lower relative to surface level during the summer as compared to the winter period. The shrinking and swelling capacity of this top layer is an extremely important characteristic for the survival of *Sphagnum* species (Streefkerk and Casparie, 1989). In order for the more aquatic *Sphagnum* species to survive during periods of low rainfall and high evapotranspiration, they must be able to follow the water table as it lowers to a greater or lesser extent. This is often seen in hollows where the *Sphagnum cuspidatum* lawn drapes down, the higher edge sections die but the central area which has followed the water table survives until the hollow is re-wetted, unless the period of desiccation is too long. This shrinking process is seen over the whole area where there is an acrotelm which is functioning correctly. This water loss is soon replaced when precipitation exceeds evapotranspiration, if the system is functioning correctly. This is primarily controlled by the hydraulic conductivity of the surface layer which influences infiltration rates and thus the re-wetting of the bog surface (Rycroft et al., 1975). This process is dependant on the presence or absence of an acrotelm. The acrotelm (So called from the Greek *acro*, meaning top and *telm*; meaning marsh) is the thin (5-40 cm) upper living layer of the bog, consisting mostly of a loose network of *Sphagnum* stems with many open spaces. It has a high hydraulic conductivity so that excess water is quickly dispersed and infiltrated through the open air spaces. If the acrotelm is absent surface runoff will occur, which often leads to peat erosion (Ingram and Bragg, 1984).

An active raised bog consists of two layers (Ingram, 1983). The catotelm is the lower layer (from the Greek *Katá*, meaning underneath) which, in a raised bog, may be many metres thick. It consists of strongly humified peat, which is constantly waterlogged and thus anaerobic. It has a large water storage capacity and hydraulic conductivity is low (Streefkerk and Casparie, 1989). Table 1.1 illustrates the important characteristics of both layers (Ingram and Bragg, 1984; Streefkerk and Casparie, 1989; Cross, 1990).

Table 1.1 Main Characteristics of the acrotelm and catotelm.

	ACROTELM	CATOTELM
Hydraulic Conductivity	High	Low
Humification	Low	High
Aerobic	Yes	No
Water Table	Present	Absent
Peat Formation	Yes	No
Thickness of Layer	Centimetres	Metres

For a raised bog system to function hydrologically it must have an intact acrotelm over the majority of its surface. The water table is present in the acrotelm and the maintenance of a high watertable is vital for the existence of most *Sphagnum* species. The acrotelm plays a primary role in the functioning of a raised bog. It is necessary therefore to determine where an acrotelm layer exists and when it is present how it relates to vegetation. Establishing this relationship is essential for conservation and management purposes.

Water table depth is of importance in relation to plant species and plant community distribution on raised mires (Rutter, 1955; Hammond et al., 1990). Fluctuation of the water table and the maximum and minimum values encountered during the seasonal cycle are correlated with plant community distribution on the bog (Webster, 1962). Thus it is important that the water table characteristics of different communities on a bog are recorded.

1.5.2 Hydrochemistry.

Raised bogs are ombrotrophic (from the Greek *Ombros*, meaning rainstorm) systems, implying that they are completely dependant on meteoric inputs (Small, 1972). As precipitation is generally a poor source of inorganic nutrients, raised bogs are nutrient poor, or oligotrophic habitats. In addition to having low inputs, other factors play a role in ensuring that any nutrients which are present are poorly available. Raised bogs are acid environments, as one of the main ions present in raised bog waters is the H^+ ion. The buffering capacity of bog water is decreased as the peat body is increasingly dependant on rainfall for cation inputs. The presence of the H^+ ion is increased due to the activities of Sphagna. The cation exchange capacity of the *Sphagnum* species is such that they can readily exchange H^+ ions for metal ions, from their polygalacturonic acid exchange sites (Bell, 1959; Clymo, 1963; Daniels, 1989). This lowers the pH of the surrounding area so that the typical pH of raised bog waters is in the range 3.0 - 4.2 (Bellamy, 1968). The Sphagna also indirectly contribute to the acidity of their environment as organic acids are present due to the incomplete breakdown of plant material. Under low pH conditions certain ions, important for plant nutrition, become less available due to competition on the cation exchange sites by the hydrogen ion (Sutcliffe and Baker, 1974). Other elements such as iron and manganese convert to their more soluble forms under reducing conditions. They are then more easily absorbed by the vegetation and can reach toxic levels (Jeffrey, 1987).

Waterlogging is also important as, under anaerobic conditions, nutrients which would normally be released from decaying plant material due to microbial activity, are less available. This is because microbial activity is retarded under anaerobic conditions and because *Sphagnum* species contain phenolic compounds which can inhibit microbial activity (Given and Dickinson, 1975).

Hydrochemistry, rather than peat chemistry, investigations are considered desirable in a raised bog, as most plant species occurring in the system have a significant part of their rooting zone below or just above the watertable, so that water chemistry is fundamental to their nutrient supply and uptake (Summerfield, 1974). However with measurements such as mean pH values little difference is seen between peat and water values from below plant communities (Newbould and Gorham, 1956).
The total ionic content of a raised bog can be divided into the following components as follows: (Ingram, 1967):

1. Dissolved ions in water.
2. Cation exchange sites on solid peat.
3. Plant tissues.
4. Adsorption to colloidal peat material.

The most readily available of these for plant growth are the dissolved ions in water. Therefore hydrochemical investigations on a raised bog can give an insight into the nutrient status of the different plant communities. This has been recognised for some time and much hydrochemical analysis of peat waters has been carried out over the last fifty years. Many of these investigations have been to describe the differences between bog types (Bellamy, 1968; Comeau and Bellamy, 1986; Proctor, 1992), or in studies of the distribution of particular plant species (Bell and Tallis, 1974; Daniels, 1975; Miles, 1976). However little extensive work has been carried out on establishing the hydrochemical differences between the many plant community types on a raised bog.

Due to the intricate nature of peat, the spatial variation in water chemistry can be large and because of this Summerfield (1974) suggested that water sampling must be carried out within 10 cm of the plant species or within the plant community under investigation. Thus the number of sampling points must be large if comparisons between plant communities are to be made. As the system is ombrotrophic, the quality and quantity of precipitation has a major influence on the peat water chemistry (Boatman et al., 1975). This implies that the hydrochemistry of peat waters varies with the climatic conditions. Therefore an evaluation of seasonal variation is important if the situation is to be fully investigated, so at least one year's sampling must be carried out in the study area. In addition, an analysis of precipitation chemistry should also be considered, taking into account spatial and temporal variation.

A problem which arises when examining the hydrochemistry of raised bogs is the determination of how sampling should be carried out. Different sampling procedures have been employed in the principal mire hydrochemical investigations over the last fifty years (Table 1.2). Some of the methods used have drawbacks. Surface samples can be over-influenced by recent rainfall and open pits may only be used once, unless covered to prevent rainfall or animal contamination. In many instances sampling methods are not specified, making it difficult to draw comparisons between different sets of results.

Table 1.2 Previous hydrochemical Sampling Methods

Open Pits	**Surface Sample**	**Not Specified**	**Phreatic/Probe**
Miles, 1976 Comeau and Bellamy, 1986 Proctor, 1992	Gorham, 1956 Newbould and Gorham, 1956 O'Connell, 1981 Proctor, 1992	Chapman, 1965 Sparling, 1966 Bellamy and Bellamy, 1966 Green and Pearson, 1968	Summerfield, 1974 Doyle, 1990

The most suitable method for collecting hydrochemical samples is using a sampling probe (Summerfield, 1974) or collecting water from a phreatic tube (Doyle, 1990). Plant roots are generally under the influence of interstitial water rather than surface water and therefore it is only in pool communities that surface samples can be said to fully represent the conditions the plants are experiencing. Furthermore surface samples cannot be obtained from most hummock communities.

The separation of hydrology and hydrochemistry in a raised bog system is impossible as they are interdependent (Fig. 1.3). The main aims of this project are to come to a better understanding of the workings of a raised bog system as an entire unit and to discover which hydrological and hydrochemical factors are related to plant community distribution and thus how those communities may be conserved or rehabilitated. These questions have not been answered sufficiently by research in the past as hydrochemistry, hydrology and plant community ecology have mostly been treated separately in research studies. As a conclusion to this study the necessary information should be available for decisions as to the actions required for management which would lead to effective conservation of these endangered areas in the future. The issues to be addressed by this work were therefore:

1. An attempt to explain the distribution of plant communities on the two bogs both hydrologically and hydrochemically.
2. To give guide-lines, through the maintenance of particular hydrological and hydrochemical regimes, for the future management of the system, to help to ensure that no further degradation occurs.
3. To make proposals for restoration where degradation is suggested by the plant community structure and to suggest how and when the rehabilitation could take place.

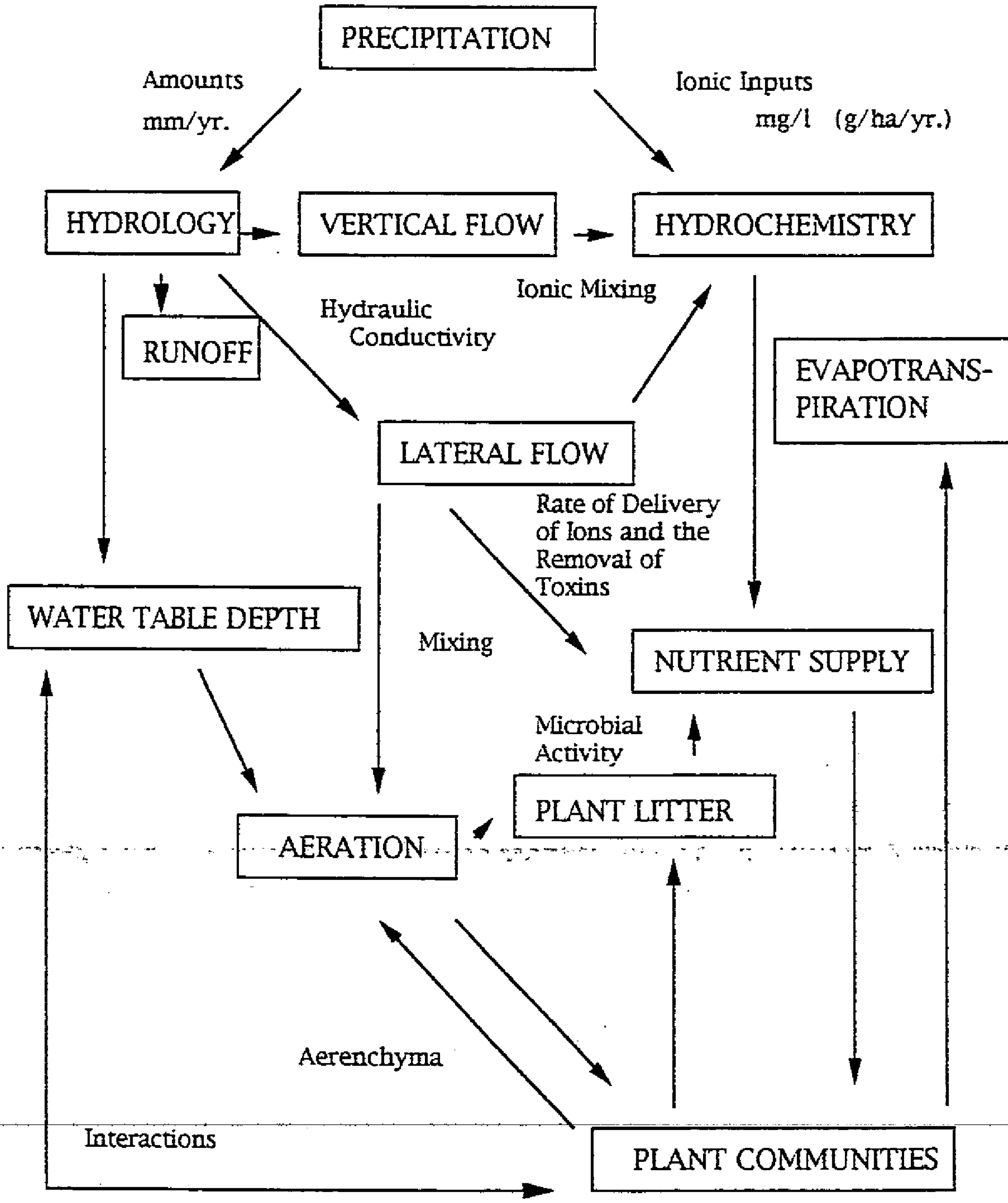


Fig. 1.3 Conceptual Model of the Inter-relationships of Vegetation, Hydrology and Hydrochemistry.

CHAPTER 2: SITE DESCRIPTIONS AND ENVIRONMENT.

2.1 GEOLOGY AND GEOMORPHOLOGY.

Both sites are located, geologically and geomorphologically, in the central lowlands region, which consists mainly of Lower Carboniferous strata bedrock. These strata are composed principally of three limestone types; lower limestone, middle or calp limestone and an upper limestone. Many of the limestones, particularly those described as middle or calp are arenaceous or argillaceous in character (Whittow, 1974). Some reef limestones also occur. This limestone bedrock is overlaid by glacial deposits, Midlandian in age, which are mostly composed of limestone tills, morainic sands and gravels. The most striking glacial features of the midlands are the long winding esker ridges, which developed due to sub-glacial drainage (Herries Davies and Stephens, 1978). One of the finest examples of an esker ridge is the Escir Riada which once divided Ireland into the Kingdom of Tara in the North and Cashel to the South (Whittow, 1974). A section of this esker bounds Clara to the north, running in an east-west direction, ranging in height from 10 - 25 metres above the surrounding area (Van Tatenhove and Van der Meer, 1990). To the south a till mound, known as The Island, is seen. The River Brosna runs to the north of Clara, its catchment being separated from the site by the esker ridge. The Silver and Clodiagh Rivers run to the south of the site.

During the early Holocene period, the basin in which Clara bog formed was a small part of a large post-glacial lake, Lough Boora. The development of Clara bog has been shown to have followed the conventional sequence of events mentioned previously. This is evident from data obtained from borehole drilling (Flynn, 1990). A borehole close to the northern edge of Clara East showed Waulsortian Carboniferous limestone overlain by sands, gravels and boulder clays, then a layer of lacustrine clay followed by a layer of peat (Fig. 2.1(a)). Peat and lacustrine clay layers are shallow in this area as it is close to the margins of the original lake. Lacustrine layers can vary in depth from 0.1 m to 2-3 m deep, depending on topography and distance from the original lake shore (Van Tatenhove and Van der Meer, 1990). In some areas of Clara a creamy deposit occurs, overlying the lacustrine clays, known as shell marl (Bloetjes and Van der Meer, 1992).

The thickness of the peat layer on Clara varies from less than one metre to 10 metres deep in the central area of the bog basin (M. Smyth, pers. comm.). The stratigraphy in most areas of Clara follows this sequence; lacustrine clay overlain by lake marl, followed by fen/woody peat; strongly humified *Sphagnum* peat, topped by poorly humified *Sphagnum* peat (Fig. 2.2) (Bloetjes and Van der Meer, 1992).

Raheenmore bog developed in a depression between a number of low hills. To the north lie Mullagharush hill (140 m) and Clonagh (123 m), to the east a low hill, Kilduff and to the south a low ridge. Close to Raheenmore an extinct volcano, with a carboniferous volcanic neck composed of basaltic lava and tuffs, forms Croghan Hill, which rises 120 m above the surrounding area (Herries Davies and Stephens, 1978).

The lithology of the site is comparable to that seen at Clara, showing a similar sequence of geological events, typical of these raised bog sites (Fig. 2.1(b)). The lacustrine layers of Raheenmore consist mainly of clays which are generally silty but occasionally sandy or gravelly. The sand and gravel content increases towards the edges of the site, corresponding to the edges of the original lake shore. At Raheenmore the thickness of the lacustrine layer varies from 0 - 5.6 metres with an average depth of 3.0 metres (Rijsdijk and Van der Meer, 1990). In the central area of the bog the lacustrine layers are so thick that bedrock was not reached during drilling (Fig. 2.1(c)).

Raheenmore is a typical basin bog with the peat reaching depths of up to 15 metres towards the centre (M. Smyth, pers. comm.). The peat stratigraphy of this site is similar to that of Clara; that is, fen peat overlain by ombrotrophic peat (Veldkamp and Westein, 1993).

The present extent of both sites form only a fraction of former large raised bog complexes, most of which have now been cut-away. This is discussed by Van Tatenhove and Van der Meer (1990) and is well illustrated in Fig. 2.3, which is a section of a map showing the former and present extent of raised bogs in Ireland (Cross, 1990). Raheenmore (SE of Tyrrellspass) is shown as a small off-shoot of a very large raised bog complex lying to the north, which is now cut-away. Clara is also surrounded by large areas of cut-away peat. This map also serves to illustrate how extensive this habitat was in the past and how little now remains.

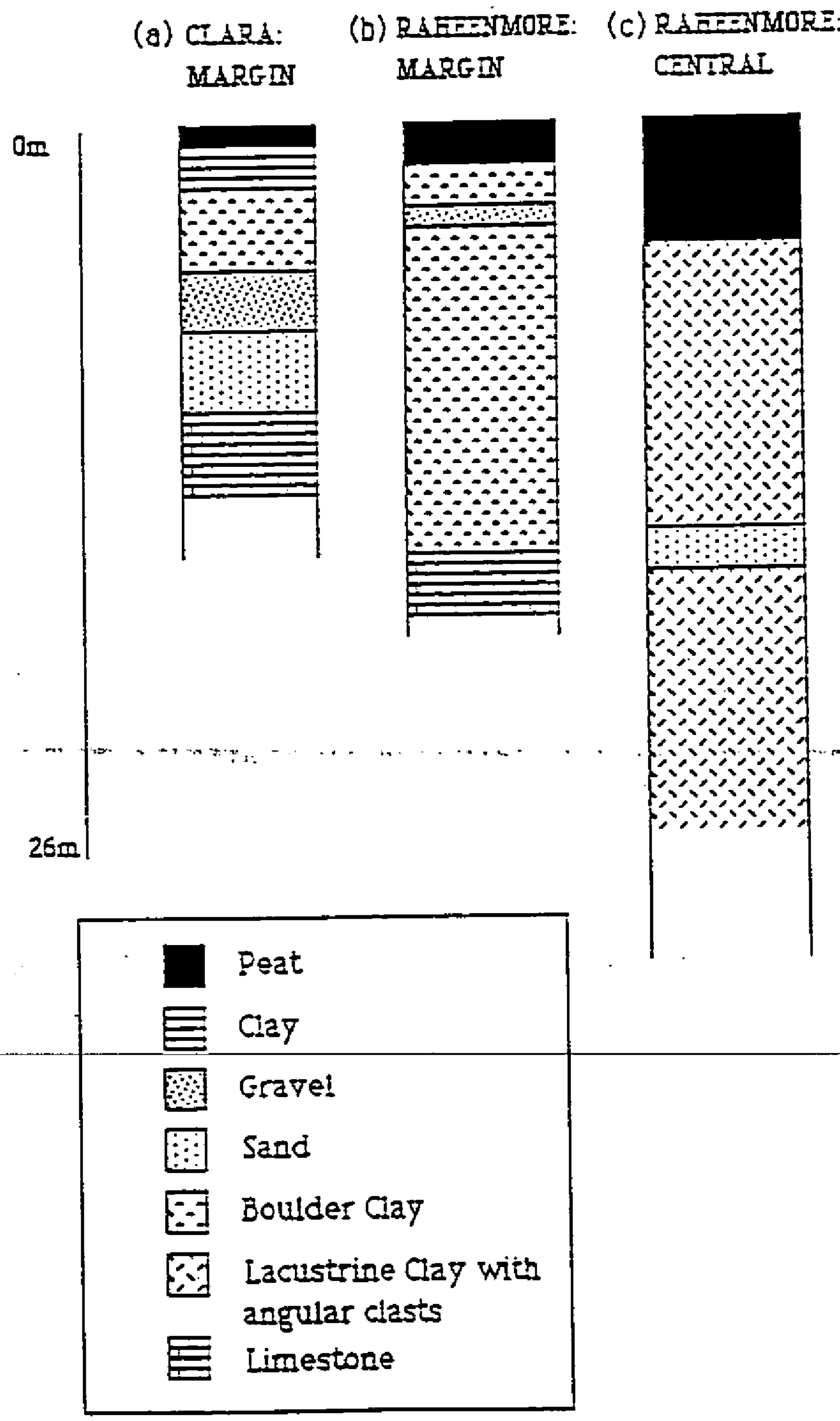


Fig. 2.1 Borehole data showing lithologies of Clara and Raheenmore. Derived from information from the Geological Survey of Ireland.

2.2 SITUATION.

2.2.1. Clara Bog.

1/2 " Map No.: 15
6" Map No.: Offaly 8
Grid Ref.: 07^0 38' W 53^0 20' N

Clara Bog is situated in Co. Offaly approximately 9 km north-north west of Tullamore and 2 km south of Clara town (Fig. 2.4). The road between Clara and the village of Rahan bisects the bog. The site is located across the townlands of Doory, Derries, Ballina, Castletown, Bohernagrisna and Erry. It is approximately 665 ha in area (including cut-away sections), 465 ha of which were purchased in 1986 by the Wildlife Service. These 465 ha are a National Nature Reserve. It is now under the management of the National Parks and Wildlife Service (Office of Public Works). The area lies at approximately 58 - 70 m OD. It is bounded to the north by an esker ridge and to the south largely by cut-away bog.

This site was listed as being of only local importance in 1981 by An Foras Forbartha. Since then it has gained international importance, due mainly to the presence of its soak systems (internal drainage features) and also because it is the largest remaining example of the midland raised bog type (Cross, 1990).

2.2.2. Raheenmore Bog.

1/2 " Map No.: 15
6" Map No.: Offaly 10
Grid Ref.: 07^0 20' W 53^0 20' N

Raheenmore Bog is located in Co. Offaly, 7 km South of Tyrrellspass and 5 km north of Daingean (Fig. 2.4) and lies at approximately 100 m OD. It is approximately 200 ha in size. A number of townlands converge in the centre of this site, namely Cloneen, Kilclonfert, Raheenmore, Puttaghan, Kilduff, Clonagh, Mullagharush and Cruit. It was designated a National Nature Reserve in 1970 and is under the management of the National Parks and Wildlife Service (Office of Public Works). It was listed as being of international importance in 1981 (An Foras Forbartha, 1981).

2.3 CLIMATE.

The accumulation of peat, in order to form a mire system, depends on the rate of production of plant material exceeding the rate of decay by micro-organisms (Moore and Bellamy, 1976). This limits the occurrence of peat deposits to tropical areas where production rates are extremely high or to temperate and upland areas where microbial decay is limited. The major zone of mire development is in the northern hemisphere, mostly confined to Europe, Canada, North America and The Russian Federation (Gore, 1983). The most important factors inhibiting microbial activity are acidity, anaerobiosis, waterlogging and low temperatures (Given and Dickinson, 1975). The most important of these factors in influencing the rate of decay in Irish raised bogs are waterlogging and thus reduced oxygen availability (Doyle, 1990).

Although the development of a raised bog is affected by a number of factors, including the local geology and drainage patterns, the most important natural control in terms of their continued growth is the humid, wet climate this country experiences. Ireland is thus ideally suited to the formation of peat bogs owing to its mild oceanic climate, high rainfall (with a high number of rain days) and high relative humidity and consequent low evapotranspiration. This ensures that the climatic conditions for microbial decay remain sub-optimal and peat will continue to accumulate if the hydrology of the bog is protected.

Meteorological data, from the Meteorological Service of Ireland, was available for two stations close to both bogs. These were Birr, Co. Offaly (70m O.D.) which is 33 km south-west of Clara and 48 km west south west of Raheenmore and Mullingar, Co. Westmeath (101 m O.D.), which is 20 km north of Raheenmore and 30 km north-east of Clara. The data from these stations represents the climate of the principal Midland raised bog distribution.

The monthly mean rainfall figures are shown for both weather stations in Fig. 2.5. The Birr data consist of the average monthly values for the years 1961 to 1990 and the Mullingar data are derived from the average monthly figures between the years 1971 and 1990.

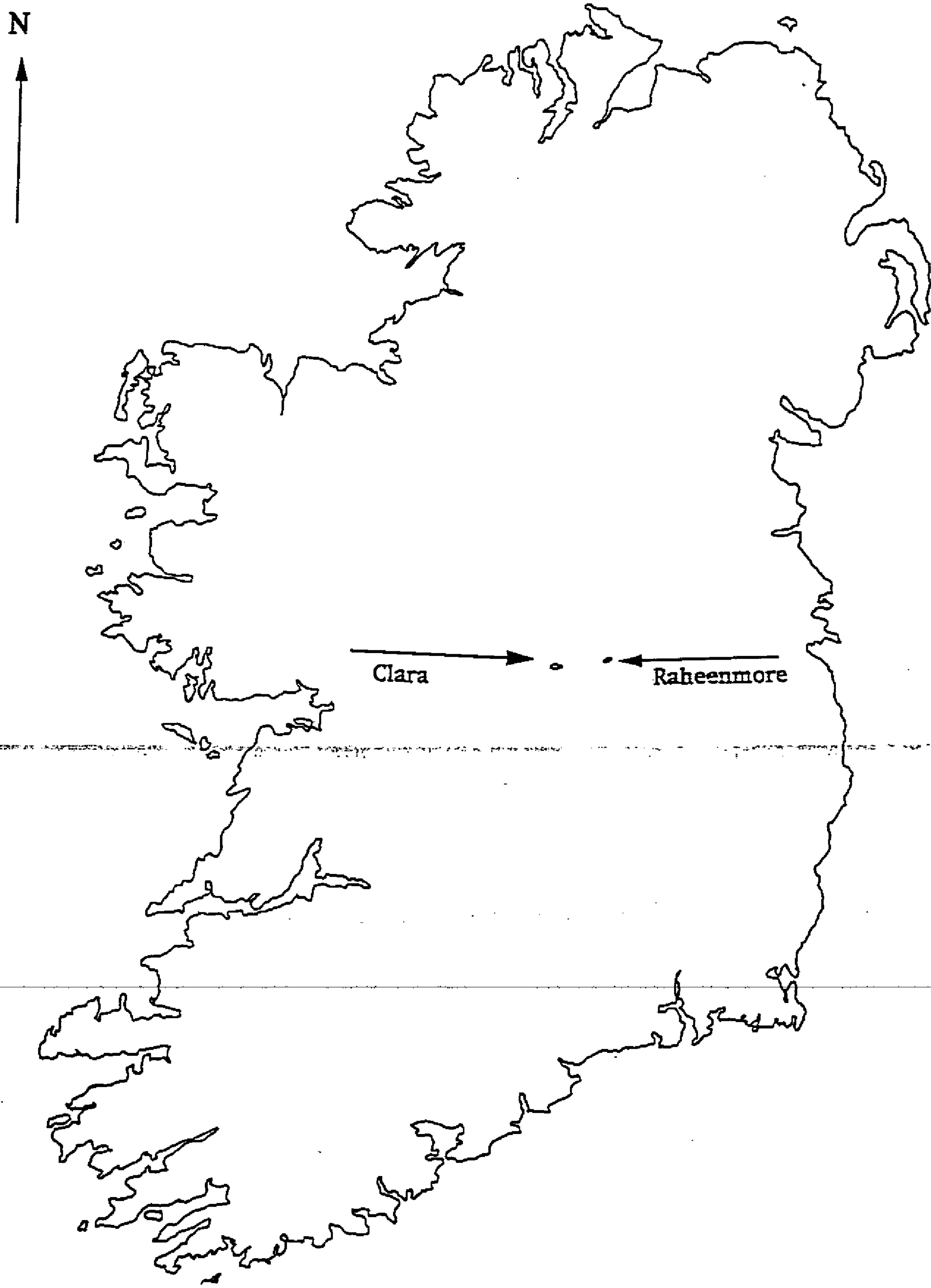


Fig. 2.4 Map of Ireland indicating the situation of Clara and Raheenmore Raised Bogs.

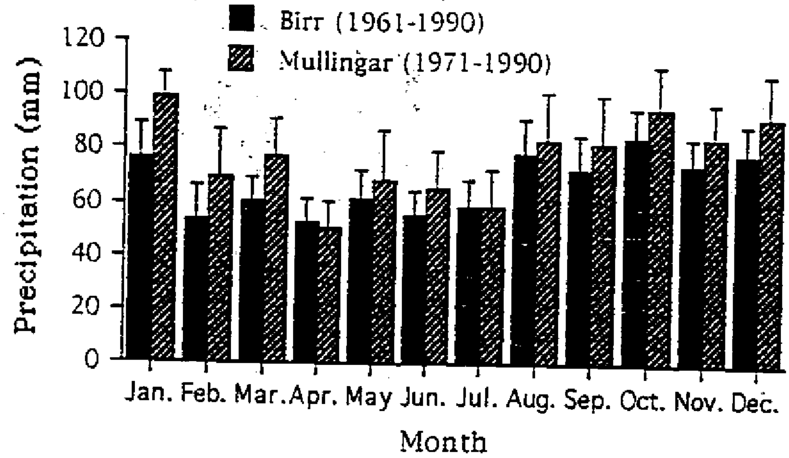
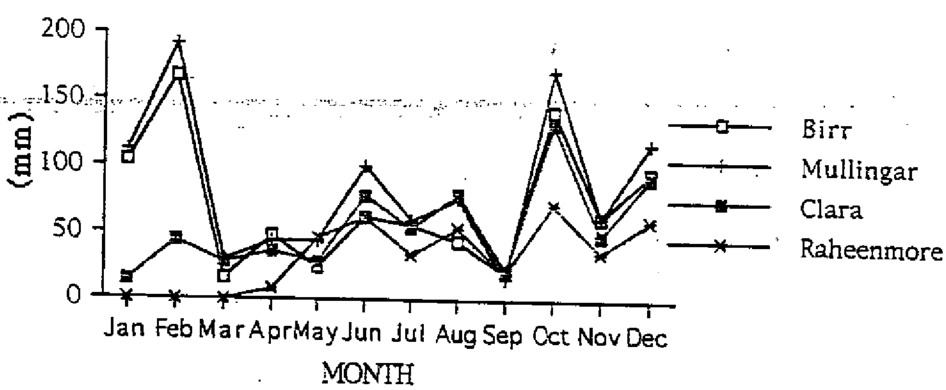


Fig. 2.5 Average monthly precipitation (± 2 S.E.) from Birr (1961-1990) and Mullingar (1971-1990).

Rainfall recorders were installed at both study sites but due to technical difficulties some information is not available. However, when all figures for a full month are available, they correspond closely to the data from Birr and Mullingar (Fig. 2.6) and the assumption can be made that they experience similar climatic conditions to the weather stations.



Note: Some daily data missing, due to technical difficulties, at Clara; January and February; Raheenmore; January, February, March and October.

Fig. 2.6 Precipitation (mm) at Clara, Raheenmore, Mullingar and Birr in 1990.

Penman evapotranspiration figures from Birr (a) and Mullingar (b) show that for at least six months of the year precipitation exceeds evapotranspiration (Fig. 2.7). 1990 was a particularly dry year and evaporation exceeded precipitation for more than usual as, on average, evapotranspiration only exceeds precipitation for two to three months each year at Birr and Mullingar (Cross, 1990).

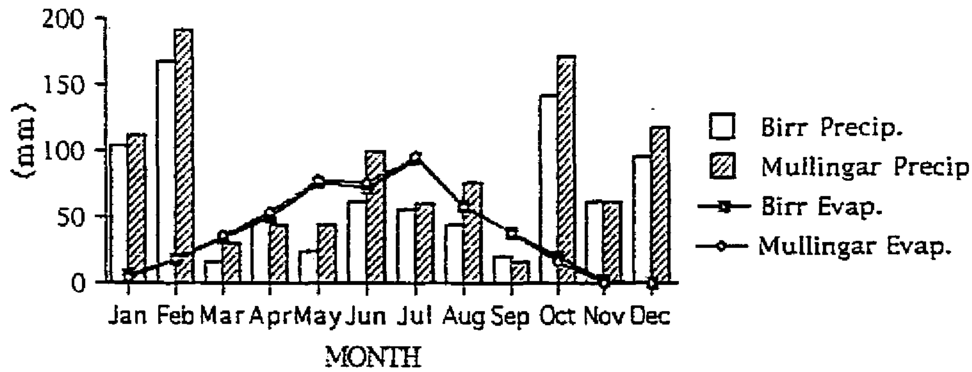


Fig. 2.7 Precipitation and evapotranspiration from Mullingar and Birr, 1990.

The maximum, minimum and average daily temperatures at both stations for each month of 1990 (a typical year in relation to average temperatures) are shown in Table 2.1. These show a pattern of mild winters and cool summers which favours the development of raised bogs.

Table 2.1 Average maximum, minimum and daily temperatures for Birr and Mullingar (1990).

	BIRR			MULLINGAR		
MONTH	Mean Max.	Mean Min.	Mean Day	Mean Max.	Mean Min.	Mean Day
January	9.6	3.7	6.6	8.8	2.8	5.8
February	9.7	3.4	6.6	8.7	2.7	5.7
March	11.8	5.5	8.7	11.1	4.0	8.0
April	12.4	3.2	7.8	12.0	2.9	7.5
May	17.8	7.1	12.5	16.8	7.2	12.0
June	16.8	9.1	13.0	16.2	8.6	12.4
July	20.9	11.3	16.1	20.2	10.9	15.6
August	20.1	12.2	16.2	19.4	11.8	15.6
September	17.0	7.4	12.2	16.1	7.4	11.8
October	13.8	8.4	11.1	13.3	7.9	10.6
November	9.7	3.0	6.4	9.4	3.3	6.3
December	7.6	1.3	4.4	6.9	0.9	3.9

2.4 PAST MANAGEMENT, DRAINAGE AND PEAT CUTTING.

During 1983 Bord na Móna drained the eastern part of Clara Bog by digging a series of north-south drains at 20 metre intervals and some east-west drains at various intervals, in preparation for peat extraction. These drains were subsequently blocked in 1987, after acquisition of the site by the National Parks and Wildlife Service (Office of Public Works). This blocking has been more successful in some areas than others. *Sphagnum cuspidatum* has colonised some of the places where blocking has been more effective and water table levels have been maintained. An investigation into the re-colonisation of these drains was carried out by McAfee (1993). A large drain runs along much of the northern boundary. On Clara East this boundary drain was deepened and widened in 1991 as part of a reclamation scheme for the areas adjoining the bog. This caused considerable damage to some marginal vegetation communities in this area. The effect of this drain on the hydrology of the bog has been examined by Blackwell (1992), who showed that it has had a significant effect on the local hydrology. In 1992 a surface drain surrounding the whole site was dug by the Office of Public Works to mark the boundary of their ownership. This drain is increasing runoff in some areas, despite being blocked at regular intervals.

The most serious drainage problem affecting Clara is caused by the road which runs through the centre of the site. This was constructed approximately 150 years ago. It has been estimated to have caused a 6 metre subsidence in the immediate area since then (Samuels, 1992). The deep drains which occur on either side of the road are affecting the hydrology of the area considerably and are thus damaging the vegetation of the bog. If conditions suitable for bog growth (that is high water table levels) are to be maintained, the hydraulic gradients in these areas must be reversed. These drains were further deepened during 1993 by Offaly Co. Council.

Peat cutting on Clara is largely confined to the southern edges where extensive commercial extraction is taking place. Possible acquisition of these areas is currently being investigated. The former southern extent of raised bog peat at this site was recorded by Van Tatenhove and Van der Meer (1990) as being to the edge of the Silver River.

At sometime in the period between the mapping of Clara Bog in 1838 and the mapping in 1910, three small roads were constructed leading, from the road which bisects the bog out onto the western side of the site. It has been suggested that these were most probably built as part of a famine relief scheme. They are composed of gravel and other limestone material probably obtained from the adjacent esker. They are drier, more eutrophic and more base rich than the surrounding bog owing to increased levels of calcium and the free draining nature of the gravely material. Their flora is therefore anomalous with the adjoining bog and, though not natural phenomenon, they have added considerably to the diversity of the flora in the local area. They are dominated by *Molinia caerulea* with the addition of other grass species such as *Briza media* and orchids such as *Plantanthera bifoliata*, *Listera ovata* and *Epipactis palustris*. For a species list of these roads see Appendix 2.1.

On Raheenmore very little peat cutting has taken place, except for two marginal areas to the south-east and north-west. However a deep peripheral drain (approximately 2 metres deep) surrounds most of the site, causing drying out of the peat and a subsequent increase in ericoid species.

A section of the eastern part of Raheenmore has a series of surface drains running through it. These were installed in the period between 1910 and 1950 (Information derived from maps and aerial photographs). They have mostly been re-colonised by *Sphagnum* species but the vegetation of the area has been adversely affected. During 1992 a marginal area to the west was reclaimed, with the clearing of scrub and the digging of drains. This will affect the marginal vegetation communities in these areas. The effects of drainage on the two bogs is discussed in more detail in Chapter 9.

CHAPTER 3 VEGETATION.

3.1 INTRODUCTION.

Vegetation classification involves the division of the vegetation cover of an area into assemblages of plant species which tend to occur together in a particular environment. These assemblages of plant species are known as plant communities. The plant community which is seen in the field is the concrete community and is described by a series of samples or relevés in which species occurrence and cover values are recorded. This relevé data then forms the abstract vegetation unit, which is the basic vegetation unit or plant association (Mueller-Dombois and Ellenberg, 1974). Each plant association contains constant, diagnostic and differental species which may be used to separate it from other plant associations.

An important consideration when examining peatland vegetation communities is that very small scale variation of vegetation communities over the bog surface is the norm. Some distinct homogeneous communities may be only 50 x 50 cm in size or less. The traditional method of dealing with this situation was to treat the whole pattern of communities as a single community type, where in fact it is a whole complex of communities with very different inherent and associated environmental characteristics (Schouten, 1990). In this study, small scale community descriptions were considered necessary to provide the units for investigations of the abiotic environment. As plot size is small, it must be ensured that the minimal area for that plant community is covered. The minimal area of a plant community is the smallest area which can be covered by a vegetation sample, where it is said to include most of its characteristic species (Mueller-Dombois and Ellenberg, 1974). Work by Schouten (1990) showed that the minimal area for the relatively species poor communities of hollows and pools was 2-4 dm^2 and that for species rich hummocks, $1m^2$ was sufficient. Thus, as minimal areas for bog communities are small and as percentage cover values are used for recording plant species abundance the size of the relevé or study plot could vary according to the size of the community.

During the field season of 1990, vegetation work was carried out along hydrological transects which were already established on the two bogs. The vegetation data collected was largely confined to these transects in order to gain as much information as possible from a combination of botanical, hydrological and geological investigations. The relevé sites were chosen along the hydrological transects close to piezometer stations and covered the range of community types in that area. Subsequent to surveying these sites it was necessary, in order to cover lagg vegetation types, to select further transects. In total six transects were studied, three on Clara bog and three on Raheenmore bog. During the field season of 1991, vegetation plots were also established to examine the soak systems on Clara bog. This survey concentrated on the two soaks, Lough Roe and Shanley's Lough. Vegetation studies were carried out in all eight areas using the same quadrat method. Plots were chosen and were described according to the species present and their percentage cover.

3.2 METHODS.

Percentage cover of each species was estimated using a revised Braun-Blanquet Scale (Mueller-Dombois and Ellenberg, 1974). Percentage cover was estimated as the vertical projection of all plant parts onto the surface area of the quadrat.

Relevé data were also used from the work of Van Dijk and Young (1984) from both Clara and Raheenmore bogs. Information from 70 of their quadrats was included in the data set for analysis by TWINSPAN. Their data were never published and the incorporation of the information into this work was agreed by them.

The following is the % cover scale used in this vegetation survey:

CATEGORY	% COVER
1	1-2 individuals <5%
2	2-25 individuals <5%
3	2-5 %
4	5-12.5 %
5	12.5-25%
6	25-50%
7	50-75%
8	75-100%

Total vegetation cover and the % cover of each of the major groups was recorded. The height of different vegetation layers was also recorded, as were bare ground, open water and litter.

Bryophytes were collected for microscopic identification and verification of identification. Often it was important to collect a handful of *Sphagnum* species from the plots in order to examine them for micro-liverworts. This survey did not include the recording of epiphytic species, such as those that occur on *Calluna vulgaris*.

NOTE: Nomenclature according to Jermy et al. (1982) for sedges, Clapham et al. (1989) for other vascular plants, Smith (1980) for mosses and Watson (1981) for liverworts.

3.3 COMPUTER PROCESSING.

In total, data from 399 relevés was used in the vegetation classification. The vegetation data information gathered from the surveys was initially processed using Vegbase 3.0 (1990) a fourth generation program based on dbaseIII. This program prepares Cornell Condensed files for analysis in TWINSPAN and CANOCO.

TWINSPAN

Initial clustering of the sites according to their vegetation was obtained using TWINSPAN (Hill, 1979), which is a fortran program for Two-Way Indicator Species Analysis. It is a divisive method of cluster analysis, where sites are classified by a repeated dichotomization into groups or clusters of plots containing a similar species composition, by the method of correspondence analysis. A direction of variation is identified by ordinating the plots. Sites can be identified using the occurrence of differential species to identify different communities. Finally a two-way table is constructed from a site and species matrix (Jongman et al, 1987). The sites or plots on the table are situated in such a way that sites with a similar species composition are grouped together and a diagonal arrangement of species occurrence is seen. TWINSPAN was designed specifically for ecologists and phytosociologists and is therefore one of the most frequently used methods for classifying vegetation communities (Hill, 1979).

3.4 MIRE VEGETATION CLASIFICATION.

Irish mires are divided into two main main types, fens and bogs (Cross, 1990). This division is based on their nutrient supply: fens being minerotrophic or receiving their nutrient supply from ground water while bogs are ombrotrophic, depending on precipitation for ionic inputs. Bogs may be further divided into blanket bogs and raised bogs depending on their morphology. Blanket bogs develop as a layer covering the landscape whereas raised bogs generally develop in basins. Blanket bogs are of two types, mountain or lowland, depending on their geographic location. Lowland blanket bogs are confined to the West of Ireland, whereas mountain blanket bogs develop in upland areas in all parts of the country.

The vegetation of raised bogs is usually distinguished from that of blanket bogs by the presence of *Vaccinium oxycoccus* and *Andromeda polifolia* (Moore, 1968). *Vaccinium oxycoccus* occurs occasionally on blanket bogs but usually in only slightly flushed areas (Doyle and Foss, 1986; Douglas et al., 1989). Raised bogs can be further divided on the basis of their vegetation into a western type and a midland type (Cross, 1990). Both Clara and Raheenmore bogs are examples of the midland type.

Two systems of vegetation classification may be used, either the continental system which is a hierarchical method of ordering plant communities or the British system which involves a lateral approach to vegetation classification.

The Continental System.

The continental system includes three main divisions in the classification of mire plant communities (Westhoff and Den Held, 1969). These are:

1. The vegetation of oligo-mesotrophic fens, the Parvocaricetea.
2. The vegetation of bog pools and oligotrophic lakes, the Scheuchzerietea.
3. The vegetation of flats and hummocks on bogs, the Oxycocco-Sphagnetea.

White and Doyle (1982) only recognise two main divisions: the Parvocaricetea and the Oxycocco-Sphagnetea. They include the Scheuchzerietea as an order within the class Oxycocco-Sphagnetea, called the Scheuchzerietalia palustris. They do this as, in the Atlantic region, the communities of pool are floristically closer to the communities of the Oxycocco-Sphagnetea, whereas on the continent bog pools contain elements more typical of the Parvocaricetea.

The Oxycocco-Sphagnetea may be divided in two ways:

1. On an ecological basis (Westhoff and Den Held, 1969; Moore, 1968)

   A) The order Sphagnetalia magellanici. This contains the vegetation communities which occur on peats deeper than 1.5 metres and are typified by an abundance of *Sphagnum magellanicum* and *Sphagnum capillifolium* - hence the term red bogs (Osvald, 1949). This order contains two alliances, the boreal Sphagnion fusci and the Atlantic Erico-Sphagnion.
   B) The order Ericetalia tetralicis, which contains the communities of shallow peats.

2. On a geographical basis (Dierssen, 1982).
   A) The boreo-continental division: the order Sphagnetalia magellanci.
   B) The Atlantic division: the order Erico-Sphagnetalia, which contains two alliances separated on an ecological basis: the Erico-Sphagnion for wet heathland vegetation and the Calluno-Sphagnion papillosi for deep peat communities. The latter includes two associations: the Sphagno tenelli-Rhynchosporetum albae encompassing pool vegetation and the Erico-Sphagnetum magellanici including the flat and hummock communities.

The British System.
The most recent classification of mire vegetation was carried out by the National Vegetation Classification Project in Britain (Rodwell, 1991). In that classification only two broad categories are indicated for raised bogs: the pool, lawn and wet hollow communities are included in the *Sphagnum cuspidatum/recurvum* pool (M2) division; the remainder of raised bog vegetation is included in the *Erica tetralix-Sphagnum papillosum* mire (M18) which is again typified by the presence of *Vaccinium oxycoccus* and *Andromeda polifolia*. It is a non-hierarchial system and is thus totally different to the continental approach.

In a general ecological and taxonomic overview of the vegetation of a particular area, the hierarchial method is probably a more useful system to adopt, as different communities may be easily related to each other. In a local study, such as this, the lateral approach to the classification of community types is sufficient.

3.5 SYNOPTIC TABLES.

When the number of relevés in a data set exceeds 100-200, it is necessary to construct synoptic tables to summarise the main phytosociological tables (Whittaker, 1973). Synoptic tables were prepared from the output of TWINSPAN subsequent to the classification of community types. The following is the method which was used. The presence of species in the relevés of a particular community type was calculated as a % value of the total number of relevés in that group. The presence degree is divided into five classes which are denoted using Roman numerals.

I	0-20%
II	21-40 %
III	41-60 %
IV	61-80 %
V	81-100 %

Species in classes IV and V are described as constants, III common, II occasional and I scarce (Rodwell, 1991). The cover value range for each species within the group is also indicated in brackets after the presence value. In the final tabulation, species are arranged according to decreasing frequency.

The total number of community types identified in this survey was 25 and a number of variants, sub-variants and phases are included within these major divisions.

In some situations, due to the restriction in size or distribution of a community type, the data from only one relevé is available. In these cases the relevé information is included with percentage cover values.

Terms commonly used in the community descriptions are described below:
(These terms are generally accepted in the study of mire ecology (Gore, 1983))

Pools: Depressions in the bog surface where the water table remains above surface level all year round or below surface level for only very short periods of time. They are characterised by the presence of aquatic plant species such as *Sphagnum cuspidatum* and *Cladopodiella fluitans*. Vascular species which frequently occur are *Eriophorum angustifolium*, *Drosera anglica* and *Rhynchospora alba*.

Hollows: These are shallow depressions in the bog surface where water collects and lies, or where the water table reaches ground level or lies just above ground level, depending on seasonal conditions. Marginal hollows tend to be elongated as they are focus points for surface water run-off. They are often dominated by *Narthecium ossifragum*. On the high bog they take many forms but are often eye-shaped.

Lawns: These are shallow hollows or flat areas where one species dominates to form a lawn. This is frequently a *Sphagnum* species, such as *Sphagnum magellanicum*, which can completely in-fill a hollow to form a small lawn.

Flats: These are more or less flat areas which are intermediate between hollow and hummock communities. They tend to be drier than the above situations.

Hummocks: These are mounds on the bog surface which can range from a few centimetres to more than a metre in height. They are usually composed mainly of *Sphagnum* species, such as *Sphagnum magellanicum*, *S. capillifolium*, *S. imbricatum* and *S. fuscum* but other bryophyte species such as *Hypnum jutlandicum* and *Leucobryum glaucum* are also important, especially as the hummock grows taller and becomes drier. *Calluna vulgaris* is another important element, as it flourishes where the water table is not at surface level.

Soaks: These are areas particular to Clara bog, where they make up part of the internal drainage system of the high bog. They support a suite of plant communities different to the high bog, due either to the influence of increased nutrient or base availability caused by ground water inputs or water movement.

The following community descriptions are not an attempt to classify raised bog communities in Ireland but rather to form a suitable and meaningful vegetation basis for ecological investigations on the two bogs under study.

3.6 VEGETATION CLASSIFICATION AND COMMUNITY DESCRIPTIONS.

The following is a non-hierarchial classification of the main plant communities found on Clara and Raheenmore. The communities are given local names according to the dominant or characteristic species. A phytosociological classification (continental system) of the communities is included in Appendix 3.1. The authorities for the phytosociological classification are those used in White and Doyle (1982) except where they do not include the community concerned in which case Westhoff and den Held (1969) are followed. A synoptic table for each community, sub-community, variant or phase follows a description of the type and its habitat, apart from the exceptions mentioned above, where the relevé information is included. The average cover and range of values of the major physiognomic divisions are indicated where appropriate. The number of relevés, which were sampled for each community, sub-community, variant and phase is also included. A diagnostic species assemblage is also indicated for each type. This consists of the combination of species which typically occur together and dominate in that community which enables an identification. Sometimes the species combination used may also occur in another community type but at low abundancies. Within a community type sub-communites, variants, sub-variants and phases may occur. These are separated using differential species or, in the last case, dominant species.

Section A.
This section covers the communities which occur on the mire expanse of both bogs, occasionally including some plots which are under the influence of the soak systems or are located in areas of cut-away. In general these are characterised by the presence of ericoid and *Carex* species and an abundance of *Sphagnum* species.

Section A1.
This section includes the communities of hollows, pools and lawns of the high bog. These are generally typified by a low cover of dwarf shrubs and include indicators of aquatic conditions. In the case of pool and lawn communities, they are mostly confined to the wetter central sections of both bogs. The hollows and erosion channel communities are more frequent in the marginal areas of the two bogs.

Type 1.
Local Name: The community of *Rhynchospora alba* and *Zygnemalis.*
(number of samples = 7).
Diagnostic Species Assemblage: *Rhynchospora alba, Zygnemalis* and *Narthecium ossifragum.* (*Zygnemalis* includes a group of algal species).
This community type is confined to hollows and erosion channels on the margins or rand of the high bog. During the winter months or periods of high rainfall they are waterlogged and surface runoff is high, as the acrotelm in these marginal areas is mostly non-functional. They tend to be narrow, linear features with the long axis corresponding to the direction of flow. During the summer months, the *Zygnemalis* element becomes crisp. The average bryophyte cover is low, 15 % (2-55), with few *Sphagnum* species occuring. Algal cover is generally high, with an average cover of 52% (2-90). *Rhynchospora alba* is the dominant herb with *Eriophorum angustifolium* and *Narthecium ossifragum* also occuring frequently.

Rhynchospora alba	V(2-7)	*Sphagnum cuspidatum*	II(2-7)
Zygnemalis	V(2-8)	*Cladonia portentosa*	II(1-2)
Eriophorum angustifolium	V(2-4)	*Cladonia uncilalis* subsp. *biuncialis*	II(1-2)
Narthecium ossifragum	IV(2-5)	*Ondontoschisma sphagni*	I(4)
Carex panicea	III(1-6)	*Campylopus paradoxus*	I(2)
Trichophorum cespitosum	III(2)	*Drosera anglica*	I(2)
Sphagnum subnitens	II(2-3)	*Andromeda polifolia*	I(2)
Sphagnum papillosum	II(2-4)	*Sphagnum capillifolium*	I(1)
Sphagnum tenellum	II(2-4)	*Cephalozia connivens*	I(1)
Erica tetralix	II(2-3)	*Cladonia ciliata* var. *tenuis*	I(1)
Sphagnum magellanicum	II(2)	*Calluna vulgaris*	I(1)
Drosera rotundifolia	II(1-2)		

Type 2.
Local Name: Community of *Sphagnum cuspidatum* and *Eriophorum angustifolium*
Diagnostic Species Assemblage: *Sphagnum cuspidatum* and *Rhynchospora alba*.

2 A Typical Variant (Plates 1 and 2).
(number of samples = 11).
The community of permanent pools and wet hollows on the high bog. These communities occur only where the water table remains above ground level all year round or where drying out occurs only for very short periods of time. This is indicated by the high cover of the aquatic species *Sphagnum cuspidatum* and the presence of *Cladopodiella fluitans*, which is also an aquatic species. Bryophyte cover is typically high with an average value of 92% (50-100) and dwarf shrub cover is low 3% (0-10).

Sphagnum cuspidatum	V(6-8)	*Odontoschisma sphagni*	I(2-4)
Eriophorum angustifolium	V(1-4)	*Sphagnum papillosum*	I(2-4)
Rhynchospora alba	V(2-4)	*Carex panicea*	I(2-4)
Sphagnum magellanicum	II(2-5)	*Eriophorum vaginatum*	I(2)
Calluna vulgaris	II(1-2)	*Menyanthes trifoliata*	I(2)
Andromeda polifolia	II(2)	*Vaccinium oxycoccus*	I(1-2)
Drosera anglica	II(1-3)	*Cephalozia connivens*	I(1)
Erica tetralix	II(2-3)	*Trichophorum cespitosum*	I(1)
Cladopodiella fluitans	I(3-7)		

2 B Variant with *Rhynchospora fusca*.
(number of samples = 3).
Differential Species: *Rhynchospora fusca*.
Community of species poor, shallow pools and hollows at the marginal areas of the bog. The presence of *Zygnemalis* indicates a fluctuating water table. No typically aquatic herb species occur, indicating that these are not permanent pools.

Sphagnum cuspidatum	V(5-7)	*Andromeda polifolia*	IV(1-2)
Zygnemalis	V(4-7)	*Carex panicea*	IV(2)
Rhynchospora fusca	V(3-4)	*Sphagnum papillosum*	II(3)
Eriophorum angustifolium	V(2)	*Narthecium ossifragum*	I(1)

2 C Variant with *Molinia caerulea* and *Juncus bulbosus*.
(number of samples = 8).
Differential Species: *Molinia caerulea*, *Juncus bulbosus* and *Sphagnum recurvum*.
The community of pools and hollows on the cut-away marginal areas or those areas located close to the soak systems. They are slightly enriched due to their proximity to a ground water influence or to water movement. This is indicated by the presence of species such as *Molinia caerulea* and *Juncus bulbosus*, which require a slightly enriched environment. The occasional occurrence of *Hydrocotyle vulgaris* also indicates enrichment. Although *Menyanthes trifoliata* is a common species of pools on other raised bogs, it is not very common in the pools on Clara and Raheenmore. Its presence in this variant indicates very wet conditions. Bryophyte cover is high, 94% (50-100) and herbs are more frequent, 30% (3-55), than in the previous community type.

Sphagnum cuspidatum	V(6-8)	*Sphagnum recurvum*	II(3-4)
Eriophorum angustifolium	V(2-6)	*Andromeda polifolia*	II(2)
Vaccinium oxycoccus	V(2-3)	*Hydrocotyle vulgaris*	I(4)
Menyanthes trifoliata	IV(2-7)	*Cephalozia sp.*	I(3)
Molinia caerulea	IV(2-5)	*Aulacomnium palustre*	I(3)
Juncus bulbosus	III(2-3)	*Calypogeia muellerana*	I(2)
Trichophorum cespitosum	III(2-3)	*Calluna vulgaris*	I(2)
Drosera rotundifolia	III(2)	*Odontoschisma sphagni*	I(2)
Rhynchospora alba	II(2-4)	*Drepanocladus fluitans*	I(2)
Cladopodiella fluitans	II(2-4)	*Juncus effusus*	I(2)
Erica tetralix	II(2-3)	*Hypnum jutlandicum*	I(2)

Type 3
Local Name: Community of *Narthecium ossifragum, Sphagnum magellanicum* and *S. tenellum.*
Diagnostic Species Assemblage: *Narthecium ossifragum, Sphagnum tenellum, Sphagnum magellanicum* and *Sphagnum papillosum.*
Rhynchospora alba is also common in these community types but at low abundancies.

3 A Typical variant (Plate 3).
(number of samples = 15).
This is a community of damp hollows, which occur over the whole bog surface and also becomes the dominant community type in a zone of the marginal complex. They tend to be elongated features, which hold water during periods of high rainfall and during the winter months. They are dominated by *Narthecium ossifragum* (herb cover 25% (10-30)) with a relatively high dwarf shrub cover 28% (5-55) indicating that average water table levels are not high. However bryophyte cover is also high 86%(20-100) suggesting that they remain damp for long periods of time.

Narthecium ossifragum	V(2-7)	*Cladonia uncialis* subsp. *biuncialis*	II(1-3)
Sphagnum tenellum	V(2-7)	*Sphagnum fuscum*	I(6)
Sphagnum capillifolium	V(2-6)	*Sphagnum subnitens*	I(2-5)
Odontoschisma sphagni	V(3-6)	*Campylopus paradoxus*	I(2-4)
Erica tetralix	V(2-5)	*Rhynchospora alba*	I(3-4)
Calluna vulgaris	V(2-6)	*Sphagnum cuspidatum*	I(2-4)
Eriophorum angustifolium	V(2-4)	*Calypogeia sp.*	I(3)
Sphagnum magellanicum	IV(3-6)	*Calypogeia fissa*	I(3)
Drosera rotundifolia	IV(2-3)	*Cephalozia connivens*	I(3)
Andromeda polifolia	IV(1-3)	*Mylia anomala*	I(3)
Vaccinium oxycoccus	IV(1-3)	*Pleurozium schreberi*	I(3)
Hypnum jutlandicum	IV(2-5)	*Sphagnum palustre*	I(3)
Trichophorum cespitosum	IV(2-3)	*Cephaloziella sp.*	I(3)
Eriophorum vaginatum	III(2-5)	*Calypogeia muellerana*	I(3)
Sphagnum papillosum	III(2-7)	*Cephalozia bicuspidata*	I(3)
Cladonia portentosa	III(1-3)	*Lophocolea bidentata*	I(2)
Aulacomnium palustre	II(2-7)	*Bryum sp.*	I(2)
Carex panicea	II(2-3)	*Cladonia ciliata* var. *tenuis*	I(1)
Kurzia pauciflora	II(1-3)		

3B Phase with *Sphagnum magellanicum.*
Dominant species: *Sphagnum magellanicum.*
These are communities where *Sphagnum magellanicum* dominates. They are mainly confined to pools or very wet hollows which are completely infilled and remain wet throughout the year.

3Ba Sub-variant with *Sphagnum cuspidatum.*
(number of samples = 5).
Differential Species: *Sphagnum cuspidatum, Cladopodiella fluitans, Menyanthes trifoliata and Drosera anglica.*
This is the variant of the wettest *Sphagnum magellanicum* pools or lawns. This is indicated by the presence of *Sphagnum cuspidatum* and *Cladopodiella fluitans*. Bryophyte cover is always complete (100%) and dwarf shrub cover is low, 9% (5-10). Herb cover is variable but relatively low, 21% (5-50). Extensive *Sphagnum* growth such as this is confined to the wettest central areas of the high bog. On Raheenmore this community type appears to be infilling previous *Sphagnum cuspidatum* pool communities as the bog is drying out due to the peripheral drainage.

Sphagnum magellanicum	V(7-8)	*Drosera anglica*	IV(2-3)
Narthecium ossifragum	V(3-5)	*Andromeda polifolia*	IV(2)
Drosera rotundifolia	V(2-4)	*Rhynchospora alba*	III(2-5)
Eriophorum angustifolium	V(3-4)	*Menyanthes trifoliata*	III(2)
Sphagnum cuspidatum	V(2-5)	*Cladopodiella fluitans*	III(3-5)
Erica tetralix	V(2-3)	*Hypnum jutlandicum*	I(4)
Calluna vulgaris	V(1-2)	*Aulacomnium palustre*	I(2)
Vaccinium oxycoccus	V(2)	*Trichophorum cespitosum*	I(2)
Odontoschisma sphagni	IV(2-4)		

3Bb Sub-variant with *Sphagnum capillifolium.* (Plate 4).
(number of samples = 11).
Differential Species: *Sphagnum capillifolium.*
This is a drier version of *Spagnum magellanicum* lawn which can also form low hummocks, indicated by the higher percentage cover of species such as *Calluna vulgaris*, *Sphagnum capillifolium* and *Erica tetralix* (dwarf shrub cover 29% (5-60)). However the water table is still close to surface level for most of the year and bryophyte cover is high, 98% (90-100). The average herb cover is 14% ranging from 5-40%.

Sphagnum magellanicum	V(7-8)	*Trichophorum cespitosum*	II(1-2)
Erica tetralix	V(2-4)	*Cladonia portentosa*	II(1-4)
Drosera rotundifolia	V(2-4)	*Carex panicea*	II(1-2)
Eriophorum angustifolium	V(1-4)	*Cladonia uncialis* subsp. *biuncialis*	II(1-2)
Narthecium ossifragum	IV(2-5)	*Mylia anomala*	I(3)
Odontoschisma sphagni	IV(3-6)	*Sphagnum cuspidatum*	I(3)
Sphagnum capillifolium	IV(2-4)	*Calypogeia muellerana*	I(3)
Calluna vulgaris	IV(2-6)	*Sphagnum palustre*	I(3)
Eriophorum vaginatum	IV(2-3)	*Cladopodiella fluitans*	I(2)
Andromeda polifolia	IV(2)	*Calypogeia fissa*	I(2)
Vaccinium oxycoccus	III(1-3)	*Campylopus paradoxus*	I(2)
Sphagnum papillosum	III(2-5)	*Cephalozia connivens*	I(2)
Rhynchospora alba	II(1-5)	*Sphagnum subnitens*	I(1)
Hypnum jutlandicum	II(2-3)	*Drosera anglica*	I(1)
Kurzia pauciflora	II(2-3)		

3Bc Sub-variant with *Molinia caerulea.*
(number of samples = 4).
Differential Species: *Molinia caerulea* and *Potentilla erecta.*
This is also a relatively wet variant but the presence of *Molinia caerulea* indicates enrichment. This community type is generally situated close to the soak systems, where there is an influence of water flow causing enhanced aeration or enrichment. The bryophyte layer has a high cover of 94% (85-100). Herbs have an average cover of 25% (5-70) and dwarf shrubs, 25% (10-55), have a similar cover.

Molinia caerulea	V(2-4)	*Narthecium ossifragum*	II(6)
Erica tetralix	V(3-4)	*Cladopodiella fluitans*	II(5)
Drosera rotundifolia	V(2-3)	*Sphagnum papillosum*	II(4)
Sphagnum magellanicum	IV(6-8)	*Drosera anglica*	II(4)
Odontoschisma sphagni	IV(3-4)	*Mylia anomala*	II(4)
Eriophorum angustifolium	IV(2-4)	*Calypogeia muellerana*	II(4)
Calluna vulgaris	III(4-7)	*Sphagnum tenellum*	II(3)
Sphagnum capillifolium	III(4-7)	*Sphagnum cuspidatum*	II(3)
Vaccinium oxycoccus	III(3-4)	*Cephalozia bicuspidata*	II(3)
Hypnum jutlandicum	II(2-4)	*Pleurozium schreberi*	II(2)
Trichophorum cespitosum	III(4)	*Cephalozia sp.*	II(2)
Cladonia portentosa	III(2-3)	*Dicranum scoparium*	II(2)
Aulacomnium palustre	III(3)	*Andromeda polifolia*	II(2)
Campylopus paradoxus	III(2-3)	*Rhynchospora alba*	II(2)
Potentilla erecta	III(1-2)	*Calypogeia sp.*	II(2)
Eriophorum vaginatum	III(2)		

3C Phase of *Sphagnum papillosum.*
(number of samples = 5).
Dominant species: *Sphagnum papillosum.*
This is the variant where *Sphagnum papillosum* (bryophyte cover 98% (95-100)) dominates. In some of the wetter areas of the two bogs *Sphagnum papillosum* can become an important element in hollows and lawns, or it may also form low hummocks.

Sphagnum papillosum	V(7-8)	*Sphagnum capillifolium*	III(3-4)
Narthecium ossifragum	V(2-5)	*Rhynchospora alba*	III(2-3)
Drosera rotundifolia	V(2-3)	*Andromeda polifolia*	III(2)
Eriophorum angustifolium	V(2-3)	*Mylia anomala*	II(2)
Odontoschisma sphagni	V(3-5)	*Sphagnum magellanicum*	II(4)
Trichophorum cespitosum	V(2-4)	*Sphagnum tenellum*	II(3)
Calluna vulgaris	V(2-6)	*Sphagnum subnitens*	II(3)
Erica tetralix	V(2-3)	*Sphagnum fuscum*	II(2)
Hypnum jutlandicum	IV(2-3)	*Kurzia pauciflora*	II(2)
Carex panicea	IV(2)	*Eriophorum vaginatum*	II(2)
Cladonia portentosa	IV(1-2)	*Cladonia uncialis* subsp. *biuncialis*	II(1)

3D Variant with *Campylopus introflexus* and *Zygnemalis.*
(number of samples = 9).
Differential Species: *Campylopus introflexus, Campylopus paradoxus* and *Zygnemalis.*
This variant is characterised by the presence of species which indicate burning or disturbance in the past; those species which tend to colonise areas of bare peat which develop after vegetation has been destroyed by burning or disturbance. These species or group of species include *Campylopus introflexus* (Watson,1981) and *Zygnemalis.* The former is a non-native species which was probably introduced around 1940 (Smith. 1980). This type is found on both bogs, suggesting that fire has played a important role in the vegetation distribution present today. It is particularly abundant on Clara East, where drainage has caused considerable disturbance to the bog surface. Average algal cover is 34% (5-90) and bryophyte cover is generally low at 25% (15-75).

Zygnemalis	V(3-8)	*Campylopus introflexus*	II(2-3)
Sphagnum tenellum	V(1-5)	*Cladonia ciliata* var. *tenuis*	II(1-2)
Erica tetralix	V(2-4)	*Aneura pinguis*	II(1-3)
Odontoschisma sphagni	V(2-5)	*Sphagnum capillifolium*	II(2)
Narthecium ossifragum	V(3-6)	*Sphagnum papillosum*	II(2-4)
Eriophorum angustifolium	V(1-3)	*Sphagnum subnitens*	II(3)
Calluna vulgaris	IV(1-5)	*Cladonia uncialis* subsp. *biuncialis*	II(1-2)
Cladonia portentosa	IV(2-5)	*Kurzia pauciflora*	II(2)
Trichophorum cespitosum	IV(1-6)	*Rhynchospora alba*	II(2)
Andromeda polifolia	IV(1-3)	*Sphagnum magellanicum*	I(2)
Drosera rotundifolia	IV(1-3)	*Eriophorum vaginatum*	I(3)
Campylopus paradoxus	IV(2-6)	*Cephalozia connivens*	I(2)
Carex panicea	IV(2-5)	*Vaccinium oxycoccus*	I(2)
Hypnum jutlandicum	IV(2-5)	*Succisa pratensis*	I(1)

A2

3E Variant of *Trichophorum cespitosum*.
(number of samples = 3).
Differential Species: *Trichophorum cespitosum*.
This is a community type with a high abundance of *Trichophorum cespitosum*. It is a dominant type in some of the marginal areas. *Trichophorum cespitosum* at high abundancies tends to indicate past disturbance, for example drainage or fire. *Calluna vulgaris* also occurs with high cover values in this community type. Different to the above type, it has less bare peat areas and fewer colonisers of bare peat conditions.

Trichophorum cespitosum	V(5)	*Narthecium ossifragum*	II(3)
Calluna vulgaris	V(5-6)	*Zygnemalis*	II(4)
Erica tetralix	V(3-5)	*Leucobryum glaucum*	II(3)
Hypnum jutlandicum	V(3-6)	*Cladonia portentosa*	II(3)
Sphagnum tenellum	V(3)	*Campylopus introflexus*	II(2)
Odontoschisma sphagni	V(2-3)	*Cladonia floerkeana*	II(2)
Eriophorum angustifolium	V(2)	*Carex panicea*	II(2)
Sphagnum capillifolium	IV(4-5)	*Sphagnum subnitens*	II(2)
Sphagnum papillosum	II(5)	*Cladonia uncialis* subsp. *biuncialis*	II(2)
Sphagnum cuspidatum	II(3)	*Andromeda polifolia*	II(2)
Drosera rotundifolia	II(3)	*Eriophorum vaginatum*	II(1)
Campylopus paradoxus	II(2-3)		

3F Variant with *Myrica gale*.
(number of samples = 4).
Differential Species: *Myrica gale*.
This variant is mainly confined in areas to the south of Shanley's Lough. The presence of *Myrica gale* (shrub cover 13% (0-20)) tends to indicate lateral water movement. Bryophyte cover is high, 80% (50-100), as is dwarf shrub cover, 60% (30-80). This variant is also found on Clara bog, in small circular patches on the high bog, where it seems to have originated from a bush of *Myrica* becoming established and spreading vegetatively.

Myrica gale	V(4-5)	*Calypogeia muellerana*	III(3)
Sphagnum magellanicum	V(3-7)	*Cephalozia bicuspidata*	II(2-4)
Sphagnum capillifolium	V(3-5)	*Sphagnum papillosum*	II(4)
Odontoschisma sphagni	V(3-6)	*Rhynchospora alba*	II(4)
Calluna vulgaris	V(6-7)	*Zygnemalis*	II(4)
Erica tetralix	V(2-5)	*Calypogeia fissa*	II(3)
Drosera rotundifolia	V(2-3)	*Cephalozia connivens*	II(3)
Narthecium ossifragum	IV(3-4)	*Sphagnum tenellum*	II(3)
Eriophorum vaginatum	IV(3-4)	*Eriophorum angustifolium*	II(2)
Campylopus paradoxus	IV(2-3)	*Vaccinium oxycoccus*	II(2)
Hypnum jutlandicum	IV(1-6)	*Cladonia sp.*	II(2)
Trichophorum cespitosum	III(3)	*Melampyrum pratense*	II(2)
Cladonia portentosa	III(3-6)	*Leucobryum glaucum*	II(2)

3G Variant with *Molinia caerulea* and *Potentilla erecta.*
(number of samples = 7).

Differential Species: *Molinia caerulea* and *Potentilla erecta.*

This is the variant of wet hollows or small pools in the cut-away. It tends to occur in areas close to old face-banks or where water collects in old turf pits. Some enrichment, either from increased mineralisation or from ground water, is indicated by the species composition. The species which indicate enrichment are *Potentilla palustris, Sphagnum recurvum. Potentilla erecta* and *Molinia caerulea.*

Erica tetralix	V(2-5)	*Rhynchospora alba*	II(3)
Calluna vulgaris	V(2-5)	*Cephaloziella rubella*	II(3)
Eriophorum angustifolium	V(1-4)	*Potentilla palustris*	II(3)
Narthecium ossifragum	IV(3-5)	*Sphagnum squarrosum*	II(3)
Odontoschisma sphagni	IV(3-6)	*Menyanthes trifoliata*	I(5)
Drosera rotundifolia	IV(2-4)	*Campylopus paradoxus*	I(3)
Sphagnum cuspidatum	IV(3-7)	*Pleurozium schreberi*	I(3)
Calypogeia sp.	IV(3)	*Calypogeia fissa*	I(3)
Trichophorum cespitosum	III(2-3)	*Carex panicea*	I(3)
Sphagnum papillosum	III(3-5)	*Anthoxanthum odoratum*	I(3)
Sphagnum tenellum	III(3-4)	*Lophocolea bidentata*	I(3)
Hypnum jutlandicum	III(3-5)	*Dicranum scoparium*	I(3)
Sphagnum subnitens	III(3-6)	*Mylia anomala*	I(3)
Aulacomnium palustre	III(2-7)	*Cephalozia connivens*	I(2)
Kurzia pauciflora	III(2-3)	*Vaccinium oxycoccus*	I(2)
Cephalozia sp.	III(3)	*Calliergon giganteum*	I(2)
Sphagnum magellanicum	III(3-7)	*Salix cinerea* subsp. *oleifolia*	I(2)
Potentilla erecta	III(1-3)	*Drosera anglica*	I(1)
Molinia caerulea	III(3-5)	*Hypochoeris radicata*	I(1)

Section A2.

The communities of flats and hummocks of the high bog, which are characterised by an increase in dwarf shrub cover and a lack of aquatic species.

Type 4

Local Name: Community of *Calluna vulgaris, Sphagnum capillifolium* and *Cladonia portentosa.*

Diagnostic Species Assemblage: *Calluna vulgaris, Sphagnum capillifolium, Cladonia portentosa, Dicranum scoparium* and *Hypnum jutlandicum.*

Leucobryum glaucum occurs at low abundancies throughout these community types and *Polytrichum alpestre* occurs only in this section of the high bog communities but again at low abundancies.

4A Typical variant.
(number of samples = 32).
The variant of hummocks or flat areas where no species dominate, but where a number of species occur at low abundancies. This is a common variant over the whole bog surface, tending towards a heath type vegetation due to the abundance of ericoids (dwarf shrubs 42% (10-75)). Although bryophyte cover is high, 85% (35-100), the species that occur, such as *Hypnum jutlandicum*, indicate drier conditions.

Calluna vulgaris	V(3-7)	*Aulacomnium palustre*	I(1-4)
Sphagnum capillifolium	V(1-4))	*Cephalozia connivens*	I(1-4)
Erica tetralix	V(2-5)	*Leucobryum glaucum*	I(2-5)
Odontoschisma sphagni	V(3-6)	*Campylopus introflexus*	I(2-3)
Hypnum jutlandicum	V(2-8)	*Sphagnum imbricatum*	I(3-5)
Cladonia portentosa	IV(1-6)	*Cladonia uncialis* subsp. *biuncialis*	I(1-4)
Eriophorum angustifolium	IV(2-3)	*Kurzia pauciflora*	I(2-4)
Eriophorum vaginatum	IV(2-5)	*Campylopus paradoxus*	I(1-7)
Andromeda polifolia	IV(2-3)	*Zygnemalis*	I(2)
Sphagnum papillosum	III(2-6)	*Cladonia ciliata* var. *tenuis*	I(1-2)
Narthecium ossifragum	III(2-3)	*Cladonia pyxata*	I(2)
Drosera rotundifolia	III(2-3)	*Sphagnum fuscum*	I(3)
Vaccinium oxycoccus	III(1-5)	*Cladonia floerkeana*	I(2)
Carex panicea	II(2-5)	*Rhynchospora alba*	I(3)
Trichophorum cespitosum	II(2-5)	*Calypogeia muellerana*	I(2)
Sphagnum tenellum	II(2-5)	*Aneura pinguis*	I(2)
Sphagnum magellanicum	II(3-6)	*Potentilla erecta*	I(2)
Polytrichum alpestre	II(2-7)	*Succisa pratensis*	I(2)
Dicranum scoparium	II(2-5)	*Eurhynchium praelongum*	I(2)
Sphagnum subnitens	II(1-6)	*Huperzia selago*	I(1)
Calypogeia fissa	I(1-4)	*Cladonia coccifera*	I(1)
Pleurozium schreberi	I(2-4)		

4B Variant with *Campylopus introflexus* (Plate 5).
(number of samples = 13).
Differential Species: *Campylopus introflexus, Cladonia furcata, Cladonia uncialis* subsp. *uncialis* and *Carex panicea*
The variant typical of areas which have been burnt or disturbed in the past which are characterized by the presence of *Campylopus introflexus*, a species which tends to colonise bare disturbed peat situations. This community type is also seen extensively on the spoil from the drains on the eastern section of Clara. Bryophyte cover is intermediate, 54% (5-95) and dwarf shrub cover quite high, 47% (15-75), indicating the increasing importance of *Calluna vulgaris* in this community type.

Calluna vulgaris	V(3-7)	*Sphagnum subnitens*	II(2-3)
Hypnum jutlandicum	V(3-7)	*Cladonia furcata*	II(1-3)
Carex panicea	V(2-5)	*Sphagnum papillosum*	II(2-4)
Erica tetralix	V(2-6)	*Cephalozia rubella*	II(2-3)
Odontoschisma sphagni	V(2-5)	*Leucobryum glaucum*	II(2-3)
Eriophorum angustifolium	V(1-3)	*Cladonia floerkeana*	II(1-2)
Campylopus introflexus	IV(2-5)	*Cephalozia connivens*	II(2)
Cladonia portentosa	IV(3-6)	*Sphagnum fuscum*	I(5)
Sphagnum capillifolium	IV(2-5)	*Calypogeia sp.*	I(4)
Narthecium ossifragum	IV(1-4)	*Campylopus pyriformis*	I(3)
Drosera rotundifolia	IV(1-3)	*Bryum sp.*	I(3)
Trichophorum cespitosum	III(2-4)	*Cephaloziella sp.*	I(3)
Andromeda polifolia	III(2)	*Huperzia selago*	I(2)
Cladonia uncialis subsp. *biuncialis*	III(1-2)	*Rhynchospora alba*	I(2)
Eriophorum vaginatum	III(2-3)	*Vaccinium oxycoccus*	I(2)
Sphagnum magellanicum	II(3-5)	*Kurzia pauciflora*	I(1)
Zygnemalis	II(3-5)	*Cladonia ciliata* var. *tenuis*	I(1)
Campylopus paradoxus	II(5-7)	*Potentilla erecta*	I(1)

4C Phase with *Leucobryum glaucum* (Plate 6).
(number of samples = 6).
Dominant Species: *Leucobryum glaucum* .
Community of hummocks where *Leucobryum glaucum* becomes dominant. This is not a common community type, but some large *Leucobryum glaucum* hummocks do occur on Raheenmore and occasional smaller ones on Clara. Dwarf shub cover is relatively high, 55% (45-60), indicating comparatively dry conditions. Bryophyte cover is complete at 100%.

Leucobryum glaucum	V(7-8)	*Lophocolea bidentata*	II(2-3)
Calluna vulgaris	V(3-7)	*Vaccinium oxycoccus*	II(2)
Hypnum jutlandicum	V(2-5)	*Kurzia pauciflora*	II(2-3)
Odontoschisma sphagni	V(3-5)	*Polytrichum alpestre*	I(4)
Cladonia portentosa	V(2-4)	*Sphagnum subnitens*	I(4)
Sphagnum capillifolium	V(2-3)	*Sphagnum magellanicum*	I(3)
Drosera rotundifolia	V(2-3)	*Sphagnum papillosum*	I(3)
Eriophorum vaginatum	V(2-3)	*Campylopus introflexus*	I(3)
Eriophorum angustifolium	V(2-3)	*Carex panicea*	I(2)
Andromeda polifolia	V(2)	*Aneura pinguis*	I(2)
Erica tetralix	V(1-3)	*Cephalozia connivens*	I(2)
Trichophorum cespitosum	IV(2-3)	*Mylia anomala*	I(2)
Narthecium ossifragum	II(2)	*Cladonia coccifera*	I(2)
Cladonia floerkeana	II(2)	*Cladonia uncialis* subsp. *biuncialis*	I(1)
Dicranum scoparium	II(2-3)		

4D Phase with *Cladonia portentosa* .
(number of samples = 5).
Dominant Species: *Cladonia portentosa*.
These are communities where *Cladonia portentosa* dominates. Lichen cover is therefore high, 86% (80-95). *Cladonia portentosa* covers large areas of both bogs and its presence may be linked to areas which have not been burnt for some time. Where it dominates hummocks or flat areas, it seems to have an adverse effect on the *Sphagnum* species present, possibly due to the exclusion of light. Bryophyte cover is thus only intermediate, with an average cover of 45% (20-90).

Cladonia portentosa	V(8)	*Sphagnum tenellum*	II(5)
Calluna vulgaris	V(2-6)	*Sphagnum magellanicum*	II(4)
Odontoschisma sphagni	V(2-4)	*Leucobryum glaucum*	II(3)
Narthecium ossifragum	V(2-3)	*Vaccinium oxycoccus*	II(3)
Sphagnum capillifolium	V(4)	*Cladonia uncialis* subsp. *biuncialis*	II(2)
Hypnum jutlandicum	V(4-5)	*Campylopus paradoxus*	II(2)
Eriophorum angustifolium	V(2)	*Dicranum scoparium*	II(2)
Erica tetralix	V(2-4)	*Cephalozia bicuspidata*	II(2)
Trichophorum cespitosum	IV(2-4)	*Kurzia pauciflora*	II(2)
Carex panicea	IV(2-4)	*Andromeda polifolia*	II(2)
Eriophorum vaginatum	IV(2-3)	*Drosera rotundifolia*	II(2)
Sphagnum papillosum	II(2-3)	*Cephalozia sp.*	II(1)
Sphagnum subnitens	II(2-6)		

4E Phase with Sphagnum *capillifolium.*
(number of samples = 11).
Dominant Species: *Sphagnum capillifolium.*
Hummock community where *Sphagnum capillifolium* dominates. The average bryophyte cover is 98% (95-100). *Sphagnum capillifolium* is an important constituent in many of the hummock communities and becomes dominant in situations such as these. It is one of the most widespread species on the two bogs. The hummocks tend not to be large (< 30 cm tall) and thus dwarf shrub cover is generally low, 18% (10-50).

Sphagnum capillifolium	V(7-8)	*Campylopus paradoxus*	I(2-3)
Calluna vulgaris	V(3-7)	*Calypogeia sp.*	I(3)
Odontoschisma sphagni	V(3-4)	*Sphagnum magellanicum*	I(3-5)
Erica tetralix	V(2-4)	*Dicranum scoparium*	I(3)
Hypnum jutlandicum	V(2-7)	*Kurzia pauciflora*	I(1-3)
Eriophorum angustifolium	V(2-3)	*Sphagnum subnitens*	I(3-4)
Trichophorum cespitosum	III(3-5)	*Leucobryum glaucum*	I(3)
Narthecium ossifragum	III(2-3)	*Cladonia floerkeana*	I(4)
Andromeda polifolia	III(2-4)	*Molinia caerulea*	I(3)
Drosera rotundifolia	II(1-3)	*Sphagnum palustre*	I(3)
Cladonia portentosa	II(3-6)	*Polytrichum alpestre*	I(2)
Eriophorum vaginatum	II(2-3)	*Carex panicea*	I(2)
Rhynchospora alba	II(2-3)	*Cladonia uncialis* subsp. *biuncialis*	I(2)
Cephalozia sp.	II(3)	*Sphagnum tenellum*	I(2)
Sphagnum papillosum	II(1-5)	*Cephaloziella sp.*	I(2)
Pleurozium schreberi	I(2-4)	*Potentilla erecta*	I(1)
Vaccinium oxycoccus	I(3-4)	*Aneura pinguis*	I(2)

4F Phase with *Sphagnum imbricatum* (Plate 7).
(number of samples = 6).
Dominant Species: *Sphagnum imbricatum.*
Hummock community where *Sphagnum imbricatum* dominates (bryophyte cover 100%). *Sphagnum imbricatum* is considered to be the main large hummock former on raised bogs. However on Clara and Raheenmore few large hummocks are seen. *Sphagnum imbricatum* growth rates are slow and thus it is only on high hummocks that it can out-compete other *Sphagnum* species (Stoneman et al., 1993). The climate must be oceanic in order for it to avoid desiccation in these elevated positions. Its rarity on Clara and Raheenmore probably indicates that the two bogs have dried out considerably and have suffered burning in the past. Dwarf shrub cover is high, usually around 55 %, as the hummocks tend to be tall (50 cm to 1 metre).

Sphagnum imbricatum	V(8)	*Carex panicea*	III(2-3)
Calluna vulgaris	V(4-6)	*Calypogeia sp.*	III(2-3)
Erica tetralix	V(2-3)	*Vaccinium oxycoccus*	III(1-2)
Odontoschisma sphagni	V(2-3)	*Trichophorum cespitosum*	II(2)
Narthecium ossifragum	V(1-3)	*Sphagnum tenellum*	I(3)
Drosera rotundifolia	V(2-3)	*Aulacomnium palustre*	I(2)
Eriophorum vaginatum	V(2-3)	*Sphagnum palustre*	I(2)
Sphagnum capillifolium	V(2-4)	*Drosera anglica*	I(2)
Andromeda polifolia	V(2)	*Sphagnum fuscum*	I(2)
Eriophorum angustifolium	V(2)	*Campylopus introflexus*	I(2)
Hypnum jutlandicum	IV(2-4)	*Sphagnum papillosum*	I(2)
Mylia anomala	IV(2-4)	*Leucobryum glaucum*	I(1)
Cladonia portentosa	III(2-3)		

47

4G Phase of *Calluna vulgaris* and *Hypnum jutlandicum*.
(number of samples = 16).
Dominant Species: *Calluna vulgaris* and *Hypnum jutlandicum*.
The marginal community found at the top edges of cut-away face-banks. They tend to have a low water table and a restricted species number. *Calluna vulgaris* grows well here and flowers abundantly under the conditions of greater aeration due to lower water table levels. Dwarf shrub cover is high, 65% (25-95). Bryophyte cover is also high, 50% (10-100), but does not consist of many *Sphagnum* species but rather of those bryophyte species indicating drier conditions, such as *Hypnum jutlandicum*. This community type indicates a degradation phase of the high bog vegetation.

Calluna vulgaris	V(6-8)	*Campylopus paradoxus*	I(2-5)
Hypnum jutlandicum	V(2-8)	*Cladonia ciliata* var. *tenuis*	I(2-5)
Cladonia portentosa	V(1-8)	*Sphagnum capillifolium*	I(3-4)
Erica tetralix	V(1-3)	*Eriophorum vaginatum*	I(2-3)
Eriophorum angustifolium	V(1-3)	*Potentilla erecta*	I(2-3)
Dicranum scoparium	II(1-5)	*Ulex europaeus*	I(3)
Trichophorum cespitosum	II(2-5)	*Calypogeia sp.*	I(2)
Andromeda polifolia	II(1-3)	*Zygnemalis*	I(3)
Carex panicea	II(1-5)	*Sphagnum subnitens*	I(2)
Odontoschisma sphagni	II(2-3)	*Cladonia floerkeana*	I(1-2)
Campylopus introflexus	II(2-3)	*Cephalozia connivens*	I(2)
Pleurozium schreberi	I(3-5)	*Succisa pratensis*	I(2)
Drosera rotundifolia	I(2-4)	*Pteridium aquilinum*	I(2)
Cladonia uncialis subsp. *biuncialis*	I(2-6)	*Psedoscleropodium purum*	I(2)

4H Phase with *Pleurozium schreberi*.
(number of samples = 6).
Dominant Species: *Pleurozium schreberi* and *Calluna vulgaris*.
Hummock communities which have some enrichment elements, either due to mineralisation or ground water. They are usually situated in the cut-away areas of the bog. In addition, *Pleurozium schreberi* often grows on the top of larger hummocks of the high bog as they dry out. Bryophyte cover is high, 93% (75-100) and dwarf shrub cover is intermediate, 48% (30-75).

Pleurozium schreberi	V(6-8)	*Odontoschisma sphagni*	II(3-5)
Calluna vulgaris	V(6-7)	*Aulacomnium palustre*	II(2-3)
Eriophorum vaginatum	V(2-5)	*Betula pubescens*	II(2-3)
Eriophorum angustifolium	V(2-3)	*Dicranum scoparium*	I(3)
Erica tetralix	V(2-4)	*Trichophorum cespitosum*	I(3)
Sphagnum capillifolium	IV(3-6)	*Sphagnum subnitens*	I(3)
Drosera rotundifolia	IV(3-6)	*Cephalozia sp.*	I(3)
Cladonia portentosa	IV(2-5)	*Mylia anomala*	I(2)
Hypnum jutlandicum	IV(2-3)	*Calypogeia muellerana*	I(2)
Sphagnum magellanicum	III(3-4)	*Cephaloziella sp.*	I(2)
Andromeda polifolia	III(2)	*Aneura pinguis*	I(2)
Polytrichum alpestre	II(5)		

41 Variant with *Molinia caerulea* and *Potentilla erecta*.
(number of samples = 20).

Differential Species: *Molinia caerulea* and *Potentilla erecta*.

Dwarf-shrub cover is intermediate, 33% (0-65) and herbs have a cover of 32% (5-70). Bryophyte cover is relatively high, 66% (30-100), but includes species more typical of dry situations. They are mainly marginal communities of the high bog and of the cut-away, where the percentage cover of *Molinia caerulea* is below 50%, that is to say it is not completely dominant. The increase in species diversity in this community type indicates higher nutrient availability either due to mineralisation or ground water.

Molinia caerulea	V(2-7)	*Cephalozia sp.*	I(2-3)
Calluna vulgaris	V(2-7)	*Mylia anomala*	I(2-4)
Hypnum jutlandicum	V(2-8)	*Campylopus pyriformis*	I(3)
Erica tetralix	V(2-6)	*Hylocomium splendens*	I(3)
Odontoschisma sphagni	V(2-6)	*Salix cinerea* subsp. *oleifolia*	I(1-3)
Potentilla erecta	IV(1-4)	*Bryum sp.*	I(3)
Carex panicea	III(2-5)	*Galium saxatile*	I(3)
Trichophorum cespitosum	III(2-4)	*Vaccinium myrtillus*	I(3)
Dicranum scoparium	III(2-4)	*Riccia sp.*	I(3)
Sphagnum capillifolium	III(2-4)	*Agrostis canina*	I(3)
Calypogeia sp.	III(3-4)	*Calliergon cuspidatum*	I(3)
Eriophorum angustifolium	III(2-4)	*Mnium hornum*	I(3)
Drosera rotundifolia	III(2-3)	*Calypogeia fissa*	I(3)
Sphagnum subnitens	II(2-4)	*Cephalozia bicuspidata*	I(3)
Sphagnum palustre	II(2-4)	*Salix aurita*	I(3)
Aulacomnium palustre	II(2-4)	*Carex flacca*	I(2)
Campylopus paradoxus	II(2-4)	*Agrostis stolonifera*	I(2)
Campylopus introflexus	II(2-4)	*Hypericum pulchrum*	I(2)
Kurzia pauciflora	II(2-3)	*Pseudoscleropodium purum*	I(2)
Andromeda polifolia	II(2)	*Festuca ovina*	I(2)
Eriophorum vaginatum	II(2-3)	*Cladonia floerkeana*	I(2)
Pleurozium schreberi	II(1-7)	*Cephalozia rubella*	I(2)
Cladonia portentosa	II(1-4)	*Diplophyllum albicans*	I(2)
Sphagnum papillosum	II(2-6)	*Polygala serpyllifolia*	I(2)
Narthecium ossifragum	II(1-4)	*Carex echinata*	I(2)
Leucobryum glaucum	I(3-4)	*Luzula multiflora*	I(2)
Lophocolea bidentata	I(2-3)	*Betula pubescens*	I(2)
Polygala vulgaris	I(1-3)	*Aneura pinguis*	I(1-2)
Sphagnum tenellum	I(4-5)	*Polytrichum formosum*	I(2)
Anthoxanthum odoratum	I(2-3)	*Pedicularis sylvatica*	I(2)
Cladonia fimbriata	I(2-4)	*Rhytidiadelphus squarrosus*	I(2)
Zygnemalis	I(3-4)	*Juncus effusus*	I(2)
Rhynchospora alba	I(1-3)	*Cladonia chlorata*	I(1)
Cephalozia connivens	I(3-4)	*Cladonia squamosa*	I(1)
Vaccinium oxycoccus	I(2-3)	*Cladonia ciliata* var. *tenuis*	I(1)
Succisa pratensis	I(2-4)		

Section B.
This section includes the communities of the soak systems on Clara bog and occasionally some communities of the cut-away. Two divisions are clear: those communities whose plant species suggest some mineral enrichment and a poorer group of communities.

Type 5
Local Name: Community of *Carex rostrata* and *Drepanocladus fluitans.*
Diagnostic Species Assemblage: *Utricularia minor* and *Sparganium erectum.*

5A Typical variant.
(number of samples = 4).
Community of the wet central area surrounding the central community type in Lough Roe. It forms a floating raft of vegetation with a high herb cover of 71% (50-95). Bryophyte cover is intermediate, 38% (20-70) and there is a certain amount of open water, 28% (10-45). *Riccardia multifida* is characteristic of organic substrates flushed by base rich water and *Aneura pinguis* will not tolerate acid conditions (Watson, 1981). Their presence in this community indicates some base enrichment.

Carex rostrata	V(4-6)	*Lophocolea bidentata*	II(3)
Drepanocladus fluitans	V(3-6)	*Cladopodiella fluitans*	II(3)
Menyanthes trifoliata	V(3-6)	*Holcus lanatus*	II(2)
Hydrocotyle vulgaris	V(4-5)	*Potentilla palustris*	II(2)
Eriophorum angustifolium	V(2-5)	*Aneura pinguis*	II(2)
Typha latifolia	II(2)	*Cephalozia connivens*	II(2)
Odontoschisma sphagni	II(4)	*Riccardia multifida*	II(2)
Calypogeia muellerana	II(4)	*Anthoxanthum odoratum*	I(1)

5B Variant with *Nuphar lutea*.
(number of samples = 1).
Differential Species: *Nuphar lutea.*
This community is confined to the central area of Lough Roe and is restricted in size. It is a remnant community of the open water situation that occurred here in the past, indicated by the presence of *Nuphar lutea* and *Drepanocladus fluitans*. There is still some open water, approximately 20%, but herb cover is high at 75%, indicating terrestrialisation of the open water situation. This community was more extensive in the past (M. Schouten, pers. comm.).

Drepanocladus fluitans	6	*Menyanthes trifoliata*	3
Nuphar lutea	5	*Typha latifolia*	2
Carex rostrata	5	*Eriophorum angustifolium*	2
Hydrocotyle vulgaris	4	*Utricularia minor*	2

5C Variant with *Sparganium erectum.*
(number of samples = 1).
Differential species: *Sparganium erectum* and *Menyanthes trifoliata.*
A section of the very wet quaking area situated in the central section of Lough Roe Soak. Up to 20 % open water still occurs. The presence of *Sparganium erectum* and *Hydrocotlye vulgaris* indicates some groundwater influence.

Utricularia minor	7	*Carex rostrata*	4
Hydrocotyle vulgaris	6	*Drepanocladus fluitans*	4
Sparganium erectum	5		

Type 6

Local Name: The community of *Menyanthes trifoliata* and *Sphagnum squarrosum*.

(number of samples = 3).

Diagnostic Species: *Menyanthes trifoliata*, *Sphagnum squarrosum* and *Carex rostrata*.

This community is confined to patches in Lough Roe, where it gains dominance over small areas. Bryophyte cover is high, 95% (90-100), as is the herb cover at 77% (70-85). This type usually has a very high water table but is slightly drier than the central types. *Sphagnum squarrosum* is one of the few *Sphagnum* species that is confined to markedly eutrophic situations (Smith, 1980). This again suggests that this area is influenced by ground water.

Menyanthes trifoliata	V(5-7)	*Rhytidiadelphus squarrosus*	II(4)
Eriophorum angustifolium	V(2-5)	*Sphagnum recurvum*	II(4)
Carex rostrata	V(3-4)	*Odontoschisma sphagni*	II(3)
Sphagnum squarrosum	V(2-7)	*Lychnis flos-cuculi*	II(3)
Hydrocotyle vulgaris	V(3-4)	*Succisa pratensis*	II(2)
Lophocolea bidentata	V(3-5)	*Agrostis canina*	II(2)
Holcus lanatus	V(2-3)	*Angelica sylvestris*	II(2)
Anthoxanthum odoratum	IV(3-4)	*Calliergon giganteum*	II(2)
Potentilla palustris	IV(2)	*Drepanocladus fluitans*	II(2)
Galium palustre	IV(2)	*Dactylorhiza fuchsii*	II(1)
Calliergon cuspidatum	II(4)		

Type 7

Local Name: Community of *Carex rostrata* and *Sphagnum cuspidatum*.

(number of samples = 2).

Diagnostic Species Assemblage: *Carex rostrata*, *Sphagnum cuspidatum* and *S. recurvum*.

The community of very wet and quaking *Sphagnum cuspidatum* lawns situated in the region of Shanley's Lough soak. This community type is more indicative of ombrotrophic communities than the above types in Lough Roe, but some slight enrichment is indicated by the presence of *Carex rostrata*, *Juncus effusus* and *Hydrocotyle vulgaris*. Bryophyte cover, 99% (98-100) and herb cover, 58% (50-65) are high. This community type is less species rich than the preceding community types.

Sphagnum cuspidatum	V(7-8)	*Hydrocotyle vulgaris*	III(2)
Carex rostrata	V(6-7)	*Juncus effusus*	III(2)
Sphagnum recurvum	V(4)	*Vaccinium oxycoccus*	III(2)
Eriophorum angustifolium	V(2-4)	*Drosera rotundifolia*	III(1)
Menyanthes trifoliata	III(3)		

Type 8

Local Name: Community of *Menyanthes trifoliata* and *Sphagnum recurvum*.

Diagnostic Species Assemblage: *Menyanthes trifoliata*, *Sphagnum recurvum*, *Succisa pratensis*, *Carex rostrata*, *Vaccinium oxycoccus* and *Lychnis flos-cuculi*.

This is an unusual species combination but its occurrence is due to the fact that these are transition communities. They typically have a well developed bryophyte layer and a rather open herb layer. The aquatic nature of these community types is indicated by the presence of *Sphagnum recurvum*, *Juncus bulbosus* and *Cladopodiella fluitans*.

8 A Phase of *Sphagnum recurvum.*
Dominant species: *Sphagnum recurvum.*
The communities of *Sphagnum recurvum* lawns found in the vicinity of Lough Roe and Shanley's Lough.

8Aa Typical sub-variant.
(number of samples = 8).
The typical *Sphagnum recurvum* lawns. Bryophyte cover is high, 99% (98-100), with a rather open herb layer 29% (5-50). There is a low cover of dwarf shrubs, 2% (0-5), which indicates very wet conditions. These are seen both at Shanley's Lough and Lough Roe. There are some enrichment indicators such as *Molinia caerulea.*

Sphagnum recurvum	V(6-8)	*Drosera rotundifolia*	II(1-3)
Vaccinium oxycoccus	IV(2-4)	*Aulacomnium palustre*	II(2)
Eriophorum angustifolium	IV(2-4)	*Cladopodiella fluitans*	I(4)
Molinia caerulea	IV(2-3)	*Hydrocotyle vulgaris*	I(4)
Sphagnum cuspidatum	II(4-6)	*Calypogeia muellerana*	I(3)
Juncus bulbosus	II(2-5)	*Cephalozia connivens*	I(3)
Carex rostrata	II(2-4)	*Sphagnum magellanicum*	I(3)
Andromeda polifolia	II(2-3)	*Narthecium ossifragum*	I(2)
Menyanthes trifoliata	II(2-3)	*Calluna vulgaris*	I(2)
Eriophorum vaginatum	II(2-4)	*Juncus effusus*	I(2)

8Ab. Sub-variant with *Potentilla palustris.*
(number of samples = 6).
Differential Species: *Potentilla palustris, Anthoxanthum odoratum, Sphagnum squarrosum, Hydrocotyle vulgaris* and *Agrostis canina.*
Very wet and quaking *Sphagnum recurvum* lawns in the central area of Lough Roe. They are slightly richer than the above type, which is indicated by the presence of *Potentilla palustris* and *Hydrocotyle vulgaris.* Bryophyte cover is also high at 99% (95-100) but the herb layer cover is higher at 47% (20-65). Dwarf shrubs are rare, indicating the wet nature of this community type.

Sphagnum recurvum	V(6-8)	*Drepanocladus fluitans*	II(2-4)
Aulacomnium palustre	V(2-6)	*Brachythecium rutabulum*	II(2)
Carex rostrata	V(2-6)	*Holcus lanatus*	II(2)
Menyanthes trifoliata	V(2-6)	*Juncus effusus*	I(5)
Anthoxanthum odoratum	V(2-4)	*Sphagnum papillosum*	I(4)
Hydrocotyle vulgaris	V(2-3)	*Cephalozia bicuspidata*	I(3)
Potentilla palustre	V(2-3)	*Calliergon cuspidatum*	I(3)
Lophocolea bidentata	V(2-4)	*Succisa pratensis*	I(2)
Vaccinium oxycoccus	IV(2-5)	*Lychnis flos-cuculi*	I(2)
Agrostis canina	IV(2-5)	*Eurhynchium praelongum*	I(2)
Sphagnum squarrosum	III(4-5)	*Sphagnum palustre*	I(2)
Eriophorum angustifolium	II(2)	*Calluna vulgaris*	I(2)

52

8B. Phase of *Sphagnum palustre*.
(number of samples = 5).
Dominant Species: *Sphagnum palustre*.
This community type is situated at the western end of Lough Roe, close to the exit drain to the west. The cover of the bryophyte layer is high, 97% (85-100) and is dominated by *Sphagnum palustre*. Dwarf shrubs only occur occasionally and the herb layer has a cover of 42% (5-70). It has a slightly drier nature than the above community type and is located further from the central section of the site and thus from the probable source of enrichment.

Sphagnum palustre	V(6-8)	*Peltigera membranacea*	III(1)
Sphagnum recurvum	V(4-6)	*Empetrum nigrum*	I(4)
Menyanthes trifoliata	V(2-6)	*Ranunculus acris*	I(2)
Anthoxanthum odoratum	V(2-5)	*Rumex acetosella*	I(2)
Potentilla palustris	V(2-5)	*Juncus inflexus*	I(2)
Vaccinium oxycoccus	V(3-7)	*Hydrocotyle vulgaris*	I(2)
Aulacomnium palustre	V(2-4)	*Riccardia multifida*	I(2)
Carex rostrata	V(2-4)	*Calypogeia sp.*	I(2)
Succisa pratensis	V(2-3)	*Rumex acetosa*	I(2)
Molinia caerulea	IV(2-3)	*Holcus mollis*	I(2)
Luzula multiflora	IV(2)	*Rhytidiadelphus squarrosus*	I(2)
Eriophorum angustifolium	III(2-3)	*Drosera rotundifolia*	I(2)
Lophocolea bidentata	III(2-3)	*Odontoschisma sphagni*	I(2)
Holcus lanatus	III(2-3)	*Cephalozia connivens*	I(1)
Calliergon cuspidatum	III(1-3)	*Calluna vulgaris*	I(1)
Agrostis canina	III(2)	*Aneura pinguis*	I(1)
Lychnis flos-cuculi	III(1-2)		

8C Phase of *Aulacomnium palustre*.
(number of samples = 17).
Dominant Species: *Aulacomnium palustre*.
This is an extensive community type in Lough Roe, where it surrounds the wetter central communities and grades out to the drier ridge surrounding the feature. The bryophyte layer is closed, 93% (85-100) and the herb layer is important, 45% (20-95). Dwarf shrubs are of more importance, 9% (2-45), indicating the slightly drier nature of this community type. The presence of *Carex curta* in this community type is notable as it is a rather rare species. It is usually seen, when occurring in lowland areas, in mesotrophic mires (Jermy et al., 1982).

Aulacomnium palustre	V(5-8)	*Calliergon cuspidatum*	I(2-7)
Vaccinium oxycoccus	V(4-7)	*Cephalozia connivens*	I(4)
Sphagnum recurvum	V(2-7)	*Rhytidiadelphus squarrosus*	I(4)
Menyanthes trifoliata	V(2-5)	*Empetrum nigrum*	I(2-4)
Calluna vulgaris	V(2-6)	*Potentilla erecta*	I(1-3)
Drosera rotundifolia	V(1-3)	*Lychnis flos - cuculi*	I(3)
Sphagnum palustre	IV(2-6)	*Carex curta*	I(3)
Eriophorum angustifolium	IV(1-4)	*Hylocomium splendens*	I(3)
Molinia caerulea	IV(1-4)	*Hypnum jutlandicum*	I(2-3)
Carex rostrata	IV(2-5)	*Andromeda polifolia*	I(2)
Succisa pratensis	IV(2-3)	*Sphagnum capillifolium*	I(2)
Eriophorum vaginatum	III(2-8)	*Peltigera membranacea*	I(1)
Calypogeia muellerana	III(2-4)	*Holcus mollis*	I(2)
Cephalozia bicuspidata	III(2-4)	*Angelica sylvestris*	I(2)
Potentilla palustris	III(1-4)	*Galium palustre*	I(2)
Lophocolea bindentata	III(2-4)	*Brachythecium rutabulum*	I(2)
Odontoschisma sphagni	II(2-4)	*Agrostis canina*	I(2)
Anthoxanthum odoratum	II(2-3)	*Dactylorhiza maculata*	I(1)
Luzula multiflora	II(1-2)	*Aneura pinguis*	I(1)

Type 9

Local Name: Community of *Carex nigra* and *Polytrichum alpestre*.

Diagnostic Species Assemblage: *Polytrichum alpestre*, *Carex nigra*, *Sphagnum recurvum* and *Sphagnum papillosum*.

9A Typical variant.
(number of samples = 7).

The community type which occurs in the areas surrounding Shanley's Lough which are located close to the *Sphagnum recurvum* lawns but with a slightly drier nature. These drier conditions are indicated by the higher cover of dwarf shrubs, 21% (5-80) and the occurrence of *Betula pubescens*. The main bryophyte species is *Sphagnum recurvum*. The bryophyte cover is high, 97% (90-100). This is another transitional community type. The indicators of base enrichment that were present in the above community types are lacking.

Sphagnum recurvum	V(3-7)	*Betula pubescens*	III(2-6)
Calluna vulgaris	V(2-8)	*Hypnum jutlandicum*	III(2-3)
Vaccinium oxycoccus	V(2-6)	*Calypogeia muellerana*	III(3-4)
Aulacomnium palustre	V(2-6)	*Narthecium ossifragum*	II(4-5)
Eriophorum angustifolium	V(2-5)	*Sphagnum papillosum*	II(3-4)
Eriophorum vaginatum	V(2-4)	*Polytrichum alpestre*	II(2-7)
Erica tetralix	V(2-4)	*Pleurozium schreberi*	II(3-4)
Andromeda polifolia	V(2-3)	*Molinia caerulea*	II(2-3)
Drosera rotundifolia	V(2-3)	*Carex nigra*	II(2-3)
Sphagnum magellanicum	III(3-7)	*Empetrum nigrum*	I(5)
Sphagnum capillifolium	III(4-6)	*Sphagnum cuspidatum*	I(2-3)
Odontoschisma sphagni	III(3-4)	*Cladonia portentosa*	I(2)
Calypogeia fissa	III(2-4)	*Juncus effusus*	I(2)

9 B Variant with *Carex rostrata*.
(number of samples = 4).

Differential Species: *Carex rostrata*, *Potentilla erecta* and *Sphagnum palustre*.

A slighty more enriched and species diverse variant which is found in the damp cut-away marginal areas. Dwarf shrub cover is higher, 33% (5-75), indicating that it drier than the above variant. Bryophyte cover is high, 98% (95-100).

Carex rostrata	V(2-5)	*Betula pubescens*	III(1)
Calluna vulgaris	V(3-7)	*Sphagnum cuspidatum*	II(4)
Aulacomnium palustre	V(2-4)	*Pseudoscleropodium purum*	II(4)
Erica tetralix	V(2-3)	*Lophocolea bidentata*	II(4)
Potentilla erecta	V(2)	*Dicranum scoparium*	II(3)
Sphagnum papillosum	IV(4-8)	*Sphagnum capillifolium*	II(3)
Polytrichum alpestre	IV(3-7)	*Carex nigra*	II(3)
Sphagnum palustre	IV(4-5)	*Eriophorum vaginatum*	II(3)
Eriophorum angustifolium	IV(3-4)	*Juncus effusus*	II(2)
Vaccinium oxycoccus	IV(2-4)	*Aneura pinguis*	II(2)
Odontoschisma sphagni	IV(3)	*Juncus acutiflorus*	II(2)
Hypnum jutlandicum	IV(2-3)	*Polygala serpyllifolia*	II(2)
Drosera rotundifolia	III(2-3)	*Sphagnum magellanicum*	II(2)
Calypogeia sp.	III(4)	*Succisa pratensis*	II(2)
Cephalozia connivens	III(3)	*Campylopus paradoxus*	II(2)
Narthecium ossifragum	III(2)	*Cladonia portentosa*	II(2)
Sphagnum recurvum	III(1-2)	*Cephalozia sp.*	II(2)
Andromeda polifolia	III(2)	*Ulex europeaus*	II(1)
Salix aurita	III(1-2)	*Carex echinata*	II(1)

Type 10

Local Name: Community of *Polytrichum alpestre* and *Calliergon cuspidatum.*

(number of samples = 2).

Diagnostic Species Assemblage: *Polytrichum alpestre, Calliergon cuspidatum, Sphagnum capillifolium* and *Eriophorum vaginatum.*

Situated to the north of Lough Roe forming bands of enriched bog vegetation. Enrichment is suggested by the presence of *Calliergon cuspidatum.* The area where this community type occurs may be part of an internal drainage pattern leading from the Lough Roe soak system. Bryophyte cover is high, 98% (95-100) and dwarf shrubs have an average cover of 30% (10-50).

Polytrichum alpestre	V(5-7)	*Andromeda polifolia*	V(2)
Calliergon cuspidatum	V(7)	*Hypnum jutlandicum*	III(4)
Calluna vulgaris	V(4-6)	*Aulacomnium palustre*	III(4)
Sphagnum capillifolium	V(4-5)	*Carex panicea*	III(2)
Sphagnum magellanicum	V(2-3)	*Kurzia pauciflora*	III(2)
Eriophorum vaginatum	V(4-5)	*Dicranum scoparium*	III(2)
Vaccinium oxycoccus	V(3)	*Cephalozia connivens*	III(2)
Erica tetralix	V(3)	*Lophocolea bidentata*	III(2)
Cladonia portentosa	V(2)	*Eriophorum angustifolium*	III(2)

Type 11

Local Name: The community of *Sphagnum capillifolium* and *Empetrum nigrum.*

(number of samples = 7).

Diagnostic Species Assemblage: *Sphagnum capillifolium, Empetrum nigrum, Molinia caerulea, Eriophorum vaginatum* and *Pleurozium schreberi.*

This community type is situated on the marginal areas of Lough Roe where there is a raised ridge. It is also seen surrounding the old soak to the south of Lough Roe and the row of pools to the north and to a lesser extent around the soaks on Clara West. Dwarf shrub cover is mostly high, 60% (10-85), as is the bryophyte layer, 72% (35-90). Herb cover is intermediate 33% (5-70). It is a relatively species rich community type with mineral enrichment indicators such as *Molinia caerulea* and *Calliergon cuspidatum.*

Empetrum nigrum	V(2-8)	*Drosera rotundifolia*	III(2)
Molinia caerulea	V(2-8)	*Eriophorum angustifolium*	III(2)
Eriophorum vaginatum	V(2-5)	*Luzula multiflora*	III(1-2)
Sphagnum capillifolium	V(4-5)	*Hylocomium splendens*	II(5-6)
Vaccinium oxycoccus	V(2-4)	*Sphagnum recurvum*	II(2-4)
Aulacomnium palustre	V(2-4)	*Cladonia portentosa*	II(3)
Calluna vulgaris	IV(2-8)	*Lophocolea bidentata*	II(2-3)
Pleurozium schreberi	IV(2-7)	*Calliergon cuspidatum*	II(2)
Cephalozia bicuspidata	IV(2)	*Polytrichum commune*	I(3)
Sphagnum palustre	III(3-4)	*Polytrichum alpestre*	I(3)
Betula pubescens	III(2-4)	*Calypogeia fissa*	I(2)
Odontoschisma sphagni	III(3-4)	*Potentilla erecta*	I(2)
Hypnum jutlandicum	III(2-3)	*Lophozia ventricosa*	I(2)
Erica tetralix	III(2-3)	*Menyanthes trifoliata*	I(2)
Calypogeia muellerana	III(2-3)	*Anthoxanthum odoratum*	I(2)

Type 12

Local Name: Community of *Betula pubescens* and *Molinia caerulea.*

Diagnostic Species Assemblage: *Betula pubescens, Molinia caerulea* and *Sphagnum recurvum.*
These are *Betula pubescens* scrub or woodland communities in the vicinity of the soak systems on Clara bog.

12A Variant with *Sphagnum capillifolium.*

Differential Species: *Sphagnum capillifolium, Erica tetralix, Calluna vulgaris, Eriophorum vaginatum* and *Vaccinium oxycoccus.*
These communities are mainly confined to areas around the soaks. They differ from the tall tree *Betula pubescens* communities in having more typical bog elements.

12Aa Sub-variant with *Myrica gale.*
(number of samples = 2).

Differential Species: *Myrica gale* and *Sphagnum palustre.*
The community of scrub *Betula pubescens* (trees 60% (35-85)), with an average height of 1.1 metres with the addition of *Myrica gale.* Bryophyte cover is high, 70% (50-90) and dwarf shrub cover is intermediate, 35% (10-60). This type is confined to the soak systems on the east and west of Clara.

Betula pubescens	V(6-8)	*Sphagnum recurvum*	III(5)
Myrica gale	V(6-7)	*Sphagnum magellanicum*	III(3)
Sphagnum capillifolium	V(5-6)	*Dryopteris dilatata*	III(3)
Sphagnum palustre	V(4-6)	*Rhytidiadelphus squarrosus*	III(3)
Erica tetralix	V(3-5)	*Eriophorum vaginatum*	III(2)
Vaccinium myrtillus	V(4)	*Drosera rotundifolia*	III(2)
Aulacomnium palustre	V(2-5)	*Pleurozium schreberi*	III(2)
Hypnum jutlanicum	V(2-5)	*Cephalozia bicuspidata*	III(2)
Calluna vulgaris	V(2-4)	*Pteridium aquilinum*	III(2)
Odontoschisma sphagni	V(3)	*Eurhynchium praelongum*	III(2)
Calypogeia muellerana	V(3)	*Calliergon cuspidatum*	III(2)
Vaccinium oxycoccus	V(2-3)	*Juncus effusus*	III(2)
Molinia caerulea	III(8)	*Agrostis canina*	III(2)
Eriophorum angustifolium	III(5)	*Luzula multiflora*	III(1)

12Ab Typical Variant.
(number of samples = 2).
Betula pubescens (trees 27% (5-50)) scrub woodland with *Molinia caerulea.* Bryophyte cover, 68% (30-90) and herb cover, 47% (25-65), are intermediate. This type occurs at the edges of Lough Roe, extensively at Shanley's Lough and to a lesser extent around the other soaks.

Molinia caerulea	V(6-7)	*Polygala serpyllifolia*	III(3)
Betula pubescens	V(5-6)	*Calypogeia fissa*	III(3)
Calluna vulgaris	V(3-6)	*Campylopus introflexus*	III(3)
Sphagnum capillifolium	V(4-5)	*Eriophorum vaginatum*	III(3)
Hypnum jutlandicum	V(2-6)	*Vaccinium oxycoccus*	III(3)
Erica tetralix	V(2-3)	*Mylia anomala*	III(2)
Sphagnum recurvum	III(5)	*Pleurozium schreberi*	III(2)
Aulacomnium palustre	III(4)	*Cephalozia bicuspidata*	III(2)
Calypogeia muellerana	III(4)	*Potentilla erecta*	III(2)

56

12Ac Sub-variant with *Polytrichum commune*.
(number of samples = 3).

Differential Species: *Polytrichum commune*.

Located at Shanley's Lough at the edges of the *Betula pubescens* woodland. *Polytrichum commune* is an important element and the bryophyte cover is high, 92% (80-96). Scrub trees have an average cover of 18% (5-55) and the herb cover is intermediate, 36% (15-50). This is a slightly wetter variant.

Polytrichum commune	V(7-8)	*Aulacomnium palustre*	III(3-4)
Vaccinium oxycoccus	V(3-6)	*Eriophorum angustifolium*	III(2-3)
Sphagnum magellanicum	V(3-4)	*Juncus effusus*	II(2-4)
Eriophorum vaginatum	V(2-4)	*Potentilla erecta*	II(2)
Andromeda polifolia	V(2-3)	*Odontoschisma sphagni*	I(4)
Sphagnum capillifolium	IV(5-6)	*Carex nigra*	I(4)
Erica tetralix	IV(2-4)	*Polytrichum alpestre*	I(3)
Betula pubescens	III(2-7)	*Hypnum jutlandicum*	I(3)
Molinia caerulea	III(2-6)	*Cladonia portentosa*	I(2)
Calluna vulgaris	III(4-5)	*Sphagnum recurvum*	I(2)

12B Variant with *Dryopteris dilatata*.

Differential Species: *Dryopteris dilatata*.

The communities of *Betula pubescens* woodland, where trees reach heights of approximately 10-15 metres. They typically have less bog species and more woodland species, such as *Vaccinium myrtillus* and *Dryopteris dilatata*.

12Ba Sub-variant with *Juncus effusus*.
(number of samples = 1).

Differential Species: *Juncus effusus*.

Restricted area situated at the southern edge of the open water of Shanley's Lough. This sub-variant is unusual as the water-table remains high throughout the year. *Betula pubescens* (tree cover of 100%) is important, reaching heights of 5-6 metres. It is a rather species poor variant.

Betula pubescens	8	*Rhytidiadelphus squarrosus*	3
Juncus effusus	6	*Eurhynchium praelongum*	2
Sphagnum recurvum	6	*Sphagnum squarrosum*	2
Molinia caerulea	6	*Dryopteris dilatata*	2
Lophocolea bidentata	4	*Vaccinium myrtillus*	2
Sphagnum palustre	3		

12Bb Typical sub-variant.
(number of samples = 5).

Betula pubescens woodland (trees 79% (55-100)) at Shanley's Lough and also located at the westerly Birch wood soak on Clara West. Bryophyte cover is high, 76% (30-100) and herb cover is variable with an average of 41% (5-80). The presence of species such as *Dryopteris dilatata* and *Vaccinium myrtillus* indicate woodland conditions. It is more species rich than the above variant.

Betula pubescens	V(7-8)	*Calypogeia fissa*	I(4)
Molinia caerulea	V(2-5)	*Thuidium tamariscium*	I(4)
Sphagnum palustre	IV(4-8)	*Vaccinium oxycoccus*	I(3)
Sphagnum recurvum	IV(3-6)	*Erica tetralix*	I(2)
Dryopteris dilatata	IV(2)	*Andromeda polifolia*	I(2)
Myrica gale	III(2-6)	*Drosera rotundifolia*	I(2)
Calypogeia muellerana	III(2-3)	*Eriophorum vaginatum*	I(2)
Eurhynchium praelongum	II(3-4)	*Cephalozia bicuspidata*	I(2)
Lophocolea bidentata	II(3)	*Potentilla erecta*	I(2)
Aulacomnium palustre	II(2)	*Anthoxanthum odoratum*	I(2)
Vaccinium myrtillus	I(8)	*Climacium dendroides*	I(2)
Rhytidiadelphus squarrosus	I(5)	*Carex nigra*	I(2)
Hypnum jutlandicum	I(4)	*Agrostis cannina*	I(2)

Type 13
Local Name: Community of *Salix aurita* and *Sphagnum palustre.*
(number of samples = 1).
Diagnostic Species Assemblage: *Salix aurita, Sphagnum palustre, Epilobium parviflorum* and *Calliergon cuspidatum.*
A restricted community of *Salix aurita* scrub woodland, situated at the western edge of Lough Roe, where the exit drain is located. It possesses certain enrichment indicators such as *Sphagnum squarrosum, Sphagnum palustre* and *Juncus effusus.*

Salix aurita	8	*Galium palustre*	3
Calliergon cuspidatum	6	*Epilobium parviflorum*	3
Sphagnum palustre	6	*Agrostis canina*	3
Holcus lanatus	5	*Empetrum nigrum*	2
Succisa pratensis	4	*Vaccinium oxycoccus*	2
Lophocolea bidentata	4	*Luzula multiflora*	2
Juncus effusus	4	*Aulacomnium palustre*	2
Anthoxanthum odoratum	4	*Sphagnum squarrosum*	2
Sphagnum recurvum	3	*Carex echinata*	2
Molinia caerulea	3	*Lychnis flos-cuculi*	2
Potentilla erecta	3	*Poa pratensis*	2
Carex rostrata	3	*Eurhynchium praelongum*	2
Menyanthes trifoliata	3	*Rumex acetosella*	2
Potentilla palustris	3	*Angelica sylvestris*	2

Section C.
This section includes the communities of the cut-away and other marginal areas of the bogs. The first community type includes two variants which are located in the area of Shanley's Lough soak. Most community types in this section are enriched either due to peat mineralisation or base enrichment from ground water.

Type 14
Local Name: The community of *Molinia caerulea* and *Potentilla erecta.*
Diagnostic Species Assemblage: *Molinia caerulea* (dominant) and *Potentilla erecta.*
These are communities which are dominated by *Molinia caerulea* in the region of Shanley's Lough or in cut-way sections of the bog.

14A Variant with *Myrica gale.*
(number of samples = 5).
Differential Species: *Myrica gale.*
This is found to the south of Shanley's Lough on Clara West. It is a variant with *Molinia caerulea* tussocks with scattered *Myrica gale* (shrubs 2% (0-5)). The presence of *Myrica gale* possibly indicates lateral water flow. Bryophyte cover is intermediate, 42% (5-90), while herb cover is high, 79% (50-90), dominated by *Molinia caerulea.*

Molinia caerulea	V(7-8)	*Calypogeia fissa*	II(2-3)
Myrica gale	V(2-6)	*Cephalozia bicuspidata*	II(2)
Potentilla erecta	V(3-4)	*Eriophorum vaginatum*	II(2-3)
Calypogeia muellerana	IV(2-6)	*Dryopteris dilatata*	II(2)
Erica tetralix	III(2-5)	*Sphagnum magellanicum*	II(2-3)
Campylopus paradoxus	III(2-4)	*Hypnum cupressiforme*	I(4)
Hypnum jutlandicum	II(3-5)	*Vaccinium myrtillus*	I(3)
Polytrichum alpestre	II(2-5)	*Calluna vulgaris*	I(2)
Aulacomnium palutsre	II(2-5)	*Pleurozium schreberi*	I(2)
Sphagnum palustre	II(3-4)	*Sphagnum recurvum*	I(2)
Luzula multiflora	II(2-3)	*Agrostis canina*	I(2)

14B Variant with *Sphagnum recurvum*.
(number of samples = 5).
Differential Species: *Sphagnum recuvum* and *Vaccinium oxycoccus*.
A relatively species rich *Molinia caerulea* community to the south of Shanley's Lough with many typical bog elements such as *Sphagnum magellanicum*, *Calluna vulgaris* and *Sphagnum capillifolium*. Herb cover is again high, 63% (60-90) and the bryophyte average cover is slightly higher than the above variant, 53% (50-55).

Molinia caerulea	V(6-8)	*Sphagnum palustre*	I(5)
Vaccinium oxycoccus	V(2-4)	*Anuera pinguis*	I(4)
Sphagnum recurvum	IV(2-5)	*Pleurozium schreberi*	I(4)
Calypogeia muellerana	III(3-6)	*Lophocolea bicuspidata*	I(4)
Sphagnum capillifolium	III(2-6)	*Zygnemalis*	I(4)
Calluna vulgaris	III(3-5)	*Melampyrum pratense*	I(3)
Erica tetralix	III(2-5)	*Kurzia pauciflora*	I(3)
Calypogeia fissa	II(3-6)	*Narthecium ossifragum*	I(3)
Sphagnum magellanicum	II(4-5)	*Eurhynchium praelongum*	I(3)
Polytrichum alpestre	II(4-5)	*Juncus effusus*	I(3)
Odontoschisma sphagni	II(3-5)	*Potentilla erecta*	I(2)
Aulacomnium palustre	II(4)	*Hylocomium splendens*	I(2)
Hypnum jutlandicum	II(2-4)	*Pteridium aquilinum*	I(2)
Drosera rotundifolia	II(3)	*Betula pubescens*	I(2)
Cephalozia connivens	II(2-3)	*Dryopteris dilatata*	I(2)
Eriophorum angustifolium	II(2)	*Osmunda regalis*	I(2)
Eriophorum vaginatum	I(6)	*Mylia anomala*	I(2)

14C Typical variant.
(number of samples = 5).
Generally a very species poor variant of *Molinia caerulea* in cut-away areas and on bog margins. The herb layer is dominated by *Molinia caerulea* and has a cover of 67% (50-80). Bryophyte cover is intermediate, 42% (15-75) and is mainly composed of *Sphagnum capillifolium* and *Hypnum jutlandicum*. A fairly dry community type. There are a number of typical bog species occurring in this variant.

Molinia caerulea	V(7-8)	*Sphagnum subnitens*	I(3)
Calypogeia sp.	V(3-5)	*Polygala serpyllifolia*	I(3)
Eriophorum angustifolium	V(3-4)	*Thuidium tamariscium*	I(3)
Calluna vulgaris	IV(1-6)	*Festuca ovina*	I(3)
Potentilla erecta	IV(3-4)	*Lophocolea bidentata*	I(3)
Sphagnum capillifolium	III(3-4)	*Leucobryum glaucum*	I(3)
Hypnum jutlandicum	III(2-4)	*Andromeda polifolia*	I(2)
Erica tetralix	III(2-3)	*Drosera rotundifolia*	I(2)
Sphagnum papillosum	II(2-4)	*Cephaloziella sp.*	I(2)
Pseudoscleropodium purum	II(3)	*Luzula multiflora*	I(2)
Dicranum scoparium	II(3)	*Carex panicea*	I(2)
Campylopus paradoxus	II(2)	*Cladonia portentosa*	I(2)
Aulacomnium palustre	II(1-2)	*Trichophorum cespitosum*	I(2)
Odontoschisma sphagni	I(6)	*Succisa pratensis*	I(2)
Zygnemalis	I(4)	*Cladonia ciliata* var. *tenius*	I(1)
Pleurozium schreberi	I(4)	*Eriophorum vaginatum*	I(1)
Cephalozia connivens	I(4)	*Hypericum pulchrum*	I(1)
Cephalozia sp.	I(3)		

14D Variant with *Juncus effusus.*
(number of samples = 7).
Differential Species: *Juncus effusus* and *Carex nigra.*
This variant is located in cut-away marginal areas. The herb layer is closed (100%) and ranges in height from 30 cm to 1.0 metres and is dominated by *Molinia caerulea.* The bryophyte layer has an intermediate cover of 65% (50-80). This is a more species rich variant of this community type, which indicates enrichment either due to peat mineralisation or ground water influence. A number of other grass species are also present and there are no typical ombrotrophic bog species.

Molinia caerulea	V(7-8)	*Carex pulicharis*	I(5)
Potentilla erecta	V(2-4)	*Drepanocladus fluitans*	I(4)
Lophocolea bidentata	IV(3-5)	*Poa pratensis*	I(4)
Juncus effusus	IV(2-5)	*Plantago lanceolata*	I(3-4)
Carex nigra	III(2-5)	*Equisetum palustre*	I(3)
Calliergon cuspidatum	III(3-4)	*Campylium stellatum*	I(3)
Agrostis stolonifera	III(2-4)	*Rumex acetosella*	I(3)
Epilobium palustre	III(2-3)	*Brachythecium sp.*	I(3)
Holcus lanatus	III(2-3)	*Carex flacca*	I(3)
Hypericum sp.	III(2-3)	*Poa trivialis*	I(3)
Festuca ovina	III(3)	*Arrhenatherum elatius*	I(3)
Anthoxanthum odoratum	III(1-3)	*Potentilla palustre*	I(3)
Cirsium palustre	III(1-2)	*Thuidium tamariscium*	I(3)
Rhytidiadelphus squarrosus	II(5)	*Carex rostrata*	I(3)
Filipendula ulmaria	II(3-5)	*Vicciacracca*	I(2)
Carex panicea	II(4)	*Lotus corniculatus*	I(2)
Centurea nigra	II(3-4)	*Eriophorum angustifolium*	I(2)
Pseudoscleropodium purum	II(3-4)	*Aulacomnium palustre*	I(2)
Salix aurita	II(3-4)	*Luzula multiflora*	I(2)
Succisa pratensis	II(1-4)	*Dryopteris dilatata*	I(2)
Festuca rubra	II(3)	*Polytrichum alpestre*	I(2)
Juncus articulatus	II(1-3)	*Galium palustre*	I(2)
Lathyrus pratensis	II(1-2)	*Carex disticha*	I(2)
Valeriana officinalis	II(1-2)	*Eurhynchium praelongum*	I(2)
Equisetum fluviatile	II(2)	*Dactylorhiza maculata*	I(1)
Brachythecium rutabulum	I(7)	*Ranunculus acris*	I(1)
Hylocomium splendens	I(5)		

Type 15
Local Name: Community of *Calliergon cuspidatum* and *Equisetum fluviatile*.
Diagnostic Species Assemblage: *Calliergon cupidatum. Equisetum fluviatile. Galium palustre. Juncus articulatus* and *Epilobium palustre*.
These are all communities of cut-away or marginal areas. They are characterised by species which either indicate mineral enrichment or an influence of ground water.

15A Variant of *Aulacomnium palustre*.
(number of samples = 5).
Differential Species: *Aulacomnium palustre, Molinia caerulea, Potentilla erecta, Sphagnum palustre* and *Sphagnum capillifolium*.
A marginal species rich cut-away community with some typical bog elements. The bryophyte layer is mostly dominated by *Aulacomnium palustre*, while the herb layer is dominated by *Molinia caerulea*.

Aulacomnium palustre	V(3-7)	*Sphagnum squarrosum*	I(6)
Molinia caerulea	V(3-6)	*Salix cinerea* subsp. *oleifolia*	I(2-6)
Potentilla erecta	V(2-4)	*Equisetum palustre*	I(5)
Sphagnum palustre	IV(3-7)	*Betula pubescens*	I(5)
Juncus effusus	IV(3-6)	*Polytrichum commune*	I(4)
Erica tetralix	IV(2-3)	*Lophocolea bidentata*	I(4)
Sphagnum capillifolium	III(3-6)	*Narthecium ossifragum*	I(3)
Holcus lanatus	III(2-5)	*Cephalozia sp.*	I(3)
Calliergon cuspidatum	III(3-5)	*Hylocomium splendens*	I(3)
Calypogeia sp.	III(3-4)	*Carex echinata*	I(3)
Calluna vulgaris	III(3-4)	*Riccia sp.*	I(3)
Anthoxanthum odoratum	III(3)	*Galium aparine*	I(3)
Carex rostrata	III(1-3)	*Holcus mollis*	I(3)
Equisetum fluviatile	III(1-3)	*Rhytidiadelphus squarrosus*	I(3)
Sphagnum subnitens	II(3-6)	*Pseudoscleropodium purum*	I(3)
Succisa pratensis	II(5)	*Trifolium repens*	I(2)
Eriophorum angustifolium	II(3-5)	*Pedicularis sylvatica*	I(2)
Hypnum jutlandicum	II(3-5)	*Epilobium palustre*	I(2)
Dicranum scoparium	II(3)	*Mentha aquatica*	I(2)
Agrostis canina	II(3)	*Galium palustre*	I(2)
Bracythecium sp.	II(3)	*Hypericum pulchrum*	I(2)
Rumex acetosella	II(3)	*Typha latifolia*	I(2)
Eurhynchium praelongum	II(3)	*Dactylorhiza maculata*	I(1)
Potentilla palustris	II(2-3)	*Rubus fruticosus*	I(1)
Drosera rotundifolia	II(2-3)	*Cirsium palustre*	I(1)
Luzula multiflora	II(2-3)		

15B Typical Variant.
(number of samples = 16).
Within this community type the herb layer is mostly closed, 99% (95-100). The height of this layer is variable, ranging from 15 cm to 1.2 metres. The bryophyte layer is open with a average cover of 48% (10-75). It has a very rich herb layer with inciators of enrichment such as *Hydrocotyle vulgaris* and *Mentha aquatica* and occasionally *Campylium stellatum*. This typical variant is located on the areas of wet cut-away to the west of Raheenmore and is found on peaty soil of approximately 1.0 metres deep, overlying lake clays and marl.

Calliergon cuspidatum	IV(2-8)	*Lophozia bicuspidata*	I(3)
Holcus lanatus	IV(2-7)	*Salix cinerea* subsp. *oleifolia*	I(3)
Agrostis stolonifera	IV(2-6)	*Calluna vulgaris*	I(3)
Equisetum fluviatile	IV(2-4)	*Eriophorum angustifolium*	I(3)
Galium palustre	IV(2-3)	*Sphagnum squarrosum*	I(3)
Epilobium palustre	IV(2-3)	*Poa pratensis*	I(3)
Potentilla palustris	III(2-5)	*Holcus mollis*	I(3)
Molinia caerulea	III(2-5)	*Carex panicea*	I(3)
Eurhynchium praelongum	III(2-5)	*Lathyrus pratensis*	I(3)
Anthoxanthum odoratum	III(2-4)	*Aneura pinguis*	I(3)
Mentha aquatica	III(1-4)	*Galium aparine*	I(3)
Rhytidiadelphus squarrosus	II(2-7)	*Ranunculus acris*	I(2-3)
Carex rostrata	II(1-6)	*Plagiomnium undulatum*	I(1-3)
Menyanthes trifoliata	II(4-5)	*Typha latifolia*	I(2)
Juncus articulatus	II(2-5)	*Dactylorhiza majalis*	I(2)
Brachythecium sp.	II(3-5)	*Valeriana officinalis*	I(2)
Succisa pratensis	II(1-5)	*Potentilla anserina*	I(2)
Rumex acetosella	II(2-4)	*Viccia cracca*	I(2)
Potentilla erecta	II(2-3)	*Salix aurita*	I(2)
Carex nigra	II(1-3)	*Filipendula ulmaria*	I(2)
Calliergon giganteum	II(3)	*Cerastium fontana*	I(2)
Ranunculus flammula	II(1-2)	*Cirsium dissectum*	I(2)
Rubus fruticosus	II(1-2)	*Cirsium palustre*	I(2)
Cardamine pratensis	II(1-3)	*Hypnum jutlandicum*	I(2)
Pseudoscleropodium purum	I(4-6)	*Odontoschisma sphagni*	I(2)
Hydrocotyle vulgaris	I(3-6)	*Ulex europaeus*	I(2)
Festuca ovina	I(2-5)	*Sphagnum recurvum*	I(2)
Ranunculus repens	I(4)	*Sparganium erectum*	I(2)
Agrostis sp.	I(4)	*Carex echinata*	I(2)
Carex flacca	I(3-4)	*Carex hirta*	I(2)
Aulacomnium palustre	I(3-4)	*Stellaria graminea*	I(2)
Betula pubescens	I(1-4)	*Viccia sepium*	I(2)
Carex diandra	I(1-4)	*Rumex acetosella*	I(1-2)
Rhizomnium punctatum	I(4)	*Triglochin palustris*	I(1-2)
Eurhynchium striatum	I(1-4)	*Dactylorhiza fuchsii*	I(1)
Agrostis canina	I(1-4)	*Trifolium repens*	I(1)
Juncus effusus	I(2-3)	*Veronica chamaedrys*	I(1)
Angelica sylvestris	I(2-3)	*Equisetum palustre*	I(1)
Campylium stellatum	I(3)	*Plagiomnium affine*	I(1)
Nasturtium officinale	I(3)		

15C Variant with *Valeriana officinalis*.
(number of samples = 7).

Differential Species: *Valeriana officinalis*, *Potentilla palustris* and *Holcus mollis*.

The herb layer in this community is completely closed (100%) and is tall, ranging in height from 1.0 to 1.5 metres. The bryophyte cover is also high (90%). This type is mainly located on the wet cut-away on Raheenmore west. The water table remains high for most of the year and there is some indication of a ground water influence with the occurrence of species such as *Carexdiandra*. *Carex hirta* is also a notable species in this variant.

Potentilla palustris	V(3-6)	*Lophocolea bidentata*	II(1-3)
Valeriana officinalis	V(2-6)	*Ranunculus acris*	II(3)
Equisetum fluviatile	V(2-4)	*Galium aparine*	II(2)
Epilobium palustre	V(1-3)	*Rubus fruticosus*	II(2)
Calliergon cuspidatum	IV(3-7)	*Hypericum sp.*	II(1)
Holcus mollis	IV(2-4)	*Eurhynchium striatum*	I(5)
Filipendula ulmaria	III(4-6)	*Equisetum palustre*	I(5)
Juncus effusus	III(2-5)	*Pleurozium schreberi*	I(4)
Carex hirta	III(3-5)	*Carexdiandra*	I(4)
Juncus articulatus	III(3-4)	*Menyanthes trifoliata*	I(4)
Rumex acetosella	III(3-4)	*Juncus acutiflora*	I(3)
Poa pratensis	III(3-4)	*Poa trivialis*	I(3)
Anthoxanthum odoratum	III(3-4)	*Cirriphyllum piliferum*	I(3)
Holcus lanatus	III(2-5)	*Bryum sp.*	I(3)
Agrostis stolonifera	III(3)	*Pseudoscleropodium purum*	I(3)
Rhytidiadelphus squarrosus	III(2-4)	*Brachythecium rutabulum*	I(3)
Mentha aquatica	III(2-3)	*Lathyrus pratensis*	I(3)
Galium palustre	III(1-3)	*Trifolium pratensis*	I(3)
Carexrostrata	III(2)	*Climacium dendroides*	I(3)
Cirsium palustre	III(1-3)	*Plagiomnium undulatum*	I(3)
Salix cinerea subsp. *oleifolia*	II(1-6)	*Plagiomnium affine*	I(3)
Carexpanicea	II(5)	*Potentilla anserina*	I(2)
Bracythecium sp.	II(4)	*Agrostis canina*	I(2)
Festuca ovina	II(3-4)	*Viccia sepium*	I(2)
Eriophorum angustifolium	II(2-4)	*Campylopus introflexus*	I(2)
Potentilla erecta	II(2-3)	*Dryopteris carthusiana*	I(1)
Vicciacracca	II(3-4)	*Dactylorhiza fuchsii*	I(1)
Carexflacca	II(2-3)	*Succisa pratensis*	I(1)

15 D Variant with *Carex disticha.*
(number of samples = 10).
Differential Species: *Carex disticha* and *Carex nigra.*
A species rich community type situated on Raheenmore West marginal cutaway. The herb layer is closed (100%) ranging in height from 60 cm to 1.0 metres, with *Carex disticha* the most widespread species, which is indicative of a fluctuating water table (Jermy et al., 1982). Bryophyte cover is low, 21% (2-40).

Carex disticha	V(2-6)	*Carex echinata*	I(4)
Calliergon cuspidatum	IV(3-8)	*Menyanthes trifoliata*	I(4)
Carex nigra	IV(2-5)	*Eurhynchium praelongum*	I(2-4)
Potentilla palustris	IV(2-4)	*Ranunculus acris*	I(2-4)
Agrostis canina	III(3-5)	*Rhytidiadelphus squarrosus*	I(3-4)
Calliergon giganteum	III(3-4)	*Brachythecium sp.*	I(3-4)
Juncus articulatus	III(2-4)	*Festuca rubra*	I(3)
Anthoxanthum odoratum	III(2-4)	*Climacium dendroides*	I(3)
Trifolium repens	III(2-4)	*Poa trivialis*	I(3)
Holcus lanatus	III(3-4)	*Carex flacca*	I(3)
Lathyrus pratensis	III(1-4)	*Pseudoscleropodium purum*	I(3)
Galium palustre	III(1-3)	*Lophocolea bidentata*	I(3)
Epilobium palustre	III(1-2)	*Rumex acetosella*	I(3)
Molinia caerulea	II(1-7)	*Trifolium pratense*	I(3)
Equisetum fluviatile	II(2-7)	*Agrostis sp.*	I(3)
Carex panicea	II(4-6)	*Succisa pratensis*	I(2)
Juncus effusus	II(2-6)	*Valeriana officinalis*	I(2)
Poa pratensis	II(3-4)	*Ranunculus repens*	I(2)
Hydrocotyle vulgaris	II(1-4)	*Galium aparine*	I(2-3)
Potentilla anserina	II(1-3)	*Equisetum palustre*	I(2-3)
Cirsium palustre	II(1-3)	*Triglochin palustris*	I(2)
Festuca ovina	II(2-3)	*Taraxacum sp.*	I(2)
Filipendula ulmaria	II(2-3)	*Mentha aquatica*	I(1-2)
Potentilla erecta	II(2-3)	*Plantago lanceolata*	I(1)
Lycopus europaeus	II(2)	*Nastursium officinale*	I(1)
Ranunculus flammula	II(2)	*Dactylorhiza maculata*	I(1)
Salix cinerea subsp. *oleifolia*	I(6)	*Viccia craca*	I(1)
Plagiomnium undulatum	I(4)	*Centurea nigra*	I(1)

Type 16
Local Name: Community of *Filipendula ulmaria* and *Festuca ovina.*
Diagnostic Species Assemblage: *Filipendula ulmaria. Festuca ovina* and *Lathyrus pratensis.*
Wet grassland communities which develop in marginal areas. They are found at both Clara and Raheenmore. These types are now under threat due to reclamation and drainage. There are more grass species present in these communities than in the type 15 community variants.

16A Variant with *Rhytidiadelphus squarrosus.*
(number of samples = 8).
Differential Species: *Rhytidiadelphus squarrosus* and *Molinia caerulea.*
These are grassland communities on peaty soils which are relatively nutrient poor. The herb layer is generally almost completely closed; 81% (55-100) and ranges in height from 60 cm to 1.0 metres. Bryophytes are also frequent, 59% (35-70) and the bryophyte layer is dominated by *Rhytidiadelphus squarrosus*. There may be some enrichment due to grazing or an increase in decomposition, related to fluctuating water-tables. This variant is mainly developed on the north-west of Clara and the southern margins of Raheenmore. Although this variant possesses a rich herb layer, *Calluna vulgaris* and *Erica tetralix* also occur occasionally, indicating poorer conditions.

Rhytidiadelphus squarrosus	V(4-7)	*Pleurozium schreberi*	I(4)
Lathyrus pratensis	V(2-4)	*Rubus idaeus*	I(4)
Anthoxanthum odoratum	V(2-3)	*Erica tetralix*	I(3)
Festuca ovina	IV(2-7)	*Luzula multiflora*	I(3)
Molinia caerulea	IV(2-6)	*Triglochin palustris*	I(3)
Juncus effusus	IV(2-5)	*Eurhynchium striatum*	I(3)
Filipendula ulmaria	IV(2-5)	*Ranunculus repens*	I(3)
Rumex acetosella	IV(2-4)	*Agrostis stolonifera*	I(3)
Equisetum palustre	IV(1-2)	*Carex panicea*	I(3)
Potentilla palustris	III(3-5)	*Plagiothecium undulatum*	I(3)
Holcus mollis	III(3-5)	*Plagiomnium undulatum*	I(3)
Pseudoscleropodium purum	III(3-5)	*Climacium dendroides*	I(3)
Poa pratensis	III(2-4)	*Galium verum*	I(3)
Vicia cracca	III(2-4)	*Carex pulicharis*	I(3)
Potentilla erecta	III(2-3)	*Galium palustre*	I(3)
Cirsium palustre	III(1-3)	*Ranunculus flammula*	I(3)
Succisa pratensis	II(4-5)	*Salix cinerea* subsp. *oleifolia*	I(2)
Lophozia bicuspidata	II(3-4)	*Angelica sylvestris*	I(2)
Festuca rubra	II(3-4)	*Mentha aquatica*	I(2)
Dactylis glomerata	II(3-4)	*Equisetum fluviatile*	I(2)
Centurea nigra	II(2-4)	*Cephalozia rubella*	I(2)
Hypnum jutlandicum	II(3)	*Calluna vulgaris*	I(2)
Calliergon cuspidatum	II(3)	*Betula pubescens*	I(2)
Arrhenatherum elatius	II(2-3)	*Stellaria graminea*	I(2)
Viccia sepium	II(2-3)	*Carex disticha*	I(2)
Carex flacca	II(2-3)	*Salix aurita*	I(2)
Brachythecium rutabulum	II(2-3)	*Veronica arvense*	I(2)
Plantago lanceolata	II(2-3)	*Listera ovata*	I(2)
Holcus lanatus	II(2-3)	*Viola riviniana*	I(2)
Epilobium palustre	II(2-3)	*Agrostis sp.*	I(2)
Trifolium pratense	II(1-3)	*Hypericum sp.*	I(2)
Eurhynchium praelongum	II(2-3)	*Dactylorhiza maculata*	I(2)
Carex nigra	II(2)	*Rubus fruticosus*	I(1)
Galium aparine	II(2)	*Valeriana officinalis*	I(1)
Hylocomium splendens	I(4)	*Typha latifolia*	I(1)
Calypogeia sp.	I(4)		

16B Variant with *Carex disticha*.
(number of samples = 10).
Differential Species: *Carex disticha* and *Equisetum palustre*.
A community type with a herb rich layer, the dominant species being *Carex disticha* with the grass species *Poa pratensis, Agrostis stolonifera* and *Holcus lanatus* also of significance. There is total herb cover of 100% ranging in height from 60 cm to 1.5 metres. The bryophyte layer is mostly open 16% (3-25) and the most important species is *Brachythecium rutabulum*. This variant is mainly found on north-west Raheenmore, in areas with large fluctuating watertables, indicated by the presence of *Carex disticha*. This variant is now under threat due to reclamation and drainage. The occurrence of *Carex flacca* indicates some base enrichment.

Carex disticha	V(2-7)	*Rhytidiadelphus squarrosus*	I(3-4)
Poa pratensis	V(2-5)	*Potentilla palustris*	I(2-4)
Agrostis stolonifera	V(2-5)	*Campylopus introflexus*	I(3)
Holcus lanatus	V(3-4)	*Eurhynchium striatum*	I(3)
Equisetum palustre	V(2-3)	*Lolium perenne*	I(3)
Filipendula ulmaria	IV(2-6)	*Plantago lanceolata*	I(3)
Brachythecium rutabulum	IV(1-6)	*Holcus mollis*	I(3)
Festuca ovina	IV(2-4)	*Viccacracca*	I(2-3)
Anthoxanthum odoratum	IV(2-4)	*Ranunculus acris*	I(2-3)
Cirsium palustre	III(1-5)	*Festuca rubra*	I(3)
Trifolium repens	III(2-4)	*Carex nigra*	I(2-3)
Mentha aquatica	III(2-4)	*Juncus articulatus*	I(3)
Lathyrus pratensis	III(2-3)	*Galium palustre*	I(3)
Juncus effusus	III(2-3)	*Succisa pratensis*	I(3)
Juncus inflexus	II(2-6)	*Potentilla erecta*	I(2)
Menyanthes trifoliata	II(2-4)	*Lychnis flos-cuculi*	I(2)
Eurhynchium praelongum	II(1-4)	*Stellaria graminea*	I(2)
Calliergon cuspidatum	II(2-3)	*Triglochin palustris*	I(2)
Rumex acetosella	II(2-3)	*Viccia sepium*	I(2)
Carex flacca	II(2-3)	*Cirsium dissectum*	I(2)
Molinia caerulea	II(3)	*Veronica scutellata*	I(2)
Epilobium palustre	II(2)	*Equisetum fluviatile*	I(2)
Galium aparine	II(1-2)	*Pseudoscleropodium purum*	I(2)
Trifolium pratensis	I(6)	*Hypericum tetrapterum*	I(1)
Juncus acutifloris	I(6)	*Senecio aquatica*	I(1)
Valeriana officinalis	I(5)	*Ranunculus repens*	I(1)
Brachythecium sp.	I(4)	*Ranunculus flammula*	I(1)

Type 17

Local Name: Community of *Ulex europeaus* and *Molinia caerulea.*

(number of samples = 6).

Diagnostic Species Assemblage: *Ulex europeaus, Molinia caerulea, Calluna vulgaris, Hypnum jutlandicum* and *Potentilla erecta.*

Ulex europeaus (shrubs 45% (40-50)) is the dominant species reaching heights of 1.5 metres. The bryophyte layer cover is high, 60% (50-70) but is mostly composed of species of dry conditions such as *Hypnum jutlandicum.* This community is confined to the desiccated peaty marginal areas of the bogs and is found in similar situations to those where the community of *Pteridium aquilinum* occurs.

Ulex europaeus	V(6-7)	*Mnium hornum*	I(4)
Molinia caerulea	V(2-8)	*Sphagnum papillosum*	I(3)
Hypnum jutlandicum	V(2-6)	*Trichophorum cespitosum*	I(3)
Potentilla erecta	V(2-4)	*Cephalozia sp.*	I(3)
Calluna vulgaris	IV(2-8)	*Sphagnum subnitens*	I(3)
Aulacomnium palustre	IV(2-4)	*Polytrichum commune*	I(3)
Erica tetralix	IV(2-3)	*Vaccinium oxycoccus*	I(3)
Anthoxanthum odoratum	IV(1-3)	*Luzula multiflora*	I(3)
Calypogeia sp.	III(3-4)	*Eriophorum angustifolium*	I(3)
Eurhynchium praelongum	III(3-4)	*Sphagnum squarrosum*	I(3)
Rubus fruticosus	III(1-3)	*Hydrocotyle vulgaris*	I(3)
Sphagnum capillifolium	II(3-5)	*Thuidium tamarisicum*	I(3)
Sphagnum palustre	II(4-5)	*Equisetum palustre*	I(3)
Lophocolea bidentata	II(3-4)	*Dryopteris carthusiana*	I(3)
Calliergon cuspidatum	II(3-4)	*Rhytidiadelphus squarrosus*	I(3)
Pleurozium schreberi	II(3-4)	*Juncus effusus*	I(3)
Agrostis cannina	II(2-3)	*Narthecium ossifragum*	I(2)
Dicranium scoparium	II(3)	*Sphagnum recurvum*	I(2)
Pteridium aquilinum	II(2)	*Hypericum sp.*	I(2)
Salix cinerea subsp. *oleifolia*	II(2)	*Carex flacca*	I(2)
Betula pubescens	II(1-2)	*Agrostis stolonifera*	I(2)
Campylopus paradoxus	II(1-3)	*Pseudoscleropodium purum*	I(2)
Brachythecium sp.	I(5)		

Type 18

Local Name: Community of *Juncus effusus* and *Sphagnum subnitens.*

(number of samples = 2).

Diagnostic Species Assemblage: *Juncus effusus, Sphagnum subnitens* and *Potentilla erecta.*

This community is indicative of disturbance in the past, occurring in either areas in cutaway or in drains. A rich assemblage of bryophyte species is typical for this community type.

Juncus effusus	V(6-7)	*Sphagnum magellanicum*	III(3)
Sphagnum subnitens	V(3-6)	*Riccia sp.*	III(3)
Potentilla erecta	V(3-4)	*Calliergon giganteum*	III(3)
Anthoxanthum odoratum	V(3)	*Dicranum scoparium*	III(3)
Brachythecium sp.	V(3)	*Sphagnum capillifolium*	III(3)
Pseudoscleropodium purum	V(1-3)	*Carex echinata*	III(3)
Calypogeia sp.	V(3)	*Calliergon cuspidatum*	III(3)
Hylocomium siplendens	V(2)	*Erica tetralix*	III(2)
Salix cinerea subsp. *oleifolia*	V(1-2)	*Drosera rotundifolia*	III(2)
Holcus lanatus	V(2)	*Trifolium repens*	III(2)
Aulacomnium palustre	III(6)	*Luzula multiflora*	III(1)
Sphagnum palustre	III(5)	*Plagiomnium affine*	III(1)
Molinia caerulea	III(4)	*Cirsium palustre*	III(1)
Polytrichum commune	III(4)	*Dactylorhiza maculata*	III(1)
Cephalozia sp.	III(3)	*Equisetum fluviatile*	III(1)

Type 19

Local Name: Community of *Rubus fruticosus* and *Eurhynchium praelongum.*

(number of samples = 5).

Diagnostic Species Assemblage: *Rubus fruticosus, Eurhynchium praelongum* and *Holcus lanatus.*

A variable, relatively species rich community type of dry disturbed peaty marginal situations, which occurs on the marginal areas of both Clara and Raheenmore.

Rubus fruticosus	V(4-7)	*Potentilla erecta*	II(2)
Eurhynchium praelongum	V(4-6)	*Vicciacracca*	II(2)
Holcus lanatus	IV(3)	*Angelica sylvestris*	II(2)
Agrostis stolonifera	III(3-4)	*Galium palustre*	II(2)
Lophocolea bidentata	III(3-4)	*Pseudoscleropodium purum*	I(6)
Holcus mollis	III(3-4)	*Centurea nigra*	I(4)
Brachythecium sp.	III(3-4)	*Calliergon cuspidatum*	I(3)
Dactylis glomerata	III(2-4)	*Rhytidiadelphus squarrosus*	I(3)
Valeriana officinalis	III(2-4)	*Carex panicea*	I(3)
Rumex acetosella	III(1-3)	*Plagiomnium affine*	I(3)
Plagiothecium undulatum	III(3)	*Climacium dendroides*	I(3)
Equisetum palustre	III(2)	*Festuca rubra*	I(3)
Filipendula ulmaria	II(4-6)	*Carex rostrata*	I(3)
Thuidium tamariscium	II(3-6)	*Menyanthes trifoliata*	I(2)
Arrhenatherum elatius	II(3-6)	*Viccia sepium*	I(2)
Cirriphyllum piliferum	II(3-6)	*Lathyrus pratensis*	I(2)
Juncus effusus	II(3-5)	*Viola riviniana*	I(2)
Carex flacca	II(2-4)	*Juncus acutifloris*	I(2)
Carex nigra	II(2-3)	*Cirsium palustre*	I(1)
Anthoxanthum odoratum	II(3)	*Epilobium palustre*	I(1)
Equisetum fluviatile	II(3)		

Type 20

Local Name: Community of *Salix cinerea* subsp. *oleifolia* and *Dryopteris carthusiana.*

(number of samples = 7).

Diagnostic Species Assemblage: *Salix cinerea* subsp. *oleifolia*, *Rubus fruiticosus*, *Dryopteris carthusiana*, *Eurhynchium praelongum*, *Lonicera periclymenum* and *Hedera helix*.

Scrub woodland of *Salix cinerea* subsp. *oleifolia* (tree cover 70% (60-75)) with an average height of 3.8 metres. Bryophyte cover is high, 53% (50-60). This type is seen in places around the edges of Raheenmore Bog, particularly to the north-west. Typical woodland ground flora species are mostly absent but occasionally occur.

Salix cinerea subsp. *oleifolia*	V(5-8)	*Nasturtium officinale*	II(2-3)
Eurhynchium praelongum	V(2-7)	*Rumex acetosella*	II(3)
Rubus fruiticosus	V(1-6)	*Plagiothecium undulatum*	II(3)
Agrostis stolonifera	V(2-6)	*Ulex europaeus*	II(2)
Lonicera periclymenum	V(1-4)	*Galium aparine*	II(2)
Juncus effusus	V(2-4)	*Veronica chamaedrys*	II(2)
Anthoxanthum odoratum	V(2-4)	*Rosa cannina*	II(1-2)
Molinia caerulea	V(2-3)	*Cardamine pratensis*	II(2)
Dryopteris carthusiana	V(1-3)	*Juncus acutus*	II(1)
Holcus lanatus	IV(2-6)	*Hypericum sp.*	I(6)
Hedera helix	IV(2-6)	*Thuidium tamariscium*	I(5)
Calliergon cuspidatum	IV(2-5)	*Agrostis cannina*	I(4)
Epilobium palustre	IV(2-3)	*Typha latifolia*	I(3)
Galium palustre	IV(2-3)	*Barbula sp.*	I(3)
Potentilla erecta	IV(2-3)	*Calluna vulgaris*	I(3)
Rhytidiadelphus squarrosus	III(3-6)	*Hylocomium splendens*	I(3)
Holcus mollis	III(3-5)	*Carex rostrata*	I(3)
Equisetum fluviatile	III(2-5)	*Eriophorum angustifolium*	I(3)
Filipendula ulmaria	III(3-4)	*Arrhenatherum elatius*	I(3)
Crataegus monogyna	III(1-4)	*Agrostis sp.*	I(3)
Brachethecium sp.	III(3-4)	*Ajuga repens*	I(3)
Pseudoscleropodium purum	III(2-3)	*Ranunculus repens*	I(2)
Lophocolea bidentata	III(2-3)	*Ranunculus flammula*	I(2)
Festuca ovina	III(2-3)	*Angelica sylvestris*	I(2)
Equisetum palustre	III(2-3)	*Urtica dioica*	I(2)
Ulota crispa	III(3)	*Hypericum pulchrum*	I(2)
Frullania dilitata	III(3)	*Aneura pinguis*	I(2)
Valeriana officinalis	III(2-3)	*Dactylis glomerata*	I(2)
Viccia sepium	III(2-3)	*Rumex acetosa*	I(2)
Poa pratensis	III(3)	*Juncus inflexus*	I(2)
Hypnum jutlandicum	III(3)	*Hypericum tetrapterum*	I(2)
Cirsium palustre	III(1-3)	*Fragaria vesca*	I(2)
Potentilla palustre	III(2-3)	*Geranium robertianum*	I(2)
Viola riviniana	III(1-2)	*Ligustrum vulgaris*	I(2)
Betula pubescens	II(3-6)	*Potentilla sterilis*	I(2)
Eurhynchium striatum	II(4)	*Climacium dendroides*	I(2)
Mentha aquatica	II(2-4)	*Carex nigra*	I(2)
Carex flacca	II(2-3)	*Dactylorhiza maculata*	I(2)
Succisa pratensis	II(2-3)	*Fraxinus excelsior*	I(1)

Type 21
Local Name: Community of *Pteridium aquilinum* and *Molinia caerulea.*
(number of samples = 4).
Diagnostic Species Assemblage: *Pteridium aquilinum* and *Molinia caerulea.*
This community is confined to the desiccated marginal areas of the two bogs and where the bog adjoins the road bisecting Clara. It is one of the main community types occurring in these situations. It is relatively species poor for a marginal community type, the herb layer being dominated by tall *Pteridium aquilinum* (1.5 M). Total litter cover (100%) and shading probably prevents the growth of many other species.

Pteridium aquilinum	V(6-8)	*Calypogeia sp.*	II(4)
Molinia caerulea	IV(2-6)	*Cephalozia sp.*	II(3)
Potentilla erecta	III(2-5)	*Juncus effusus*	II(3)
Rubus fruiticosus	III(2)	*Salix cinerea* subsp. *oleifolia*	II(2)
Hypnum jutlandicum	II(6)	*Hedera helix*	II(2)
Calluna vulgaris	II(5)	*Carex nigra*	II(2)
Holcus mollis	II(4)	*Viola riviniana*	II(2)
Erica tetralix	II(4)	*Vicciacracca*	II(2)
Agrostis sp.	II(4)	*Equisetum palustre*	II(1)
Campylopus paradoxus	II(4)		

Type 22
Local Name: Community of *Carex acuta* and *Carex hirta.*
(number of samples = 2).
Diagnostic Species Assemblage: *Carex acuta*, *Carex hirta* and *Stachys palustris.*
This community type indicates a contact zone between the bog and esker materials where water-table fluctuation and nutrient levels are increased, probably due to increased mineralisation rates. Seepage is also indicated. It is confined to one area of north-east Clara. This area has been reclaimed since the time of the vegetation survey and has thus been severely damaged. The herb layer is tall with an average height of 1.0 metres.

Carex acuta	V(8)	*Viccia sepium*	III(2)
Carex hirta	V(2-3)	*Eurhynchium striatum*	III(2)
Stachys palustris	V(2-5)	*Rumex acetosella*	III(2)
Galium aparine	V(2-3)	*Eurhynchium praelongum*	III(2)
Poa pratensis	III(4)	*Potentilla anserina*	III(2)
Stellaria graminea	III(2)	*Angelica sylvestris*	III(2)
Arrhenatherum elatius	III(2)	*Juncus effusus*	III(2)

Type 23

Local Name: Community of *Ranunculus repens* and *Carex hirta.*

(number of samples = 3).

Diagnostic Species Assemblage: *Ranunculus repens. Poa pratensis, Carex hirta* and *Anthoxantum odoratum.*

These are fairly disturbed grassland communities with an unusual species assemblage. The disturbance is due either to anthropogenic effects or to dynamic close contact between two very different habitats. Disturbance indicators are *Juncus effusus* and *Triglochin palustris*. It is situated on the marginal areas of the bogs. Herb cover is total 100% and is usually tall, ranging from 60 cm to 1.5 metres.

Poa pratensis	V(3-5)	*Rumex acetosella*	IV(2)
Eurhynchium striatum	V(3-4)	*Rubus fruiticosus*	IV(2)
Holcus lanatus	V(3-4)	*Potentilla anserina*	IV(1-2)
Carex hirta	V(3-4)	*Ranunculus repens*	IV(2)
Anthoxanthum odoratum	V(2-3)	*Stellaria graminea*	IV(2)
Stachys palustris	V(2)	*Triglochin palustris*	II(4)
Ranunculus acris	V(2)	*Trifolium repens*	II(3)
Angelica sylvestris	V(2)	*Carex acuta*	II(3)
Filipendula ulmaria	IV(3-8)	*Calystegia sepium*	II(3)
Festuca ovina	IV(3-4)	*Agrostis stolonifera*	II(3)
Galium aparine	IV(2-3)	*Viola palustris*	II(2)
Succisa pratensis	IV(2-3)	*Dactylis glomerata*	II(2)
Viccia sepium	IV(2-3)	*Juncus effusus*	II(2)
Lotus corniculatus	IV(3)	*Dactylorhiza fuchsii*	II(1)
Veronica chamaedrys	IV(2)		

Type 24

Local Name: Community of *Phleum pratense* and *Juncus effusus*.

(number of samples = 4).

Diagnostic Species Assemblage: *Phleum pratense, Juncus effusus, Arrhenatherum elatius* and *Dactylis glomerata.*

These are the more species rich and generally unmanaged grasslands which occur on peaty soils at the margins of both sites. In this case they are disturbed, possibly due to anthropogenic influence and are also heavily grazed from time to time. Disturbance indicators are *Juncus effusus* and *Urtica dioica*. The latter also indicates some eutrophication.

Juncus effusus	V(2-6)	*Festuca ovina*	III(3-6)
Poa annua	V(2-5)	*Anthoxanthum odoratum*	III(2-3)
Lotus corniculatus	V(3-4)	*Veronica chamaedrys*	III(2-3)
Stachys palustris	V(2-4)	*Angelica sylvestris*	III(2)
Stellaria graminea	V(2-4)	*Cirsium arvense*	III(1-2)
Viccia sepium	V(2-4)	*Calystegia sepium*	II(6)
Holcus lanatus	IV(2-5)	*Potentilla erecta*	II(2)
Arrhenatherum elatius	IV(3-5)	*Galium aparine*	II(1)
Poa pratensis	IV(3-5)	*Ranunculus acris*	II(1)
Phelum pratensis	IV(3-5)	*Lolium perenne*	II(1)
Dactylis glomerata	IV(1-3)	*Rumex accetosella*	II(1)
Urtica dioica	IV(1-2)	*Plantago laneolata*	II(1)
Equisetum arvense	IV(1-2)	*Eurhynchium praelongum*	II(1)

71

Type 25
Local Name: Community of *Poa pratensis* and *Lolium perenne.*
(number of samples = 1).
Diagnostic Species Assemblage: *Poa pratensis, Trifolium pratense, Rumex crispus* and *Lolium perenne.*
Typical of the majority of species poor managed grasslands on cut-away peat to the northern side of Clara adjoining the esker. This community indicates managed grassland with frequent grazing.

Poa pratensis	8	*Plantago major*	2
Trifolium pratense	4	*Ranunculus acris*	2
Rumex crispus	3	*Juncus inflexus*	2
Lolium perenne	3	*Brachythecium rutabulum*	2
Holcus lanatus	3	*Juncus articulatus*	2

The raw data of this vegetation analysis are available on computer disk in The National Parks and Wildlife Service, Office of Public Works, 51, St. Stephen's Green, Dublin 2.

CHAPTER 4 HYDROLOGICAL AND HYDROCHEMICAL METHODS.

4.1 HYDROCHEMISTRY.

4.1.1 Methods.

In the examination of hydrological and hydrochemical characteristics associated with particular plant species or vegetation communities, it is necessary to sample within 10 cm of the species under investigation or within the community in question, in order to attempt to relate hydrological or hydrochemical data to species or community data (Daniels, 1975). A sampling point must therefore be placed directly within the vegetation plot under examination. It was suggested at the initiation of this project that the phreatic tubes installed by the geohydrological section could also be used for the extraction of hydrochemical samples to establish relationships between vegetation and water chemistry. This suggestion was rejected because of possible interference due to trampling and the fact that the pipes were not situated directly within the communities which were to be examined. Thus to allow the extraction of water samples for chemical analysis and the measurement of water table heights, a phreatic pipe was placed within each vegetation plot established during the vegetation survey.

These tubes consisted of a 2.5 cm diameter plastic (PVC) electrical conduit pipe drilled with four rows of holes (approximately 20% holes) to 30 cm below ground level, as this was considered to cover the rooting zone of the majority of the species under investigation (Schouten, 1984; Heath and Luckwill, 1938). The holes were covered with an inert fine-mesh nylon material, geotextile stocking, which prevented the entry of peat or debris into the pipe. A rubber bung (ferule) sealed the bottom and a plastic bottle cap prevented the entry of insects, precipitation and excluded light. This light exclusion prevented algal growth (Fig. 4.1).

In most areas, holes to 30 cm were adequate to collect water from the rooting zone. However, in some of the marginal zone plots, root growth extended to a greater depth and a deeper phreatic pipe was inserted.

Measurements started in October, 1990 for the high bog and marginal plots and in August, 1991 for the soak vegetation plots.

At each station, pH and electrical conductivity (EC) were measured monthly. The pH was measured using a WTW microprocessor pH meter and EC using a WTW conductivity meter. The EC is corrected for the concentration of the hydrogen ion to give a corrected conductivity (K_{corr} ($\mu S\ cm^{-1}$)). This is a particularly important measurement to make under acidic conditions, where the concentration of the hydrogen ion contributes considerably to the ionic concentration (Sjörs, 1950).

In October 1990, 250 ml samples for hydrochemical analysis were taken from all high bog and marginal sites. Subsequently the number of sites was reduced to 54, from which 250 ml samples were taken each second month for a year. These 54 sites were then reduced to 37 and sampled for a further year. In August 1991, 250 ml samples were collected from all soak sites (103). From these a selection of 21 was made to continue monitoring for one year. Sampling hierarchy is shown in Fig. 4.2. Site selection was based on the necessity to reduce the number of samples, while still collecting replicate samples from the more significant community types. Hydrochemical sampling was completed in September, 1992.

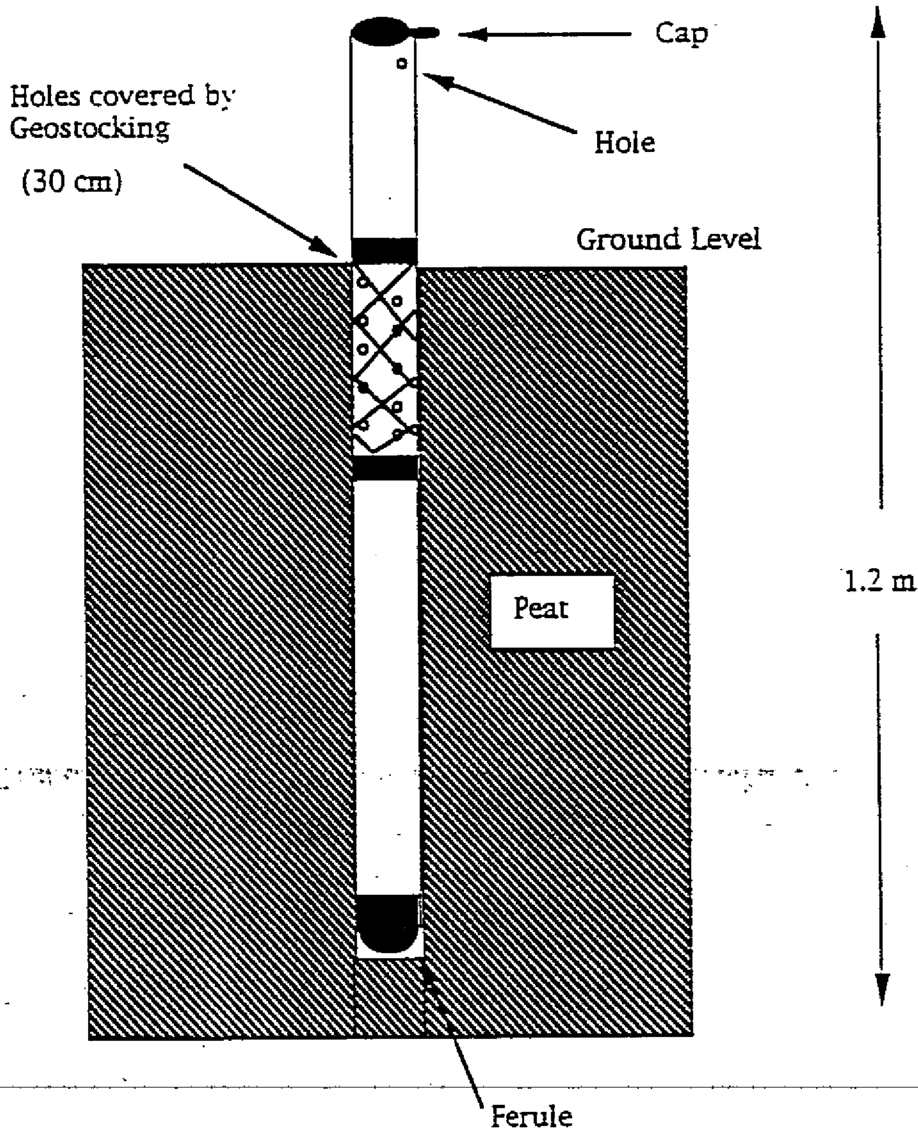


Fig. 4.1 Design of phreatic tubes used for water table measurements and hydrochemical sampling.

BOG AND MARGINAL

All sites (155) sampled in October 1990, included
Bog sites (108)
Marginal sites (47)

54 site selected for sampling 1990-1991, included
Bog sites (33)
Marginal sites (21)

37 sites selected for sampling 1991-1992, included
Bog sites (24)
Marginal sites (13)

SOAKS

All sites (103) sampled in August and October 1991, included
Lough Roe sites (39)
Shanley's Lough (64)

21 sites selected for one year's sampling.

Lough Roe
8 sites.

Shanley's Lough
13 sites.

Fig. 4.2 Sampling hierarchy of the sites selected for hydrochemical analyses.

Sampling Protocol

250 ml acid-washed polythene sample bottles were used as containers for extracted water. Water was extracted from the phreatic pipe using a vacuum hand pump. The use of a vacuum pump ensured that there was no contact between the water sample and the pump, as water was drawn directly into the polythene sample bottle. Shortly before the first collection, the pipes were totally emptied and allowed to recharge at least twice; before each subsequent collection this was done once. This procedure was followed in order to avoid contamination. The bottles were completely filled, stoppered tightly to exclude air, brought to the laboratory and stored at 4 ^{0}C to await analysis. Samples were not filtered but allowed to stand overnight, so that any suspended material sank to the bottom. The following day, samples for analyses were removed from the top of the sample bottle. Analysis usually commenced within two days of collection.

Hydrochemical Analysis

Water analyses were carried out in the Wildlife Service Laboratory, Newtownmountkennedy by Ms. D. Hackett with my assistance, in the State Laboratory and in the Environmental Science Laboratory, Trinity College Dublin.

Analyses carried out were as follows:

	Nutrient	Method Used
1.	Ammonium	Indophenol Blue
2.	Nitrate	Cadmium reduction and Ion chromatography
3.	Phosphate (TP and OP)	Molybdenum blue
4.	Calcium	Atomic absorption
5.	Magnesium	Atomic absorption
6.	Iron	Atomic absorption
7.	Manganese	Atomic absorption
8.	Sodium	Atomic emission
9.	Potassium	Atomic emission
10.	Chloride	Ion Chromatography
11.	Sulphate	Ion Chromatography
12.	Acidity/Alkalinity	Gran Plot Method

The ion chromatography was carried out on a Dionex 2000 Ion Chromatograph; atomic absorption and atomic emission on a Varian spectrophotometer; phosphorus analysis on a Shimatzu spectrophotometer. Ammonium and some nitrate analyses were carried out on a Skalar continuous flow analyser. For full methods see Appendix 4.1

4.1.2 Precipitation Chemistry.

In June, 1991 the collection of precipitation for analysis commenced. A collecting vessel was installed on each of the bogs. These consisted of a plastic funnel leading to a plastic bottle within a specially designed container (Fig. 4.3). This was fabricated from standard 100 mm diameter sewer pipe fittings.

It is important that the top of a collecting vessel should be at least 35 - 45 cm above ground level, in order to prevent splash back and contamination from the bog surface (Allen et al., 1968). The main sources of possible contamination are insects, plant debris and bird faecal material. The former two contaminates were minimised by placing a piece of geotextile stocking across the funnel entrance. Bird faecal contamination was largely prevented by placing a few perching posts at a higher level in the area of the sampling vessel. Analysis of the precipitation was carried out using the same hydrochemical methods outlined above.

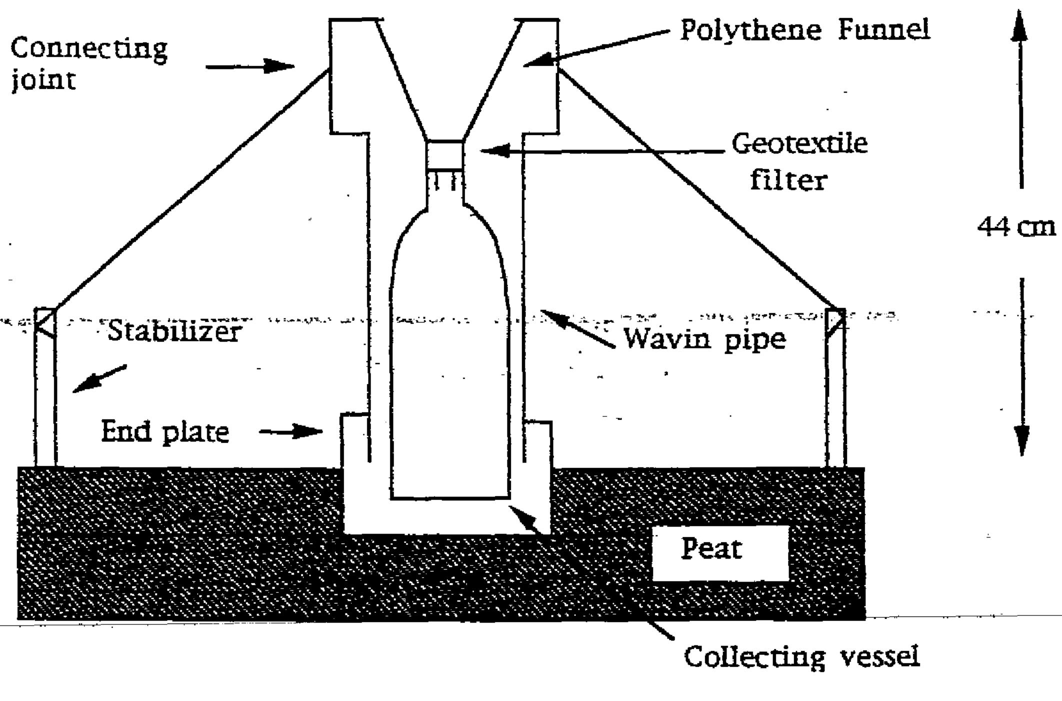


Fig. 4.3 The design of the precipitation collecting vessel.

4.1.3 Water Classification.

Water type classification was carried out on the results of the hydrochemical analyses using the computer program Chemprog (Stuyfzand, 1990). This derives an ionic balance with an error value which should be below 10%, otherwise the sample results should be ignored. In some instances the ionic balance error is large, possibly due to the presence of humic acids which were not measured. These samples were not included in calculations. A water type classification is also derived. This classification can help to indicate the main source of water supply. A NaCl water type indicates mineral poor conditions and suggests that the system depends on precipitation for ionic inputs, that is, that the chemistry of the water does not differ significantly from that of rain. A CaCl type indicates some mineral ground water with still some influence of rainfall. A $CaHCO_3$ type indicates a largely regional ground water input. A CaMiCl type indicates a sample which is classified as CaCl but is tending towards NaCl type, that is with an influence of rainwater.

76

4.2. HYDROLOGY.

4.2.1 Methods.

The phreatic pipes which were installed for the extraction of water samples were also used for the measurement of watertable levels in the vegetation plots.

Water table levels were measured monthly using a hydrological dipper and are expressed in centimetres above or below ground level.

4.2.2 Duration Lines.

A duration line or water table characteristic curve is derived by calculating the number of days the water-table is above a certain height in a particular vegetation community (Grootjans and Ten Klooster, 1985). The heights used are chosen on the basis of water table depth and frequency of measurement. A graph of watertable fluctuation with time is drawn and the number of days above the chosen watertable heights is estimated, by measuring the distance on the X-axis between points where a line of particular watertable height is crossed by the watertable curve. This distance is converted into days (Fig. 4.4). A 5 cm interval was used in this instance but could vary in other circumstances depending on watertable height and the frequency of measurement.

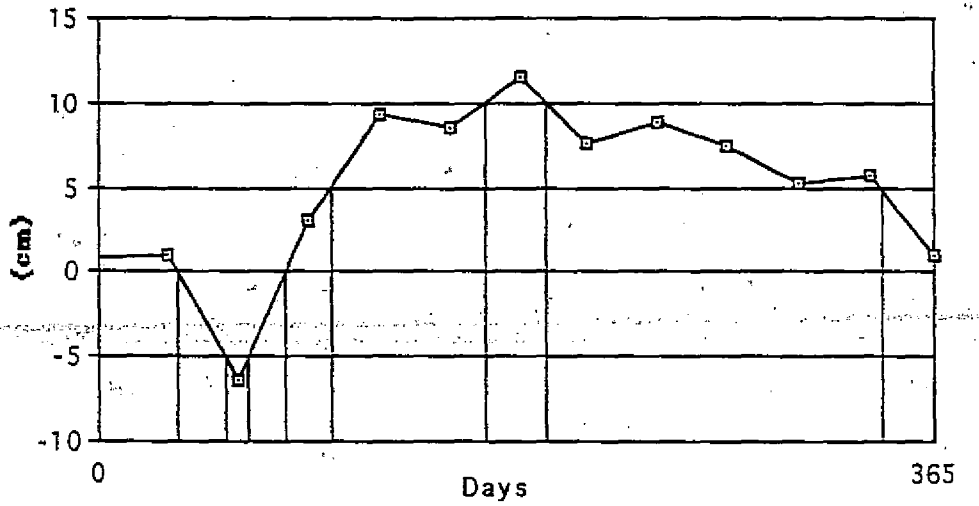


Fig.4.4 Sample graph of duration line preparation.

A further graph is then drawn using this data, where the x-axis corresponds to a cumulative time above a particular watertable height and the y-axis to watertable height in cm (Fig. 4.5) This graph represents a duration line or a watertable characteristic curve for the vegetation community under examination.

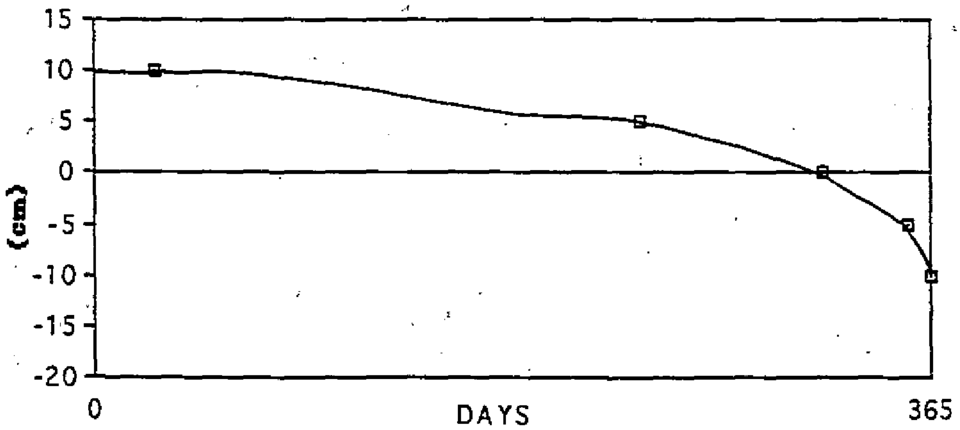


Fig. 4.5. A sample duration line.

77

Duration lines were constructed for the 1990 sites which had been selected for a further year of monitoring and also for the second year's data from these sites, for the soak sites and for the 1990 sites which represented community types not covered in the selected sites or the soak sites.

It is possible from this type of data to predict watertable characteristics for different vegetation communities. This is thought to be an important characterization of wetland vegetation communities, as the level and fluctuation of the water table influences other important processes such as aeration and mineralisation (Grootjans and Ten Klooster, 1985). These data are only preliminary, as several years data would be required to establish trends with more certainty. However they provide very useful guidelines.

Water table fluctuation was estimated by calculating the difference between the minimum and maximum water table heights experienced by a particular community type during the year.

4.3 COMPUTER METHODS.

4.3.1 CANOCO Version 3.11.

The abiotic data were prepared for analysis in CANOCO using CEDIT (Van Tongeren, 1991). This program, which edits multivariate data, was developed to be used with CANOCO. It prepares the Cornell condensed file format which is required by CANOCO. The vegetation data files were prepared using Vegbase 3.0 (1990).

The CANOCO program was designed particularly for plant ecologists (Ter Braak, 1990). It includes a number of computer techniques whereby community data may be related to environmental information. Three indirect (linear) techniques, which were previously available, are included within the program. These are Principal Component Analysis, Correspondence Analysis and Detrended Correspondence Analysis. These are techniques where major gradients are established in the species data without using measured environmental variables. In these methods the axes on the resulting ordination diagram correspond to theoretical environmental variables (Ter Braak, 1990). The program also includes a series of direct (weighted averaging) methods, where species or plant community occurrence can be directly related to a large number of observed environmental variables (Ter Braak, 1988). Thus the axes of the ordination diagram resulting from these analyses correspond to linear combinations of measured environmental variables (Ter Braak, 1990). These direct methods include Redundancy Analysis, Canonical Correspondence Analysis and Detrended Correspondence Analysis. The latter two were specially developed for this program by Ter Braak (1990). The canonical correspondence analysis technique was used. It was considered to be the most suitable, as environmental data were available for analysis. If environmental data are available, the direct ordination approach is considered to be the most effective (Ter Braak and Prentice, 1988).

Previous to the development of this program, other computer manipulations assumed a linear relationship between a plant species and an environmental variable. This would only be the case over a short range of most environmental variables, as toxicity or deficiency would usually occur at either end of the spectrum. CANOCO is able to detect unimodal responses between a species and an environmental factor. Axes are created and plots can be made of relevés, species and their related environmental variables, using the computer program Canodraw 2.1 (Smilauer, 1990).

CANOCO was used to establish possible relationships between vegetation community distribution and measured environmental parameters. The environmental data used were the water table measurements and the hydrochemical information.

On the ordination plots produced by Canodraw, drawn from the solution files of CANOCO, environmental variables are represented by arrows. These are known as vectors. The length of the vector is proportional to the rate of change of the variable in that direction. That is, the longer the vector the more strongly correlated the variable is with the ordination axes and thus more closely related to the pattern of communities on the ordination diagram (Jongman et al., 1987). The output from CANOCO also includes eigenvalues for the axes. These are a measure of the importance of the axes in the ordination. The closer the value is to 1.0, the more significant the axis. However values over 0.5 suggest a good separation along the axis (Jongman et al., 1987).

If one or more environmental variables are strongly correlated, all but one of the correlated variables may be made passive and a further ordination derived. This is necessary because the canonical coefficients of collinear variables are unstable and cannot be used in an interpretation of the output (Ter

Braak, 1988). A variable may be made passive, that is not used in the ordination, by excluding it from the analysis. This may be readily carried out within the CANOCO program. The collinearity of variables is indicated by the variance inflation factor (VIF). If the VIF is greater than 20, collinearity is suggested. To determine which variables are correlated, reference is made to the correlation matrix shown in the output of CANOCO.

A statistical test may be used to test the significance of the species-environment relationships. The Monte-Carlo permutation test was applied to all the ordinations carried out. This tests the significance of the species and environmental relationships and calculates an F-ratio for the first ordination axis and for an overall test of species and environmental relationships. It also shows the P (probability) value for each of the tests.

In total five CANOCO batches were analysed. These were;

1. All soak sites (103): using vegetation data of all soak plots and mean hydrochemistry and water table data from August and October 1991.
2. Selected soak sites (21): using mean values of one year's hydrochemical and water table data.
3. All sites, excluding soak sites: using data from October 1990 (155).
4. Selected 54 sites: using mean values of one year's (1990-1991) water table and hydrochemical data. Also divided into bog sites (33) and marginal sites (21).
5. Selected 37 sites: using mean values of one year's (1991-1992) water table and hydrochemical data. Also divided into bog sites (24) and marginal sites (13).
6. 258 sites: using October 1990 (bog and margins) and October 1991 (soak) water table and hydrochemical data.

4.3.2 Data Transformation.

Most environmental variables, except pH, were log transformed as they were log normally distributed. The following was the criterion used to establish whether data transformation was necessary (Fowler and Cohen, 1992).

Log transformation: this is used when the variance is greater than the mean value. When zero values are present, 1 must be added to all values; that is, replace x by log (x + 1).

Transformations were carried out using the program CEDIT (Van Tongeren, 1991).

The raw hydrology and hydrochemical data, which are analysed in Chapters 5, 6 and 7, are available on computer disk in The National Parks and Wildlife Service, Office of Public Works, 51, St. Stephen's Green, Dublin 2.

CHAPTER 5: HIGH BOG HYDROCHEMISTRY AND HYDROLOGY.

5.1. PRECIPITATION CHEMISTRY.

Raised bog vegetation, apart from some soak and marginal areas, depends totally on rainfall for ionic inputs. Thus a study of precipitation chemistry at the two sites was considered to be important, in order to determine the amount of ions originating from rainfall, which are potentially available for plant growth. Rainfall was collected at both sites between the 28th of June, 1991 and the 18th of June, 1992, at approximately monthly intervals. (For methods see Chapter 4). The following were measured: pH, electrical conductivity, PO_4-P, NO_3-N, NH_4-N, Na, K, Ca, Mg, Cl, SO_4-S, Fe and Mn. The results of these analyses are shown in Table 5.1 as mg l^{-1}. These concentration results are compared to data from the meteorological stations of Birr, Co. Offaly (33 km south-west of Clara and 48 km west south west of Raheenmore) and Kinnity, Co. Offaly (25 km south of Clara and 35 km south west of Raheenmore) in Fig. 5.1. The Birr data consists of the average values over nine years (1982-1990), including standard deviations. Only one complete year's data were available from Kinnity (1987). The Clara and Raheenmore data consists of the average values for each element over the sampling period.

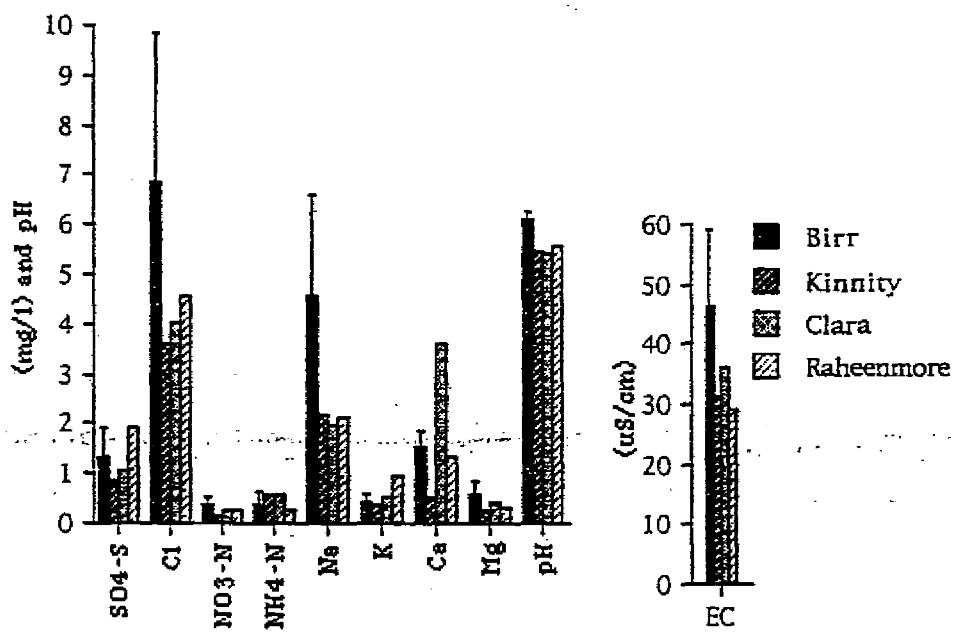


Fig. 5.1 Element concentrations (mg l^{-1}), pH and EC of precipitation from Birr, Kinnity, Clara and Raheenmore.

The overall patterns in element concentrations from Clara and Raheenmore follow the range of values from the two meteorological stations. The two exceptions are SO_4-S at Raheenmore and Ca at Clara. The latter appears to be related to gravel excavation from the esker to the north of the bog. This excavation occurs on an irregular basis but, when it does occur, generates clouds of fine dust. As the esker gravels are mainly composed of material derived from the limestone bedrock, this mining activity contributes significantly to the amount of Ca in the rain falling on Clara bog. Dry deposition into the rain gauges may also have occurred. Similar high inputs of Ca in other precipitation studies have been attributed to the liming of farmland and proximity to quarries (Allen et al., 1968; Proctor, 1992). The higher levels of SO_4-S are a little more difficult to explain. However the peaks in concentration are linked to periods of lower rainfall (Fig. 5 2). This is also true for the Birr site, as the two highest concentrations of SO_4-S recorded since 1981, 10.2 mg l^{-1} and 13.2 mg l^{-1}, were both during periods of very low rainfall (2 mm). High evaporation during these drier periods may be causing a concentration of SO_4-S. However the SO_4-S concentrations are consistently higher at Raheenmore over the year of sampling, than those at either Clara, Birr or Kinnity. This may be related to higher levels of atmospheric pollution, owing to the its closer proximity to peat fired electricity generating station. Raheenmore is situated only 5 km to the west of Derrygreenagh power station

60

Table 5.1. Results of the analyses of precipitation on Clara and Raheenmore (Note: Units for ions (mg l^{-1})). The following abbreviations are used: Electrical conductivity (EC), Total phosphate (TP) and Orthophosphate (OP).

Clara

DATE	pH	E C	TP	OP	NO_3-N	NH_4-N	Na	K	Ca	Mg	Mn	Fe	Cl	SO_4-S
28/6/91 to 29/7/91	6.7	27.0	0.034	0.001	0.14	1.496	0.91	0.47	31.2	0.28	0.02	0.00	2.20	0.89
30/7/91 to 14/8/91	4.1	45.3	0.057	0.021	0.41	0.732	1.37	0.03	0.97	0.16	0.00	0.00	1.40	1.11
15/8/91 to 03/9/91	7.4	49.6	0.060	0.020	0.57	0.622	1.60	0.68	3.24	0.66	0.01	0.00	4.10	2.40
04/9/91 to 09/10/91	6.0	48.8	0.283	0.273	0.13	0.787	2.60	0.55	0.62	0.50	0.01	0.00	4.90	0.74
10/10/91 to 16/11/91	5.8	26.3	0.290	0.003	0.44	0.569	0.40	0.49	1.96	0.37	0.01	0.03	1.80	1.23
17/11/91 to 03/12/91	5.5	37.5	0.020	0.000	0.23	0.430	2.50	0.25	0.53	0.83	0.00	0.06	6.00	0.92
04/12/91 to 22/1/92	5.0	35.3	0.009	0.004	0.09	0.272	3.60	3.20	0.74	0.00	0.02	0.04	6.30	0.77
23/1/92 to 25/2/92	4.6	45.1	0.007	0.003	0.25	0.593	3.20	0.23	0.91	0.58	0.02	0.06	5.70	1.41
26/2/92 to 24/3/92	5.4	29.2	0.007	0.003	0.20	0.281	3.00	0.09	0.81	0.40	0.01	0.06	5.70	0.77
25/3/92 to 21/4/92	4.9	39.3	0.007	0.004	0.34	0.386	2.09	0.15	0.91	0.54	0.03	0.03	5.60	0.65
22/4/92 to 25/5/92	4.9	23.8	0.007	0.007	0.05	0.018	1.96	0.16	1.07	0.37	0.00	0.02	3.81	0.80
26/5/92 to 18/6/92	4.0	28.2	0.011	0.004	0.52	0.916	0.35	0.16	0.66	0.11	0.00	0.02	1.18	1.14
MEAN	5.4	36.3	0.066	0.029	0.28	0.592	1.97	0.54	3.64	0.40	0.01	0.03	4.06	1.07

Raheenmore

DATE	pH	E C	TP	OP	NO_3-N	NH_4-N	Na	K	Ca	Mg	Mn	Fe	Cl	SO_4-S
28/6/91 to 29/7/91	6.3	28.9	0.837	0.501	0.11	0.73	10.7	5.2	5.9	0.36	0.02	0.00	19.0	2.95
30/7/91 to 15/8/91	6.4	58.1	0.464	0.553	0.36	0.721	0.02	0.65	1.04	0.20	0.00	0.00	3.0	10.38
16/8/91 to 02/9/91	7.4	35.9	0.060	0.009	0.23	0.531	1.40	0.73	1.94	0.42	0.02	0.00	4.8	2.70
03/9/91 to 08/10/91	5.2	20.5	0.020	0.004	0.05	0.057	1.70	0.14	0.62	0.30	0.00	0.08	3.4	0.43
9/10/91 to 16/11/91	6.7	26.6	0.025	0.005	0.37	0.538	0.50	0.21	2.39	0.30	0.01	0.00	1.8	1.50
17/11/91 to 03/12/91	4.3	30.1	0.010	0.001	0.21	0.170	1.60	0.10	0.39	0.66	0.00	0.05	4.0	0.71
04/12/91 to 21/1/92	4.2	18.7	0.014	0.003	0.05	0.142	1.60	4.0	0.42	0.22	0.00	0.69	2.5	0.43
22/1/92 to 24/2/92	6.6	27.3	0.010	0.004	0.15	0.000	1.70	0.06	0.91	0.35	0.01	0.25	3.4	0.83
25/2/92 to 24/3/92	4.9	24.8	0.010	0.003	0.17	0.000	1.80	0.05	0.50	0.30	0.00	0.06	3.2	0.80
25/3/92 to 20/4/92	6.4	27.5	0.003	0.005	1.24	0.000	2.50	0.08	0.40	0.33	0.03	0.04	5.6	0.65
21/4/92 to 26/5/92	4.2	26.9	0.004	0.002	0.06	0.124	1.80	0.13	0.73	0.31	0.00	0.01	3.4	0.86
27/5/92 to 17/6/92	4.9	23.2	0.191	0.004	0.26	0.101	0.37	0.15	0.62	0.11	0.00	0.05	1.3	0.89
MEAN	5.6	29.0	0.137	0.091	0.27	0.260	2.14	0.96	1.32	0.32	0.01	0.10	4.6	1.92

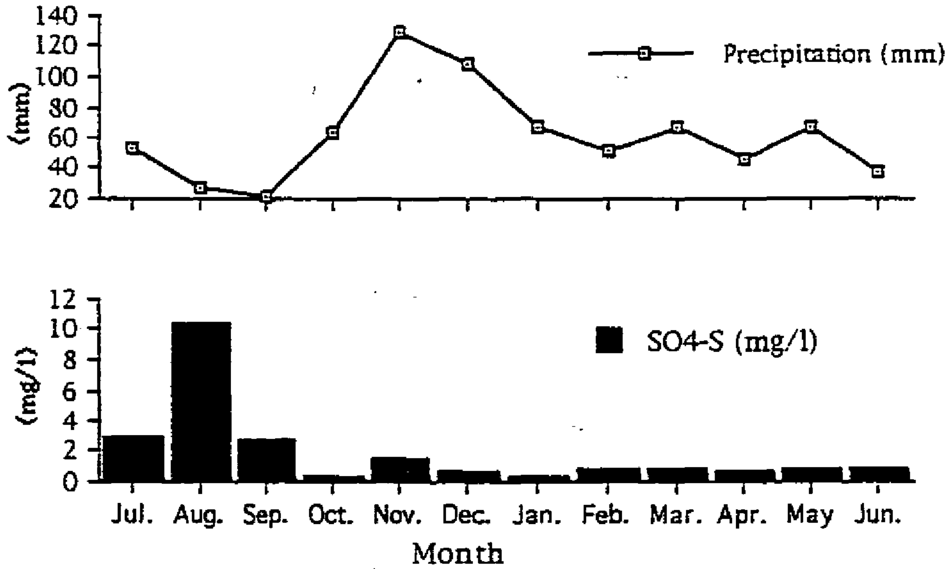


Fig. 5.2 Relationship between SO_4-S concentration and quantities of precipitation at Raheenmore.

The excess SO_4-S, which is not of marine origin, may be estimated by assuming that all the Cl present in precipitation is of marine origin. Using the ratio of SO_4: Cl in seawater (0.105), the amount of SO_4 which could be derived from sea water can be measured by subtracting the SO_4 of marine origin from the total SO_4 measured in precipitation (Gorham et al., 1985). These values were calculated for Clara and Raheenmore (Table 5.2).

Table 5.2 Calculations to estimate the amount of SO_4 derived from sources other than seawater.

SITE	Cl ($kg\ ha^{-1}\ yr^{-1}$)	SO_4-S ($kg\ ha^{-1}\ yr^{-1}$)	SO_4-S (marine) ($kg\ ha^{-1}\ yr^{-1}$)	Excess SO_4-S ($kg\ ha^{-1}\ yr^{-1}$)
Clara	28.93	6.68	3.04	3.64
Raheenmore	31.7	10.35	3.33	7.02

These calculations prove that the SO_4 in precipitation at both sites cannot be derived totally from marine sources and thus must be attributed to some degree of air pollution.

The sodium, chloride and magnesium in rainfall are usually of marine origin (Ahmad-Shah and Rieley, 1989). This is reflected in the close relationship between the concentrations of these ions throughout the year at both Clara and Raheenmore (Fig. 5.3). The close relationship (R^2= 0.943) between Na and Cl, shown in Fig. 5.4, suggests that these two ions are derived from NaCl salt of marine origin. The maritime influence on precipitation chemistry may be calculated using the ratio of Na/K, as Na is usually of marine origin while K is usually derived from terrestrial inputs. The closer this ratio is to that of sea-water (28), the greater the maritime influence (Allen et al., 1968). For Clara this ratio is 3.56 and for Raheenmore the ratio is 2.32. The higher value at Clara is probably related to the fact that it is closer to the sea in terms of the prevailing wind, which is south-westerly (Rohan, 1986).

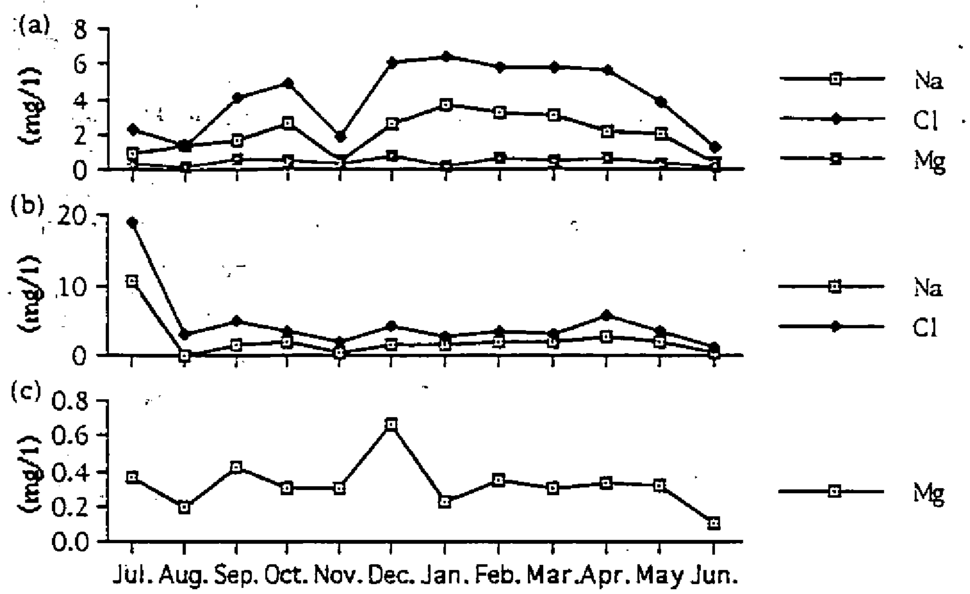


Fig. 5.3 Relationship between sodium, chloride and magnesium in precipitation at Clara (a) and Raheenmore (b) and (c).

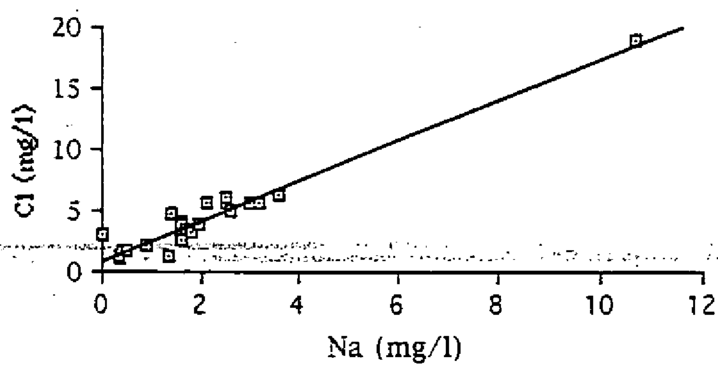


Fig. 5.4 Relationship between Na and Cl inputs at Clara and Raheenmore.

Quantities of elemental input per ha may be calculated from amounts of precipitation and the concentration of each element per litre of rainfall. The number of litres ha^{-1} of rain were calculated from the rain gauge information available from both bogs for the time periods the rain chemistry samples covered. These periods approximately correspond to months (see Table 5.1) and are so treated in further discussion. The inputs from precipitation (kg ha^{-1}) are shown in Table 5.3. The total inputs (excluding H^+) at both sites are similar: 89.37 kg ha^{-1} yr^{-1} at Clara and 80.95 kg ha^{-1} yr^{-1} at Raheenmore. However the balance between cation and anion input at the sites differs considerably. At Clara the total input of cations is 51.46 kg ha^{-1} yr^{-1} (57.58%) and anions 37.91 kg ha^{-1} yr^{-1} (42.42%). At Raheenmore the values for cations are 36.59 kg ha^{-1} yr^{-1} (45.2%) and for anions 44.36 kg ha^{-1} yr^{-1} (54.8%). The difference between values at the two sites can be attributed to the higher inputs of Ca at Clara. The Raheenmore values correspond closely to those obtained from rain falling on open *Sphagnum* lawns in Britain, with 33.5 kg ha^{-1} yr^{-1} for cations and 63.1 kg ha^{-1} yr^{-1} for anions (Ahmad-Shah and Rieley, 1989). Table 5.4 compares the inputs from precipitation at Clara and Raheenmore to precipitation gathered above an open *Sphagnum* lawn site at Chartley moss National Nature Reserve, Staffordshire, Britain (Ahmad-Shah and Rieley, 1989). The error values indicated for Chartley Moss are standard deviation values derived from data for different sample points.

Table 5.3 Ionic inputs (kg ha^{-1}) from precipitation on Clara and Raheenmore

Clara

MONTH	RAIN (l ha^{-1})	PO_4-P	NO_3-N	NH_4-N	Na	K	Ca	Mg	Mn	Fe	Cl	SO_4-S
July	660000	0.022	0.09	0.987	0.60	0.31	20.59	0.18	0.01	0.00	1.45	0.59
August	136000	0.008	0.06	0.100	0.19	0.00	0.13	0.02	0.00	0.00	0.19	0.15
September	91000	0.005	0.05	0.057	0.15	0.06	0.29	0.06	0.00	0.00	0.37	0.22
October	662000	0.187	0.09	0.521	1.72	0.36	0.41	0.33	0.01	0.00	3.24	0.49
November	1121000	0.325	0.49	0.638	0.45	0.55	2.20	0.41	0.01	0.03	2.02	1.38
December	1019000	0.020	0.23	0.438	2.55	0.25	0.54	0.85	0.00	0.06	6.11	0.94
January	583000	0.005	0.05	0.159	2.10	1.87	0.43	0.00	0.01	0.02	3.67	0.45
February	421000	0.003	0.11	0.250	1.35	0.10	0.38	0.24	0.01	0.03	2.40	0.60
March	686000	0.005	0.14	0.193	2.06	0.06	0.56	0.27	0.01	0.04	3.91	0.53
April	419000	0.003	0.14	0.162	0.88	0.06	0.38	0.23	0.01	0.01	2.35	0.27
May	708000	0.005	0.04	0.013	1.39	0.11	0.76	0.26	0.00	0.01	2.70	0.56
June	437000	0.005	0.23	0.400	0.15	0.07	0.29	0.05	0.00	0.01	0.52	0.50
TOTAL	6943000	0.594	1.71	3.916	13.57	3.81	26.96	2.91	0.07	0.22	28.93	6.68

Raheenmore

MONTH	RAIN (l ha^{-1})	PO_4-P	NO_3-N	NH_4-N	Na	K	Ca	Mg	Mn	Fe	Cl	SO_4-S
July	531300	0.445	0.058	0.388	5.685	2.763	3.135	0.191	0.011	0.000	10.10	1.57
August	264000	0.122	0.095	0.190	0.005	0.172	0.275	0.053	0.000	0.000	0.79	2.74
September	223000	0.013	0.051	0.118	0.312	0.163	0.433	0.094	0.004	0.000	1.07	0.60
October	637000	0.013	0.032	0.036	1.083	0.089	0.395	0.191	0.000	0.051	2.17	0.27
November	1291000	0.032	0.478	0.695	0.646	0.271	3.085	0.387	0.013	0.000	2.32	1.94
December	1081000	0.011	0.227	0.184	1.730	0.108	0.422	0.713	0.000	0.054	4.32	0.76
January	674000	0.009	0.034	0.096	1.078	2.696	0.283	0.148	0.000	0.465	1.69	0.29
February	513000	0.005	0.077	0.000	0.872	0.031	0.467	0.180	0.005	0.128	1.74	0.43
March	675000	0.007	0.115	0.000	1.215	0.034	0.338	0.203	0.000	0.041	2.16	0.54
April	457000	0.001	0.567	0.000	1.143	0.037	0.183	0.151	0.014	0.018	2.56	0.29
May	674000	0.003	0.040	0.084	1.213	0.088	0.492	0.209	0.000	0.007	2.29	0.58
June	379500	0.072	0.099	0.038	0.140	0.057	0.235	0.042	0.000	0.019	0.49	0.34
TOTAL	7399800	0.734	1.870	1.829	15.12	6.51	9.74	2.56	0.05	0.78	31.7	10.35

Table 5.4 Comparison between inputs (kg ha^{-1} yr^{-1}) at Clara, Raheenmore and Chartley Moss.

ION	Chartley Moss	Clara	Raheenmore
PO_4-P	1.49 (± 0.34)	0.594	0.734
NO_3-N	10.1 (± 1.48)	1.71	1.870
NH_4-N	6.26 (± 2.41)	3.916	1.829
Na	11.8 (± 1.39)	13.57	15.12
K	5.16 (± 2.49)	3.81	6.51
Ca	6.3 (± 1.16)	26.96	9.74
Mg	1.92 (± 0.63)	2.91	2.56
Mn	0.28 (± 0.13)	0.07	0.05
Fe	0.13 (± 0.06)	0.22	0.78
Cl	20.8 (± 2.79)	28.93	31.7
SO_4-S	30.8 (± 3.2)	21.69	33.7

This comparison highlights the fact that for non-pollution linked ions, inputs are similar at these sites despite their different locations. However at Chartley Moss the levels of NO_3 and NH_4 are much higher and indicate atmospheric pollution. SO_4 is also high, in common with Clara and Raheenmore and is attributed to atmospheric pollution. An annual percentage (kg ha^{-1} yr^{-1}) of each ion measured at Clara (a) and Raheenmore (b) is shown in Fig. 5.5a and 5.5b. These show that SO_4, Cl and Na are the major ionic components of the rainfall, while those ions which can be limiting to plant growth make up only a very small percentage of the input each year.

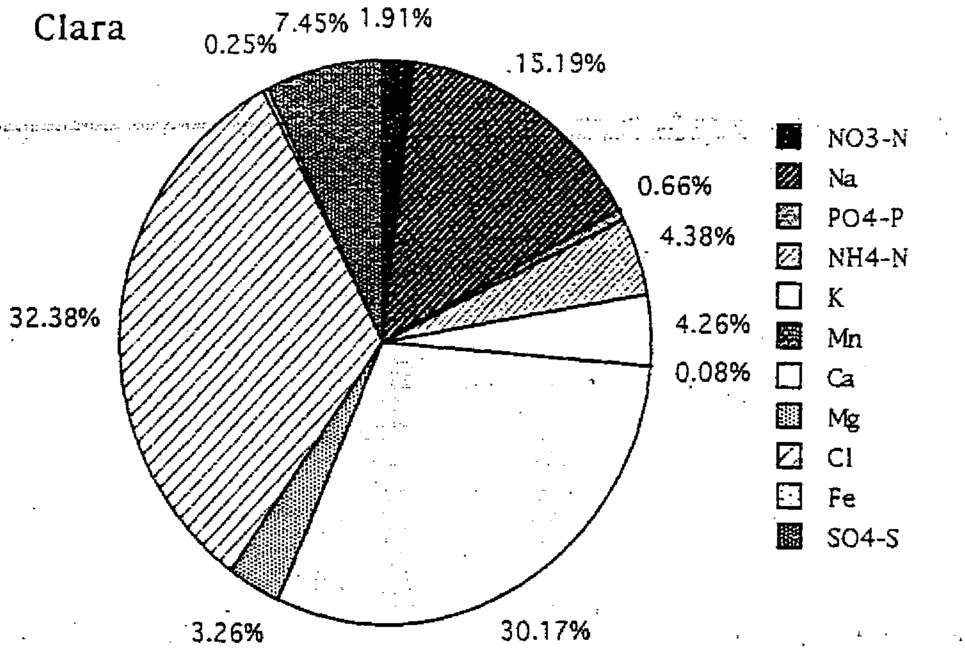


Fig. 5.5a The percentage input from precipitation (kg ha^{-1} yr^{-1}) of each element at Clara.

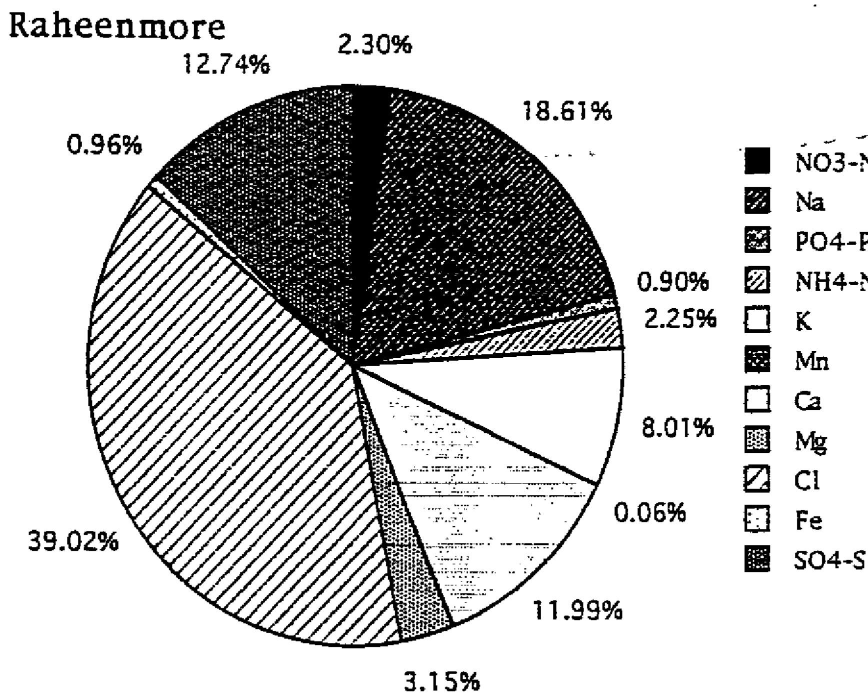


Fig. 5.5b The percentage input from precipitation (kg ha^{-1} yr^{-1}) of each element at Raheenmore .

5.1.1 CONCLUSIONS.

This investigation into the inputs from precipitation at the two raised bog sites supports the accepted view that the nutrient content in rainfall is generally low. However it does raise the point that local variations in agricultural, industrial or mining activities may result in significant differences in the inputs of some ions. This may have a important effect on the variation in plant communities seen in these oligotrophic habitats, as small changes are likely to have significant effects.

5.2 HYDROLOGY, HYDROCHEMISTRY AND BOG VEGETATION.

Ivanov, 1981 states that the most important factors which influence the plant community distribution on mires are: water table depth and fluctuation, seepage (lateral and vertical water movement) and hydrochemistry. The importance of these factors has been recognised by many others, with a number of investigations into water movement in mires (Sparling, 1966; Ingram, 1967), bog hydrochemistry and/or mire water table characteristics (Gorham, 1956; Newbould and Gorham, 1956; Green and Pearson, 1968; Summerfield, 1974; Bell and Tallis, 1973; Miles, 1976; Comeau and Bellamy, 1986). These studies have usually concentrated on inter-site comparisons, on the autecology of one or two species or on comparisons between a limited number of community types occurring within one site. It appears that no study has been made on the hydrology and hydrochemistry of the range of community types within one system. This is certainly the case in relation to Irish raised bogs.

This study is an attempt to describe and compare the hydrological and hydrochemical characteristics of the range of plant communities on Clara and Raheenmore, including an examination of seasonal variation. This was undertaken with a view to the conservation of community diversity within the two sites.

In total, eighteen raised bog communities, which were identified during the vegetation survey, were monitored. These fall into the broad structural divisions of hummock, flat, lawn, hollow and pool communities (see Chapter 3 and Fig 5.6).

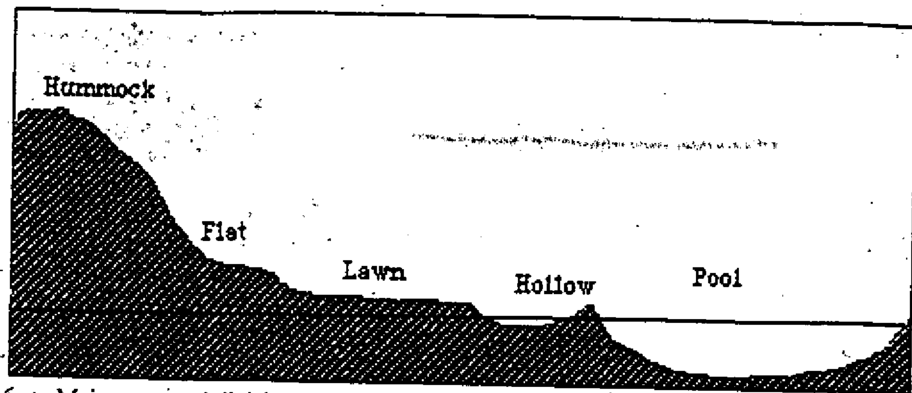


Fig.5.6 Main structural divisions of the high bog communities. An approximate average water table is indicated.

The communities examined in this chapter are:

Pool, Hollow and Lawn communities (including some low hummocks and flats).

1. The community of *Rhynchospora alba* and *Zygnemalis* hollows.
2A. The community of *Sphagnum cuspidatum* and *Eriophorum angustifolium*, typical variant.
2C. The community of *Sphagnum cuspidatum* and *Eriophorum angustifolium*, variant with *Molinia caerulea* and *Juncus bulbosus*.
3A. The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, typical variant.
3Ba The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, phase with *Sphagnum magellanicum*, sub-variant with *Sphagnum cuspidatum*.
3Bb The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, phase with *Sphagnum magellanicum*, typical sub-variant.
3Bc. The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, phase with *Sphagnum magellanicum*, sub-variant with *Molinia caerulea* .
3C. The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, phase of *Sphagnum papillosum*.
3D. The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, variant with *Campylopus introflexus* and *Zygnemalis*.
3E. The community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, variant with *Trichophorum cespitosum*.

Hummock and Flat communities.

4A. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, typical variant.
4B. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, variant with *Campylopus introflexus*.
4C. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase with *Leucobryum glaucum*.
4D. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase with *Cladonia portentosa*.
4E. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase with *Sphagnum capillifolium*.
4F. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase with *Sphagnum imbricatum*.
4G. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase with *Calluna vulgaris* and *Hypnum jutlandicum*.
10. The community of *Polytrichum alpestre* and *Calliergon cuspidatum*.

(For further details on species composition refer to Chapter 3).

5.2.1 HYDROLOGY

The water table depth was monitored within these communities for at least one year and within a selection of the more widespread community types for two years. The annual average mean, maximum and minimum (± 2 S.E.) water table depths within each community type are shown in Table 5. 5. This information is illustrated in Fig. 5.7, where the communities of pools, lawns and hollows (A) are shown separately to the communities of low hummocks, hummocks and flats (B).

The difference in water table depths between these two main groups is readily apparent. Pool communities all have their mean water table above ground level and hollows and lawns have their mean water table just above or just below surface level, while the hummock communities' mean watertable is below ground level. Within the first group, the pool communities (2A, 2C and 3Ba) are the wettest, having the highest maximum water table levels with what appears to be a critical minimum level of closer to the surface than -10.0 cm. The vegetation link between these pool communities is the occurrence of the aquatic *Sphagnum cuspidatum*. This species cannot survive long periods of desiccation and is thus mainly confined to these pool communities. The aquatic nature of these communities is confirmed by the presence of species such as *Cladopodiella fluitans* and *Drosera anglica*.

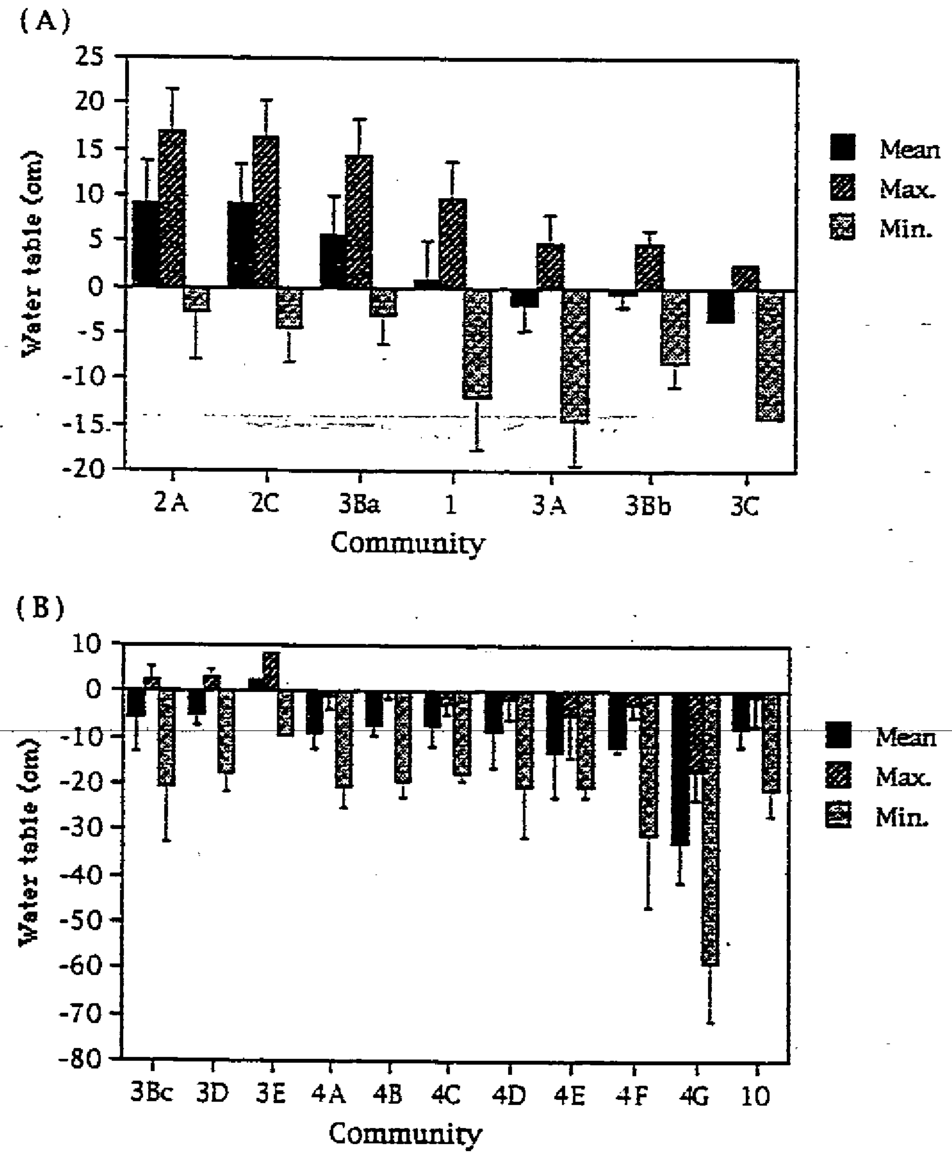


Fig. 5.7 Average annual mean, maximum and minimum water table depths (± 2 S.E (95% C.I.)) for the pool, hollow and lawn communities (A) and the flat and hummock communities (B).

88

Table 5.5 Summary of the hydrological and some hydrochemical characteristics of the main bog plant communities. The annual average, mean, maximum and minimum values (± 2 S.E.) are shown for water table depth (cm), K_{corr} (μScm^{-1}) and pH. A water type is also indicated, according to the classification of Stuyfzand (1990).

	Water Table			pH			K_{corr}			Water Class.
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	
1	0.9 (±4.4)	9.7 (±4.1)	-11.7 (±6.0)	4.2 (±0.1)	4.7 (±0.2)	3.8 (±0.1)	65.0 (±6.6)	102.5 (±18.4)	41.0 (±5.8)	NaCl
2A	9.1 (±4.8)	17.1 (±4.4)	-2.7 (±5.2)	4.1 (±0.0)	4.3 (±0.1)	3.8 (±0.1)	58.6 (±9.2)	94.5 (±19.8)	36.0 (±9.6)	NaCl
2C	9.3 (±4.4)	16.3 (±4.2)	-4.2 (±3.8)	4.0 (±0.0)	4.4 (±0.2)	3.7 (±0.1)	51.9 (±8.8)	79.3 (±11.0)	28.9 (±8.2)	NaCl
3A	-1.7 (±3.0)	4.9 (±3.2)	-14.3 (±3.0)	4.1 (±0.1)	4.4 (±0.1)	3.7 (±0.1)	52.6 (±4.4)	79.9 (±8.2)	30.3 (±4.4)	NaCl
3Ba	5.9 (±4.2)	14.4 (±4.2)	-2.8 (±3.2)	4.1 (±0.1)	4.2 (±0.2)	3.9 (±0.1)	52.2 (±11.0)	78.5 (±13.6)	31.0 (±6.0)	NaCl
3Bb	-0.5 (±1.6)	5.0 (±1.4)	-8.2 (±4.2)	4.1 (±0.0)	4.3 (±0.1)	3.7 (±0.2)	56.4 (±7.2)	94.7 (±22.0)	31.9 (±4.6)	NaCl
3Bc	-5.8 (±7.2)	2.2 (±3.0)	-20.9 (±11.8)	4.4 (±0.6)	4.7 (±0.9)	3.9 (±0.1)	52.4 (±6.0)	96.5 (±45.7)	28.4 (±34.6)	NaCl
3C	-3.6	2.6	-14.1	3.8	4.0	3.7	49.5	76.7	29.2	NaCl
3D	-5.0 (±2.6)	3.0 (±1.8)	-17.8 (±4.2)	4.1 (±0.1)	4.5 (±0.2)	3.7 (±0.1)	62.9 (±6.2)	112.5 (±30.0)	30.7 (±5.0)	NaCl
3E	2.2	8.1	-9.8	4.1	5.1	3.7	69.2	108.3	41.0	NaCl
4A	-9.2 (±3.6)	-4.0 (±2.6)	-21.0 (±4.6)	4.2 (±0.1)	4.5 (±0.2)	3.8 (±0.0)	58.8 (±5.0)	97.0 (±11.8)	33.5 (±4.2)	NaCl
4B	-7.4 (±2.4)	-0.2 (±1.8)	-19.5 (±3.8)	4.0 (±0.1)	4.5 (±0.2)	3.7 (±0.1)	66.8 (±6.4)	124.4 (±27.2)	40.6 (±4.8)	NaCl
4C	-7.6 (±4.6)	-2.8 (±2.4)	-17.6 (±2.0)	4.0 (±0.1)	4.2 (±0.0)	3.7 (±0.1)	55.8 (±18.4)	82.0 (±20.0)	30.2 (±3.4)	NaCl
4D	-8.7 (±8.0)	-1.8 (±4.8)	-20.7 (±11.2)	4.1 (±0.1)	4.4 (±0.2)	3.4 (±0.2)	72.3 (±7.8)	149.5 (±36.8)	34.2 (±6.0)	NaCl
4E	-13.0 (±9.8)	-5.2 (±9.2)	-21.0 (±2.0)	4.1 (±0.4)	4.6 (±0.9)	3.8 (±0.2)	52.4 (±3.2)	82.7 (±6.4)	26.7 (±1.4)	NaCl
4F	-12.2 (±1.2)	-2.7 (±3.2)	-31.1 (±15.4)	4.1 (±0.2)	4.8 (±1.0)	3.7 (±0.2)	69.6 (±7.8)	150.7 (±36.8)	37.5 (±29.0)	NaCl
4G	-32.8 (±18.6)	-17.3 (±6.6)	-58.6 (±13.0)	4.2 (±0.2)	4.8 (±0.3)	3.8 (±0.1)	66.2 (±5.4)	116.8 (±28.4)	41.2 (±6.0)	NaCl
10	-8.2 (±4.2)	-1.2 (±6.4)	-21.1 (±6.0)	4.0 (±0.1)	4.2 (±0.1)	3.8 (±0.0)	66.3 (±0.2)	122.1 (±30.6)	37.3 (±0.2)	NaCl

Note: Where no standard errors are indicated, replicate data was not available.

The average monthly water table values follow similar trends within the group of pool communities. They remain high almost all year, with the effects of the dry summer period only becoming apparent towards the end of the summer season (Fig. 5.8).

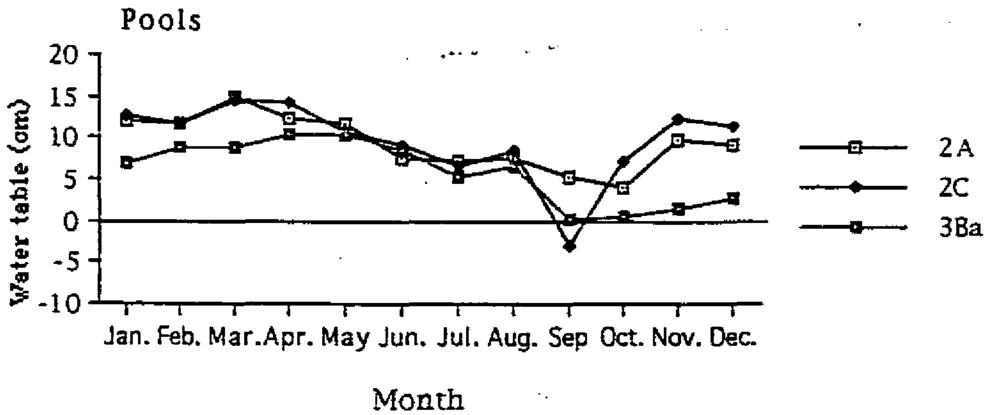


Fig. 5.8 The average monthly water table depths (cm) for the pool communities.

The lawn communities (3Bb and 3C) have their mean water table just below surface level and are only flooded during periods of high rainfall (Fig. 5.9). The lawn communities have an average bryophyte cover of between 85% and 100% and this lawn of *Sphagnum* growth means that the hydraulic conductivity of the top layer is very high and excess water can diffuse rapidly through a layer of *Sphagnum*. This helps to reduce surface runoff and so prevent peat erosion (Ingram and Bragg, 1984). Thus the *Sphagnum* lawn communities contribute significantly toward desired acrotelm conditions (Chapter 8).

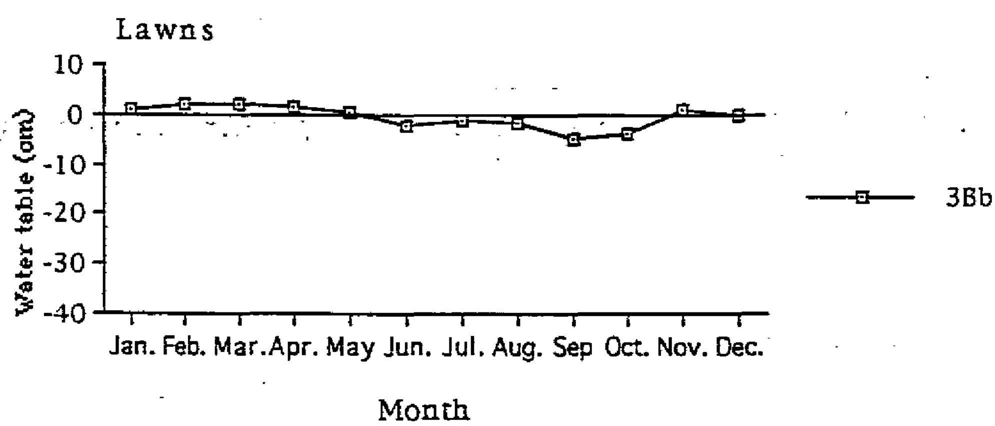


Fig. 5.9 The average monthly water table depths (cm) for the lawn community (3Bb). (Community 3C is not illustrated as no average figures are available).

In contrast the hollows communities (1 and 3A) occur most frequently in the marginal and sub-marginal areas of the bog, where an acrotelm layer is quite often absent (see Chapter 8). In addition, the *Sphagnum* species of hollows tend to have faster decay rates (Johnson et al., 1990) and thus the peat of hollows has a higher humification degree than that occurring under lawn communities. These two factors ensure that the hydraulic conductivity of the hollow peat is low and as a result excess water does not diffuse rapidly. The maximum water table level can therefore be high during winter months but during the dry summer period the water table can fall to relatively low levels (Fig. 5.10). In contrast to the pool community water table levels, the water table remains below surface level for much longer periods of time. These longer low summer levels prevent the development of pool vegetation communities.

90

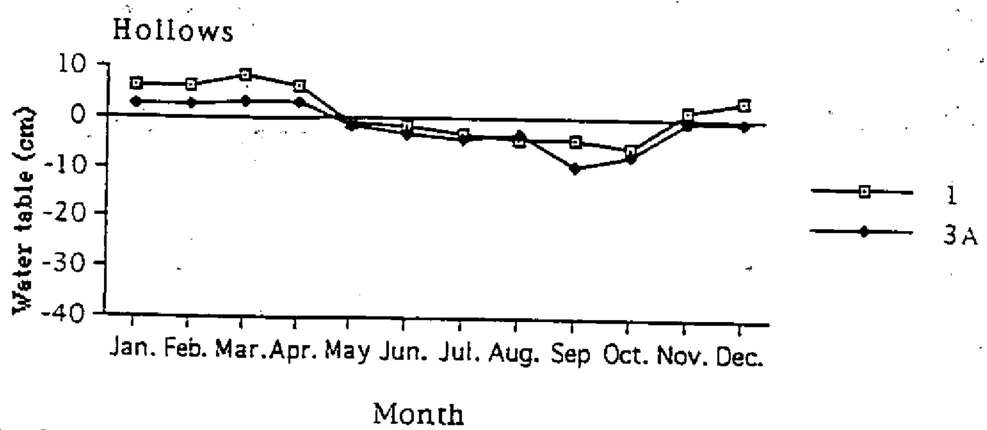


Fig. 5.10 The average monthly water table depths (cm) for the hollow communities.

The group consisting of hummocks and flats is characterised by a high abundance of dwarf shrubs (30-60%), consisting predominantly of the species *Calluna vulgaris* and *Erica tetralix*. The face-bank community (4G) can have a dwarf shrub cover of up to 95%. The communities of flats have relatively variable water table heights (Fig 5.11). The variants 4D and 4E follow a similar pattern, whereas 3Bc appears to respond like a low hummock community. Water table levels are within -10 cm of surface level during the winter period owing to the flat nature of these communities. As the summer progresses water table levels fall to depths below -15 cm and greater. These communities are therefore unable to support the more aquatic *Sphagnum* species.

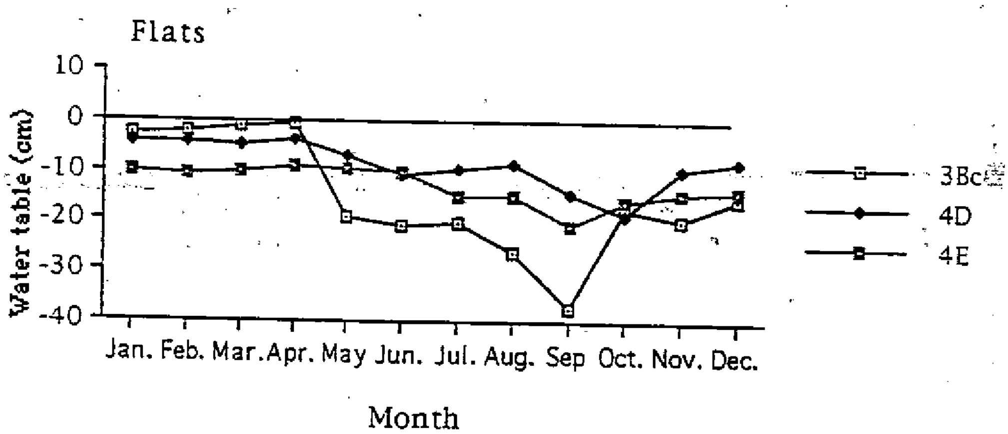


Fig. 5.11 The average monthly water table depths (cm) for the flat communities.

The two main variants of disturbed and/or burnt (meaning variants containing species indicating a fire history) conditions have similar water table patterns to the hollow communities, with winter water table heights close to surface level but then falling rapidly during the summer (Fig. 5.12). The variant 3D has a slightly wetter nature than the variant 4B. This is reflected in their species composition; 4B has a higher dwarf shrub cover and a significant occurrence of *Sphagnum capillifolium*. In contrast 3D has a floristic composition more typical of wetter situations, for example the occurrence of *Sphagnum tenellum* and a high algal cover. Burning and disturbance (drainage) to a bog system usually disrupts the functioning of the acrotelm layer, which in turn affects the infiltration and dispersal of precipitation, which influences water table depth.

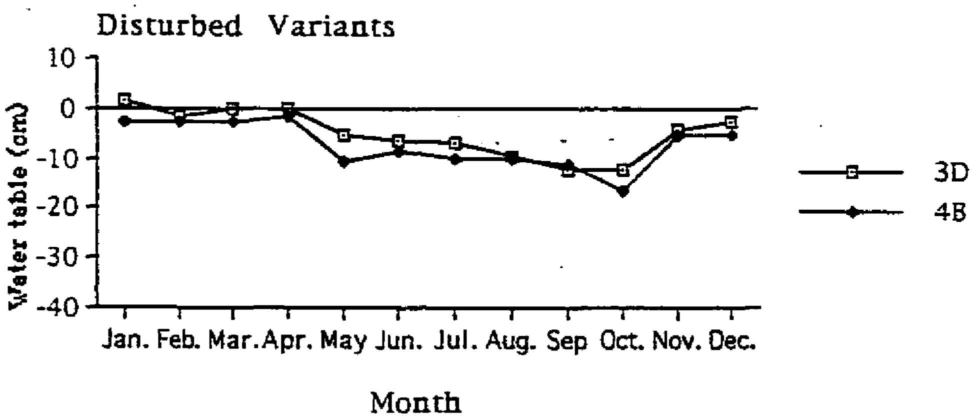


Fig. 5.12 The average monthly water table depths (cm) for the disturbed/burnt variants.

Although the water table patterns are similar between the hollow communities and the disturbed variants, the length of time the water table remains below surface level is longer in the burnt/disturbed variants than in the group of hollow communities. This is illustrated by a comparison between the duration lines of the different types. Duration lines are an approximation of the length of time the water table remains at certain levels throughout the year (see Chapter 4). They are useful indicators of the water table characteristics of a community. Two communities may have similar mean water table levels for the year, but one may remain at a relatively constant level throughout that time and the other may fluctuate considerably. These different patterns of water table could support very different plant communities although their average water table may be similar. This is particularly true in wetland situations where water table levels are high and small changes may greatly influence the plant species which can survive. The duration lines of the hollow communities show that the water table spends a longer time above surface level than it does in the disturbed community types, although their mean water table levels for the year are similar (Fig. 5.13).

The water table levels in the hummock communities are variable, as the height of the hummock above the surrounding area influences the water table depth it experiences. The height of hummocks can range from 10 cm to 1 metre or more. Water table levels are below surface level all year and thus the species which dominate these communities are the hummock-forming *Sphagnum* species and dwarf shrubs. The water table levels in the different hummock communities follow similar patterns (Fig. 5.14). The lowest water table levels are experienced by the *Sphagnum imbricatum* hummocks (4F). These tend to be the tallest hummocks encountered at the two sites.

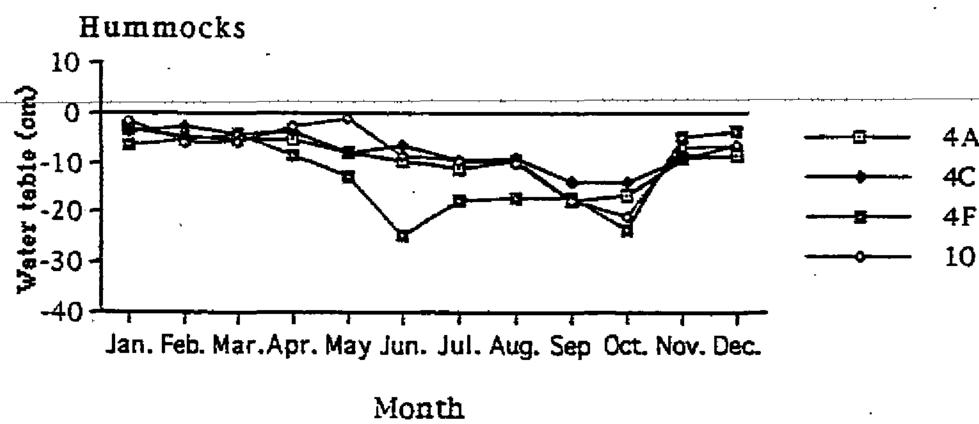


Fig. 5.14 The average monthly water table depths (cm) for the hummock communities.

The face-bank community (4G) represents the most extreme high bog community in terms of water table depth (Fig. 5.15). Average water table levels are below -20 cm throughout the year, falling to an average minimum value of almost -50 cm. This ensures that the number of species which can survive in this community is limited. The occurrence of any *Sphagnum* species is extremely rare and, when they do occur, they are usually only associated with runnels which carry surface water runoff. *Calluna vulgaris* is the dominant species and reaches its tallest heights on these drier areas. This face-bank

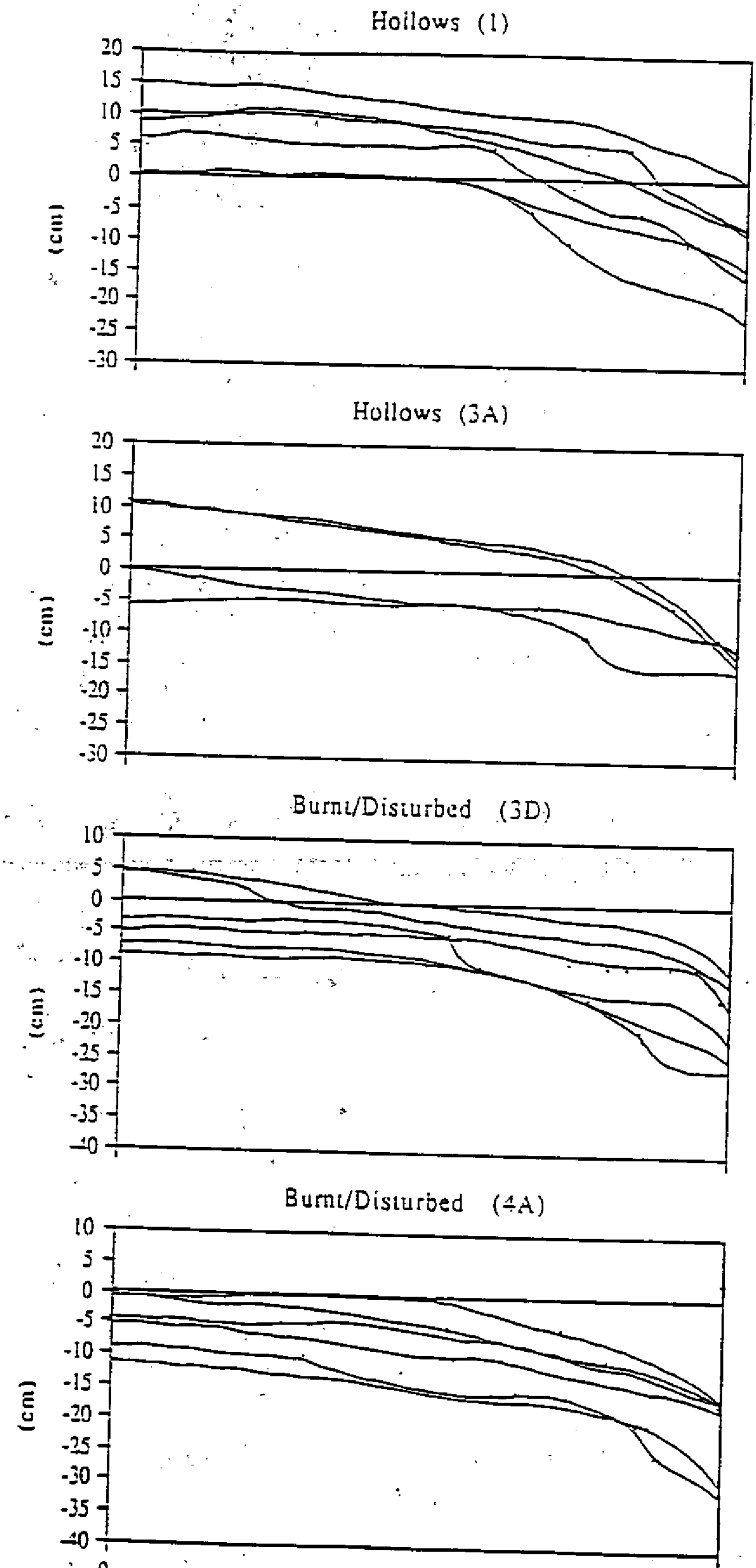


Fig. 5.13 Compares duration lines of hollow (1 and 3A) communities to those of burnt/disturbed types (3D and 4B).

community was also recognised by Hammond et al. (1990) as being associated with the lowest watertable levels measured on an area of disturbed raised bog.

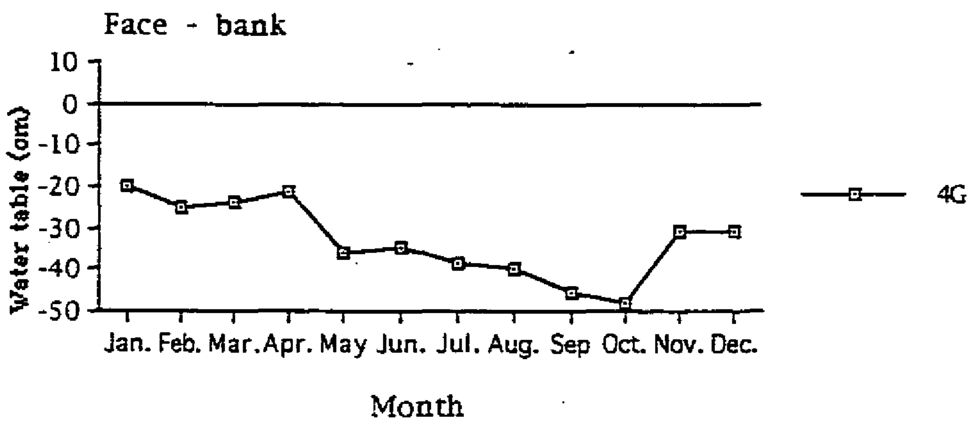


Fig. 5.15 The average monthly water table depths (cm) for the face-bank community.

Statistical analyses were carried out on these data using the statistics program Statistix Version 3.1 on an IBM compatible computer. Some community types could not be included in the statistical analysis owing to a lack of sufficient replicate information. These were (3C, 3E, 4C, 4E and 4F). One-way analysis of variance (ANOVA) was carried out on the mean, maximum and minimum values. Summary tables of the results of ANOVA are shown in Fig. 5.16. All show that there is a very significant statistical difference ($p < 0.001$) between communities. To test which communities were statistically different, t-tests were applied.

The t-tests carried out on the maximum water table levels of the different communities showed that hollows ($P < 0.05$), pools and lawns had statistically significantly different values to each other. The pools had the highest maximum water table levels followed by the hollow communities and then the lawn communities. However there was no statistical difference between the two hollow communities ($P > 0.05$) or within the group of pool communities ($P > 0.05$). These similarities within the groups are also apparent from the average water table curves for the year. Hummock and flat values are significantly lower than either pools ($P < 0.001$), hollows ($P < 0.01$) or lawns ($P < 0.01$). Yet within the group of hummocks and flats, no significant differences were detected, even between the burnt/disturbed and non-burnt/disturbed types. The face bank community is statistically significantly different from all others: pools ($P < 0.001$); hollows ($P < 0.001$); lawns ($P < 0.001$) and hummocks ($P < 0.01$).

ANOVA summary table of Minimum Water table.

SOURCE	DF	SS	MS	F	P
Between	11	31160	2833	18.5	0.00001
Within	130	19910	153.1		
Total	141	51070			

ANOVA summary table of Maximum Water table.

SOURCE	DF	SS	MS	F	P
Between	11	11130	1012	21.32	0.00001
Within	130	6168	47.44		
Total	141	17290			

ANOVA summary table of Mean Water table.

SOURCE	DF	SS	MS	F	P
Between	11	16900	1536	20.56	0.00001
Within	130	9789	74.72		
Total	141	26680			

DF (degrees of freedom), SS (sums of squares), MS (mean square), F (variance ratio) and P (probability).

Fig. 5. 16 ANOVA summary tables for the annual minimum, maximum and mean water table depths of the bog communities.

9A

The same statistical differences are seen between the communities and variants, in an examination of the minimum and mean water table, as in those outlined above for the maximum water table heights, with one exception where the minimum water tables of the hollow group do not differ significantly from those of the flat communities. This suggests that it is the higher water table levels that the hollow communities experience which results in the difference between the species composition of hollows and flats.

5.2.2 SPECIFIC CONDUCTIVITY AND pH OF PEAT WATERS.

Ombrotrophic peat waters are characterised by low pH values (pH < 4.5) (Moore and Bellamy, 1974; Gorham et al., 1983) and also have low values of electrical conductivity. This is because the raised bog system derives its mineral supply from precipitation, which is usually acidic and low in nutrients (see Section 5.1): The electrical conductivity (EC) and pH of the interstitial water within each plot were measured monthly. The EC was corrected for the concentration of the H^+ ion to give specific conductance (K_{corr} ($\mu S\ cm^{-1}$)) (See Chapter 4). This is a measure of the overall ionic status of the water, excluding the H^+, ion and gives a useful indication of the chemical character of the water. pH measures the acidity or alkalinity of a water sample and is an important hydrochemical character to measure, particularly in ombrotrophic peat waters where small changes in pH may cause notable differences in the plant communities that occur.

Average mean, minimum and maximum (± 2S.E.) values of pH and K_{corr} are shown for each community in Table 5.5.

The average mean, maximum and minimum values of K_{corr} (± 2 S.E.) are shown for each community type in Fig 5.17. Unlike the water table depth measurements, this information does not immediately show any obvious differences between the various communities of the high bog.

Statistical analyses were carried out on the data. One-way analysis of variance of mean, maximum and minimum values detected a significant difference between the communities. Summary tables are shown in Fig. 5.18.

t-test analysis, to test which communities were statistically different, showed that there was no significant difference between the mean, maximum or minimum values for the lawn, hummock and pool groups. No significant difference was detected within the pool group. However there was a statistically significant difference between the two hollow communities ($P < 0.01$), the *Rhynchospora alba* and *Zygnemalis* (1) hollows having statistically significantly higher K_{corr} values than those measured in the typical variant of the community of *Narthecium ossifragum*, *Sphagnum magellanicum* and *S. tenellum*, (3A) hollows. The mean, maximum and minimum values from the face-bank variant (4G) were not significantly different to pools, lawns or the *Rhynchospora alba* and *Zygnemalis* hollows (1) but were significantly different to those of the *Narthecium* hollows (3A). The maximum face-bank values were not significantly different to the disturbed variants 4B and 3D but were different to the undisturbed hummock communities, the face-bank and burnt/disturbed communities having higher values of K_{corr} than the unburnt/disturbed hummock communities.

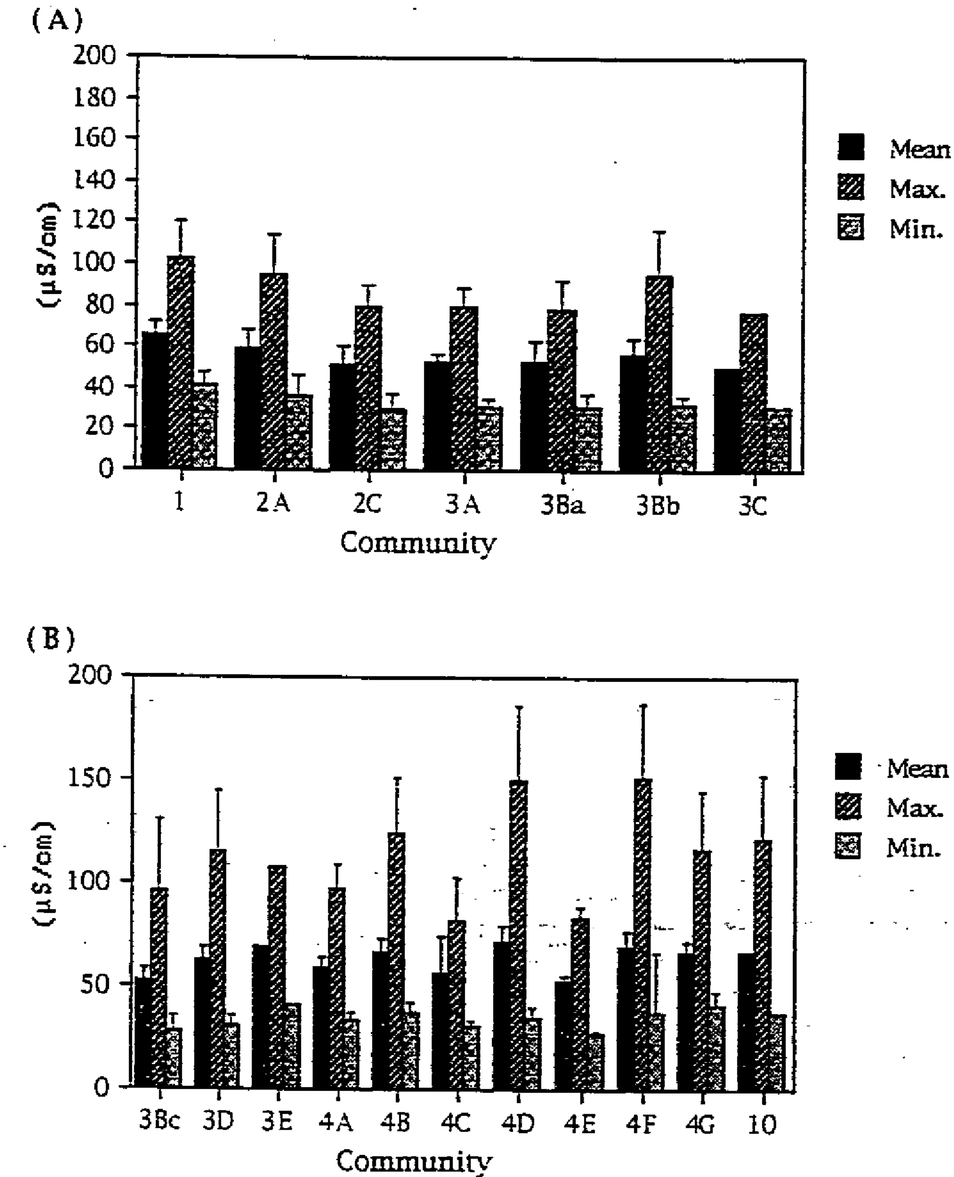


Fig. 5.17 Average annual mean, maximum and minimum K_{corr} (± 2 S.E) for the pool, hollow and lawn communities (A) and the flat and hummock communities (B).

The disturbed community variants experience higher conductivity values in common with the face-bank community type. This suggests that mineralisation of the peat in these areas is higher and that more ions are available in the peat water. No statistical differences were detected in water table heights between the burnt/disturbed and non-burnt/disturbed hummock types, so the differences that do occur cannot be due to differences in peat mineralisation rates caused by differences in water table height, but must be due to the effects of disturbance (drainage) and/or fire causing release of ions.

96

ANOVA summary table of mean K_{corr}.

SOURCE	DF	SS	MS	F	P
Between	11	5716	519.6	3.67	0.0002
Within	130	18270	141.6		
Total	141	23980			

ANOVA summary table of minimum K_{corr}.

SOURCE	DF	SS	MS	F	P
Between	11	2282	207.5	2.01	0.0327
Within	130	13340	103.4		
Total	141	15630			

ANOVA summary table of maximum K_{corr}.

SOURCE	DF	SS	MS	F	P
Between	11	103700	9430	4.59	0.00001
Within	130	265200	2056		
Total	141	369000			

DF (degrees of freedom), SS (sums of squares), MS (mean square), F (variance ratio) and P (probability).

Fig. 5. 18 ANOVA summary tables for the annual mean, maximum and minimum K_{corr} values of the bog communities.

The higher maximum conductivity values experienced by pool communities in comparison to the unburnt/disturbed hummocks may be related to the fact that the hummock forming *Sphagnum* species have higher cation exchange capacities than those *Sphagnum* species of more aquatic communities (Clymo and Hayward, 1982). This means that the K_{corr} levels will be low in the water of hummock communities, as the cation exchange sites will bind the available cations, which contribute to the EC and the release H^+ ions into the water column. As K_{corr} is a measure of ionic concentration minus the concentration of the H^+ ion: the balance of increased H^+ in the water is not recorded. Thus K_{corr} levels will be lower in hummocks than in pool communities, where the cation exchange capacity of the aquatic *Sphagnum* species is lower. Flushing of these excess ions may occur during periods of high rainfall and thus the K_{corr} of hummock waters may be high during the winter months (Fig. 5.19). High ionic concentrations may also occur in pools due to concentration caused by high evaporation during drier periods. The K_{corr} levels in hummock communities fluctuate more than in pool communities.

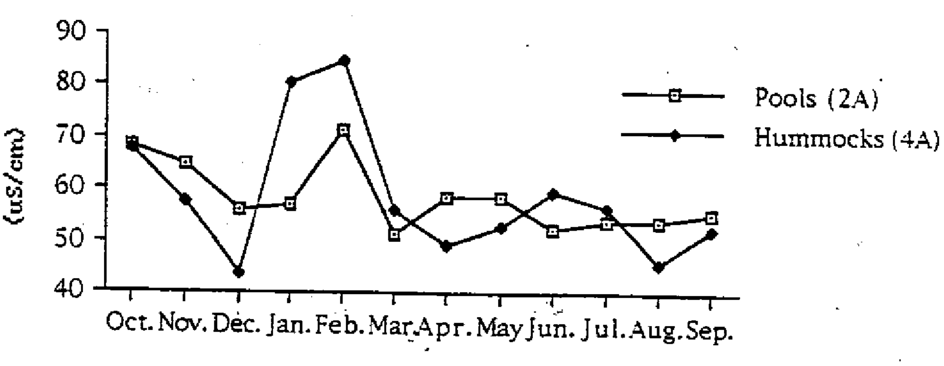


Fig.5.19 K_{corr} values over the year in the typical pool and hummock communities.

97

The average mean, maximum and minimum pH values for each community are illustrated in Fig. 5.20.

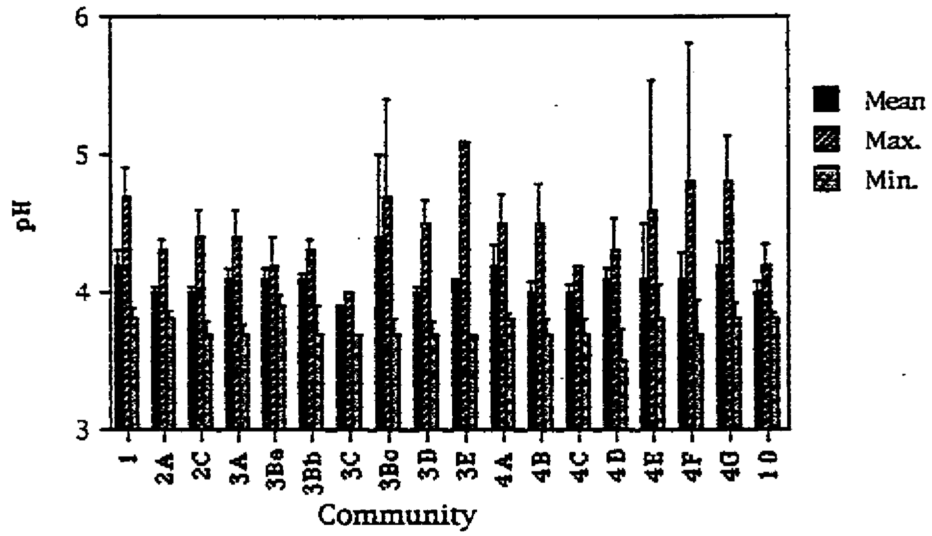


Fig. 5. 20 Average annual mean, maximum and minimum pH (± 2 S.E) for the pool, hollow, lawn, flat and hummock communities.

The differences in pH values between the various communities appear to be slight. Analysis of variance of the mean, maximum and minimum pH values of the bog vegetation showed no statistical significant difference between any of the communities (P> 0.05 in all cases). Although the pH of raised bog communities would be expected to vary only within a small range, some detectable variation between the different communities was anticipated. Nevertheless, these findings are in agreement with those of Doyle (1990), who found, in her study of decomposition, that pH values differed little between hollows, pools and hummocks. The explanation, outlined above, for the higher K_{corr} levels seen in pools should result in lower pH values in hummock communities, but perhaps the pH change is not sufficiently large to be detected. It may also suggest that the second explanation, of concentration of ions due to evaporation, is more plausible.

5.3. BOG HYDROCHEMISTRY

In addition to measuring pH and K_{corr} (KC) of water samples from the various communities, more detailed hydrochemical analyses were carried out at selected sites. Sampling took place every second month over a two year period (for details see Chapter 4). The concentrations of the following ions were measured: Na^+ and Cl^-, as they are indicators of the level of ombrotrophy of the system; HCO_3^- and Ca^{2+}, as they can indicate the amount of ground water influence (Fe and Mn may also be used); N and P (total phosphate (TP) and orthophosphate (OP)), as they can indicate rates of mineralisation; SO_4^- as an indicator of marine influence or atmospheric pollution; K^+ as it may be limiting to plant growth and supply from precipitation is low. Water table height (WT) and water table fluctuation (WTFL) were also included in the analysis.

These analyses showed that that the high bog communities are indeed ombrotrophic and receive their ionic inputs only from rain. The hydrochemistry of a typical raised bog sample is shown in Fig. 5.21. If this is compared to Fig. 5.5 above, which illustrates the % ionic content of precipitation at both Clara and Raheenmore, the similarity to rainfall chemistry is apparent. The concentration of Cl and Na are higher in the bog sample than in precipitation. This is due to the preferential absorption of other ions from solution by the vegetation and to the cation exchange sites on peat particles.

98

Typical High Bog Water Chemistry

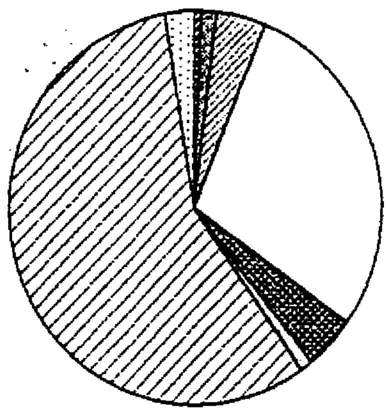


Fig. 5.21 Hydrochemistry of a typical high bog sample.

5.4. CANONICAL CORRESPONDENCE ANALYSIS.

The data from the hydrological and hydrochemical investigations carried out over the two year period for the high bog sites were used in the program CANOCO to perform canonical correspondence analyses. This program detects species - environment relationships and thus community - environment relationships. Two batches were run; one using the mean data from the period October 1990 - September 1991; the other using the mean values of the data from October 1991 - September 1992. The variables used included water table measurement and the hydrochemical data of selected high bog communities (not all communities are represented, as not all were included in the more detailed hydrochemical investigations).

No passive analysis of variables was required in the CCA of the 1990-1991 data, as the variance inflation factors given in the out put were all below 20. The eigenvalues for the axes were 0.604, 0.460, 0.346 and 0.251. The correlation matrix from the CCA output showed that the following variables were strongly correlated: K_{corr} with Na, Cl, Ca, Mg and SO4: water table was negatively related to water table fluctuation.

For the ordination of the 1991-1992 data the variable of water table was analysed passively as it was negatively correlated with NH_4. Both these variables had high inflation factors in the first CCA, which had no passive variables. The eigenvalues for the axes in this plot were 0.629, 0.578, 0.541 and 0.474. The variables Ca, Fe and Mn are correlated with each other as are Cl, Na and Mg. pH and alkalinity are also correlated.

A Monte-Carlo test was carried out on each of these ordinations, and in both cases gave an overall highly statistically significant result ($P < 0.01$).

The two ordination plots are shown in Fig. 5.22 (1990-1991) and in Fig. 5.23 (1991-1992). The most significant difference between the plots from the two different years is the position of the community of typical pools (2A). In the drier year of 1990-1991, they plot out close to the hollow communities, whereas in a wetter year (1991-1992) they plot out on their own, related strongly to the vector of water table and higher levels of Na and Cl, indicating a larger rainwater input. This would suggest that, although no significant differences were detected between the individual environmental variable data collected from the different years, a dry year affects the hydrochemistry of the pool communities more than any other community type, when the sum of environmental variables are analysed. This indicates that this community type may be the most sensitive to hydrological change (Chapter 8 and associated maps show how restricted this community type is). The marginal communities 3A, 3D and 1 plot out close together in both years. The hollow community 3A does not occupy quite as an extreme position in the wetter year as it does in the drier year. The face-bank community (4G) plots out strongly related to the vector of water table fluctuation (WTFL). This suggests increased mineralisation may occur and indeed the vectors of higher total phosphate (TP) and NH_4 plot in the same direction. The typical variant of the hummock communities (4A) is a very variable type, with a spread across the ordination. This is because it is a very diverse community type with great variability in hummock height and species composition. The burnt/disturbed hummock community (4B) occupies an intermediate situation on both plots and is not strongly related to any particular environmental vector.

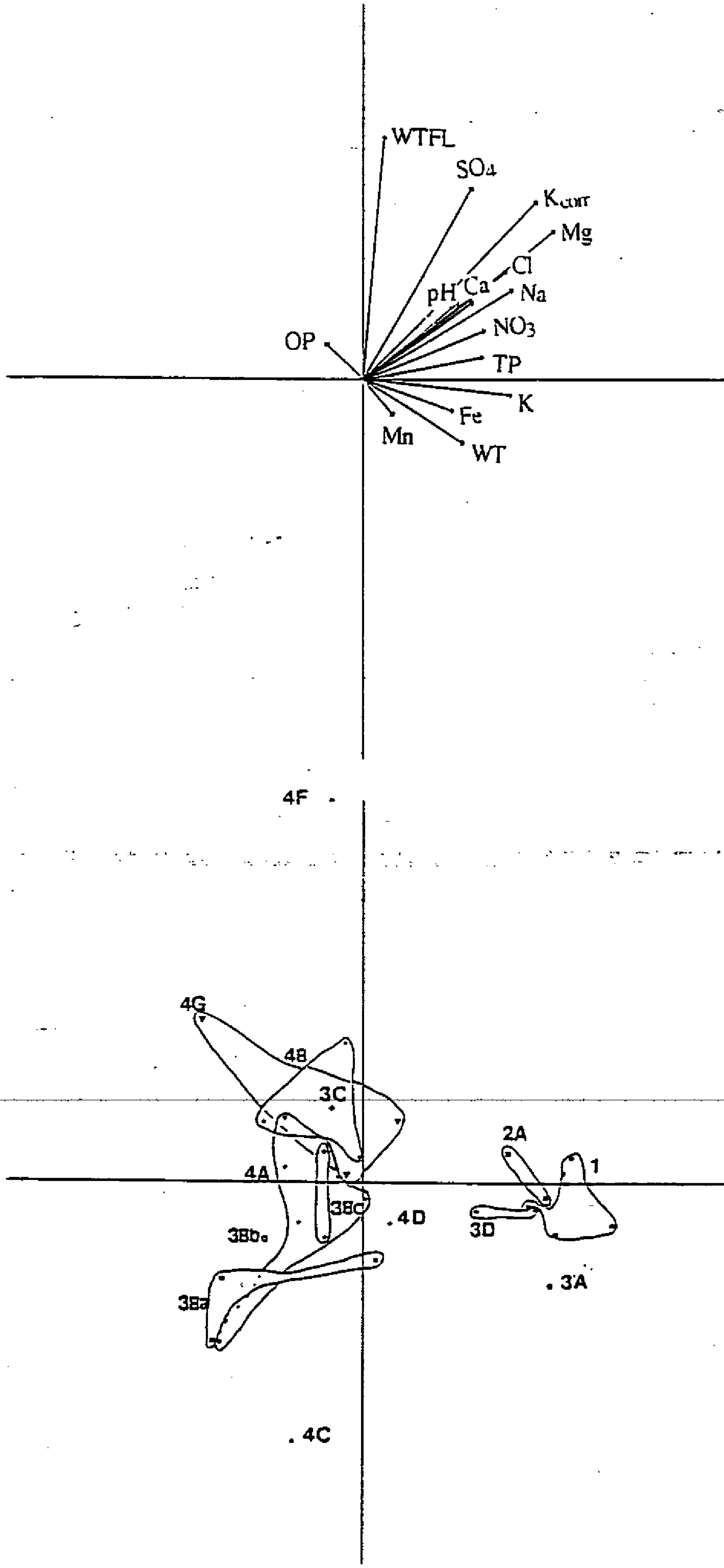


Fig. 5.22 – Ordination plots of the bog sites obtained from CCA of the average values of the environmental data from 1990-1991.

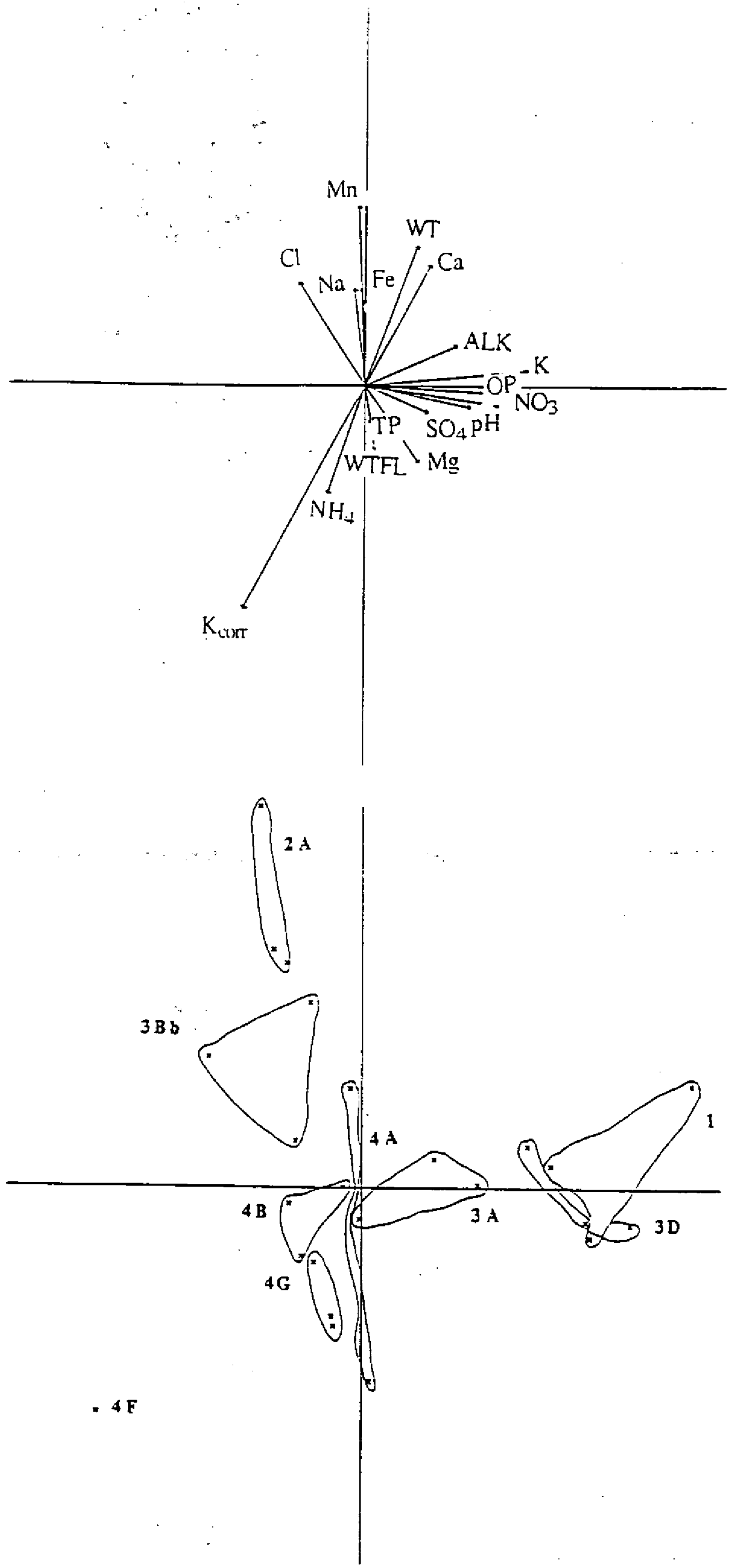


Fig. 5.23 Ordination plots of the bog sites obtained from CCA of the average values of the environmental data from 1991-1992.

The main conclusion which may be drawn from this investigation into the hydrology and hydrochemistry of raised bog communities are:

1. that water table level is by far the most important factor controlling the distribution of plant communities on the bog expanse.
2. that the pH of the high bog communities shows little variation.
3. that intra-community variability in some community types masks inter-community differences, despite samples for hydrochemical analyses being collected within small sample plots.

5.5. BOG AND MARGINAL (LAGG) HYDROCHEMISTRY AND HYDROLOGY.

Canonical Correspondence analysis was carried out on the data derived from the water table measurements and hydrochemical samples from all sites collected between 1990 and 1992. These included samples from two very different areas of the bogs; namely those discussed above, the bog sites and those, which will be discussed more fully in the following chapter, the marginal communities.

Two Canonical Correspondence analyses were carried out: one on the data from 1990-1991 and the other on the 1991-1992 data. The eigenvalues for the ordination axes for the first of these were 0.908, 0.700, 0.608 and 0.516. The first axis being the most important in separating the sites, as it has the highest eigen value. The pH and K_{corr} values were excluded from the initial analysis, as they were collinear with Ca and were later added to the ordination plot by passive analysis.

Statistical analyses using the Monte-Carlo permutation test showed that the first ordination axis was not statistically significantly in its relation to species composition ($P > 0.05$). However the Monte-Carlo permutation test quite often shows no significance when there is a high level of collinearity among variables (the case here) or where the number of samples is low in relation to the number of environmental variables. The overall statistical test on the effect of the environmental variables on the species gave a highly significant result ($P < 0.01$).

The ordination plot of the second year's data follows a similar pattern with eigenvalues of 0.958, 0.590, 0.541 and 0.490 for the axes. The pH, alkalinity and K_{corr} values were excluded from the initial analysis as they were collinear with Ca and were added later to the ordination plot by passive analysis. The Monte-Carlo permutation test also showed a similar result with the overall test showing a significant difference ($P < 0.01$) while the first ordination axis was not significant. This was presumably due to the reason cited above.

The ordination plots of these two analyses are shown in Fig. 5.24 and Fig. 5.25. These four ordination plots of sites and environmental variables highlight the difference between the hydrology and hydrochemistry of the high bog communities and the marginal communities of the two bogs. The main difference is that the high bog hydrochemistry is characterised by low pH, Kcorr, alkalinity and calcium and high levels of Na and Cl, while the marginal communities have the opposite characteristics, with high pH, K_{corr} and Ca levels.

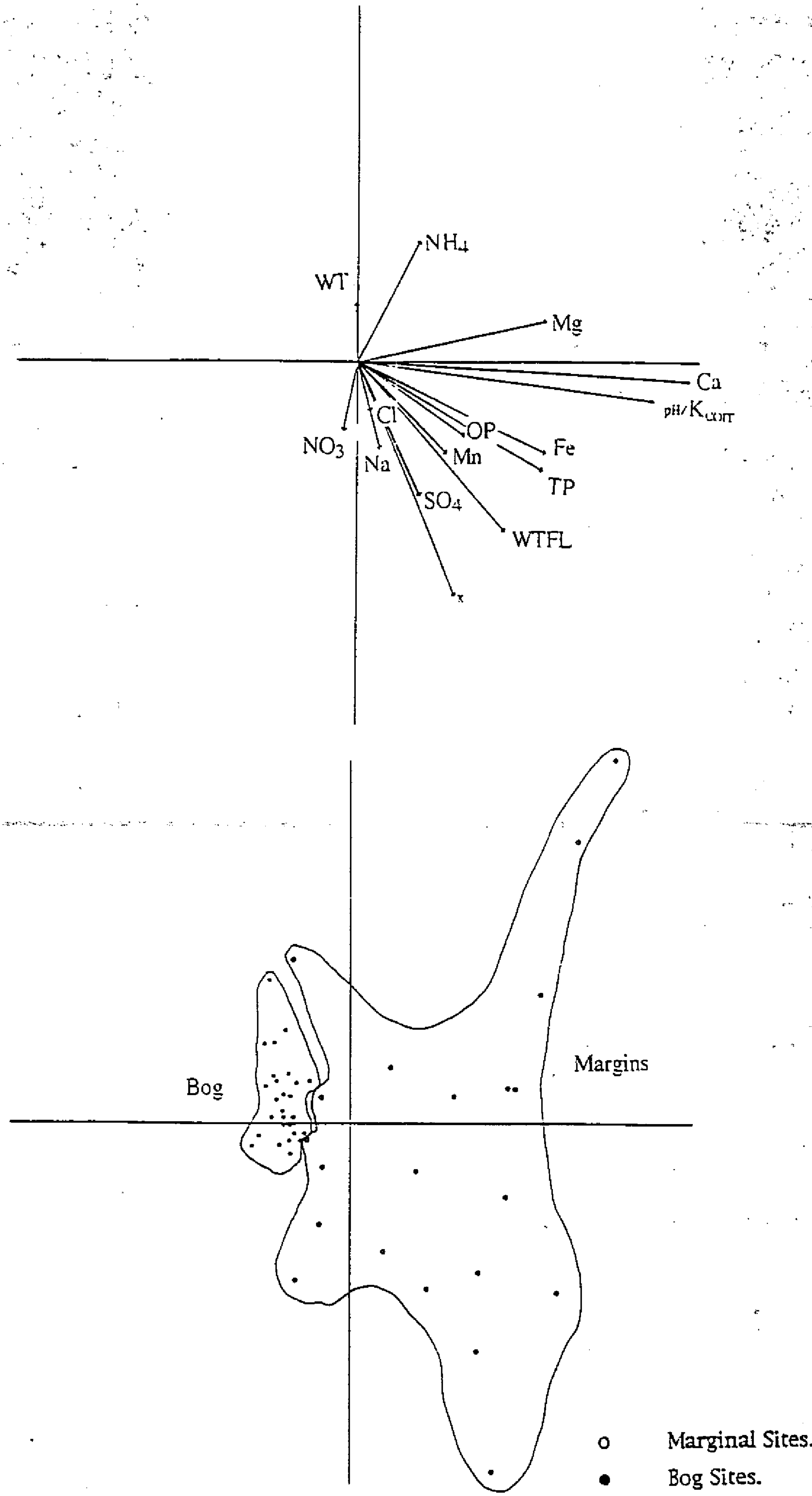


Fig. 5.24 Ordination plots of the bog and marginal sites obtained from CCA of the average values of the environmental data from 1990-1991.

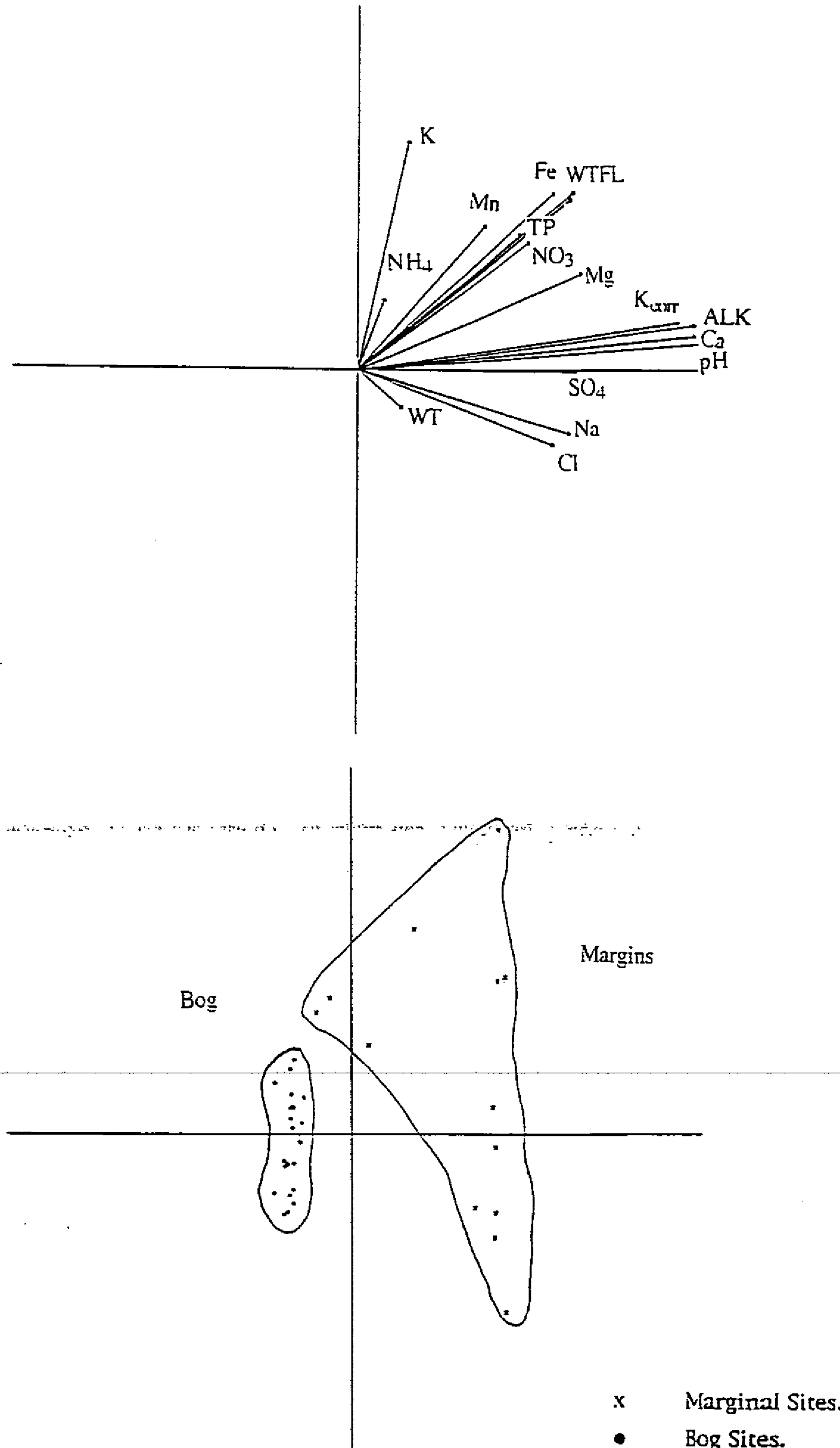


Fig. 5.25 Ordination plots of the bog and marginal sites obtained from CCA of the average values of the environmental data from 1991-1992.

CHAPTER 6: MARGINAL (LAGG) AND CUT-AWAY HYDROLOGY AND HYDROCHEMISTRY.

6.1 INTRODUCTION

The dome of an intact raised bog is usually surrounded by an area of mesotrophic (poor) fen, which is situated between the bog and the mineral soil. It forms part of the marginal drainage system and may include a stream. This area is termed the lagg and receives a mixed water supply; it is supplied both by ground water from the surrounding mineral soil and by surface runoff from the high bog (Fig. 6.1). The chemistry of the latter is usually close to that of rain water, while the former is more mineral rich. This mixing of water can create conditions suitable for the development of poor fen vegetation (Streefkerk and Casparie, 1989; Cross, 1990). Due to exploitation, most Irish raised bogs have today few or no lagg communities remaining at their margins. This vegetation type however was a feature of midland raised bogs in the past. Lagg vegetation was recorded around bogs close to Edenderry, Co. Offaly by Osvald (1949). The extent of lagg vegetation seen by Osvald depended on the local conditions, that is on the hydrology and hydrochemistry.

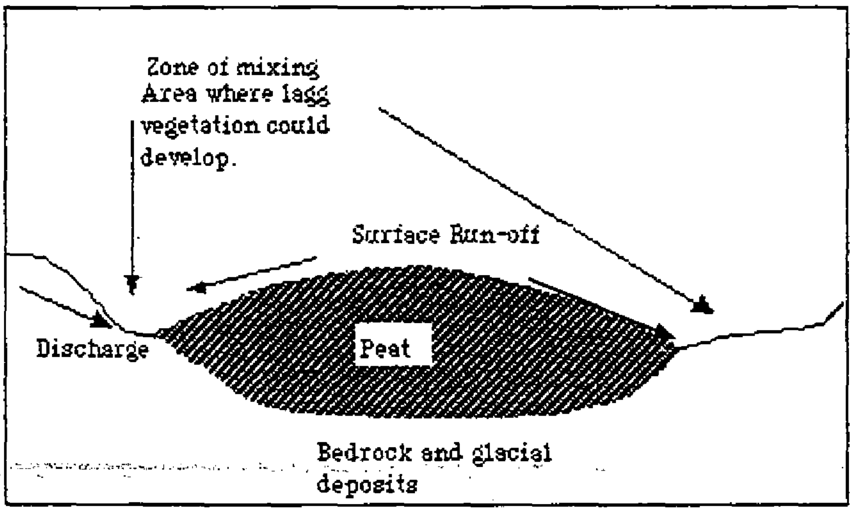


Fig. 6.1 Schematic diagram illustrating the area where lagg vegetation can develop on the margins of a raised bog.

Small relict areas of poor fen or lagg vegetation were identified at both Clara and Raheenmore (See Chapter 8 and associated maps). The hydrology and hydrochemistry of these areas were investigated to discover which environmental conditions were related to these vegetation types. It was intended that this information should be used to extend existing areas of poor fen or to attempt re-creation of lagg vegetation types. The existence of poor fen vegetation at these sites greatly enhances community diversity. As no raised bogs with an intact lagg vegetation remain in Ireland, it would be of significant importance to conservation to discover if re-creation is possible. Most importantly it is necessary to be able to conserve the few small areas that still remain.

Both bogs have undergone exploitation in the past and Clara is still suffering from extensive marginal peat cutting. This has resulted in large areas of cut-away peat at the margins of each site. When these areas are abandoned, vegetation invades but the community types that develop depend on local hydrology and hydrochemistry. Old areas of cut-away which do not completely dry out can regenerate to a certain extent, with the re-growth of *Sphagnum* species. In the wetter areas where water collects, small pools or pits form, which can support pool like plant communities. Their species composition often indicates some mineral enrichment, with the occurrence of species such as *Potentilla palustris, Hydrocotyle vulgaris* and *Carex diandra*. Old turf banks and other desiccated peat areas usually support vegetation of drier situations, with species like *Calluna vulgaris, Ulex europaeus* and *Pteridium aquilinum* commonly seen. Intermediate areas are often colonised and dominated by *Molinia caerulea*.

Vegetation work had already been carried out on marginal areas of Clara and Raheenmore by Van Dijk and Young (1984). This included a survey of lagg vegetation types with some preliminary linking to environmental parameters. However very few environmental measurements were made as the time available for their work was limited. Some mapping and ecological interpretation of marginal areas on Irish raised bogs were also undertaken by Overman et al. (1989). Their vegetation survey included an appraisal of the marginal vegetation of Clara and Raheenmore. Although their mapping work was detailed, only cut-away peat areas were included and thus no poor fen communities were identified.

Sixteen community types are examined in this chapter. These types are:

3G. The community of *Narthecium ossifragum*, *Sphagnum magellanicum and Sphagnum tenellum*, the variant with *Molinia caerulea* and *Potentilla erecta*.
4H. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, phase of *Pleurozium schreberi*.
4I. The community of *Calluna vulgaris*, *Sphagnum capillifolium* and *Cladonia portentosa*, variant with *Molinia caerulea* and *Potentilla erecta*.
9B. The community of *Sphagnum recurvum* and *Polytrichum alpestre*, variant with *Carex rostrata*.
14C. The community of *Molinia caerulea* and *Potentilla erecta*, typical variant.
14D. The community of *Molinia caerulea* and *Potentilla erecta*, variant with *Juncus effusus*.
15B. The community of *Calliergon cuspidatum* and *Equisetum fluviatile*, typical variant.
15C. The community of *Calliergon cuspidatum* and *Equisetum fluviatile*, variant with *Valeriana officinalis*.
15D. The community of *Calliergon cuspidatum* and *Equisetum fluviatile*, variant with *Carex disticha*.
16A. The community of *Filipendula ulmaria* and *Festuca ovina*, variant with *Rhytidiadelphus squarrosus*.
16B. The community of *Filipendula ulmaria* and *Festuca ovina*, variant with *Carex disticha*.
17. The community of *Ulex europaeus* and *Molinia caerulea*.
20. The community of *Salix aurita* subsp. *oleifolia* and *Dryopteris carthusiana*.
21. The community of *Pteridium aquilinum* and *Molinia caerulea*.
22. The community of *Carex acuta* and *Carex hirta*.
23. The community of *Ranunculus repens* and *Carex hirta*.

6.2. HYDROLOGY

Water table levels were measured monthly within the marginal vegetation plots for at least one year and in a selected number of plots for two years. The average mean, maximum and minimum values (± 2 S.E.) for each community type are shown in Table 6.1. This information is illustrated in Fig.6.2. All marginal and cut-way communities have their mean and minimum water table height below surface level but in some communities the maximum water table is over ground level. The most noticeable water table difference between these sites and those of the high bog sites is the large fluctuations in height that can occur.

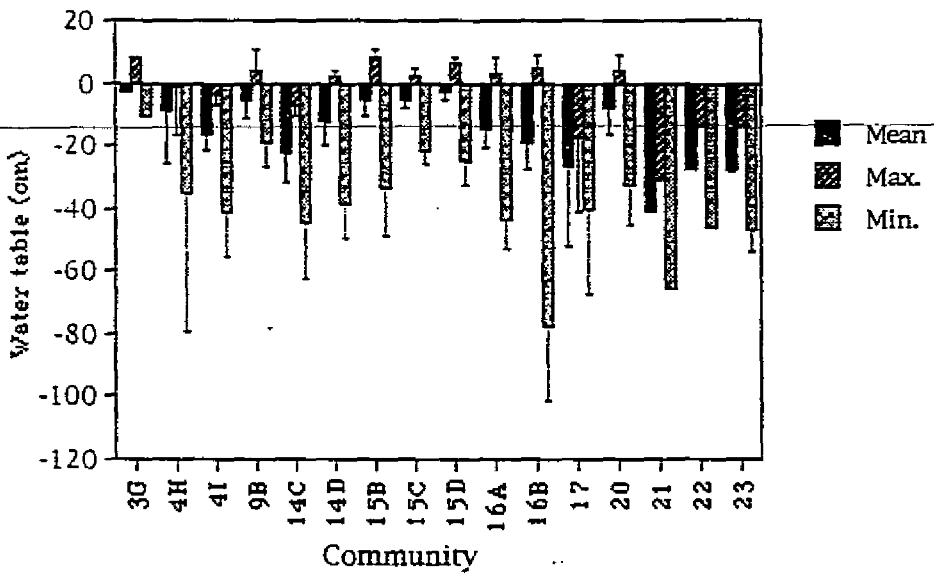


Fig. 6.2 Annual mean, maximum and minimum water table heights (cm) in the marginal and cut-away communities.

106

Table 6.1 *Summary of hydrological and some hydrochemical characteristics of the cut-away and marginal plant communities. The annual average, mean, maximum and minimum values (± 2 S.E.) are shown for water table depth (cm), pH and K_{corr} (μScm^{-1}).*

	Water Table			pH			K_{corr}		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
3G	-2.6	6.0	-11.0	5.7	5.9	4.3	108.1	139.1	82.1
4H	-8.6 (±17.0)	-1.2 (±14.6)	-35.2 (±43.6)	4.4 (±0.9)	4.7 (±1.0)	3.8 (±0.2)	52.5 (±15.4)	85.2 (±34.0)	27.0 (±12.2)
4I	-16.0 (±4.8)	-3.6 (±2.8)	-41.0 (±14.4)	4.3 (±0.2)	4.7 (±0.3)	3.9 (±0.1)	65.2 (±8.2)	113.5 (±35.6)	39.3 (±7.4)
9B	-4.8 (±6.4)	-4.1 (±7.2)	-18.5 (±8.2)	5.1 (±0.4)	6.0 (±0.7)	4.1 (±0.5)	74.2(±8.4)	95.7 (±16.2)	54.6 (±11.8)
14C	-22.1 (±9.4)	-6.4 (±3.8)	-44.3 (±17.8)	4.2 (±0.2)	5.0 (±0.6)	3.9 (±0.1)	55.5 (±12.2)	86.7 (±21.0)	33.2 (±10.8)
14D	-11.9 (±7.4)	2.6 (±1.4)	-38.5 (±10.6)	6.4 (±0.2)	6.9 (±0.2)	4.6 (±0.2)	151.7 (±8.0)	196.2 (±20.8)	95.9 (±31.2)
15B	5.2 (±5.0)	8.6 (±2.6)	-32.8 (±15.6)	6.9 (±0.2)	7.2 (±0.2)	6.3 (±0.2)	294.3 (±132.6)	399.9 (±179.4)	216.8 (±109.2
15C	-4.8 (±2.6)	2.4 (±2.6)	-21.6 (±4.2)	6.4 (±0.2)	6.8 (±0.2)	5.5 (±0.2)	112.4 (±17.0)	144.5 (±26.8)	85.3 (±12.8)
15D	-2.5 (±2.8)	7.2 (±1.6)	-24.9 (±7.6)	6.7 (±0.3)	7.1 (±0.3)	6.0 (±0.3)	219.3 (±16.8)	264.9 (±28.0)	176.2 (±13.8)
16A	-14.2 (±5.8)	3.2 (±5.0)	-42.9 (±9.4)	6.5 (±0.2)	6.9 (±0.3)	5.5 (±0.3)	149.6 (±32.2)	253.8 (±72.2)	87.8 (±28.0)
16B	-18.8 (±8.6)	-4.7 (±4.6)	-77.0 (±23.6)	6.9 (±0.2)	7.3 (±0.3)	5.9 (±0.2)	334.2 (±86.8)	493.6 (±115.6)	239.7 (±83.0)
17	-26.4 (±25.6)	-16.8 (±24.2)	-40.1 (±27.2)	4.6 (±0.1)	5.8 (±0.3)	3.8 (±0.4)	84.8 (±16.2)	133.6 (±92.0)	64.5 (±2.0)
20	-7.8 (±8.4)	-4.2 (±5.4)	-32.2 (±12.8)	6.4 (±0.3)	6.8 (±0.4)	5.7 (±0.2)	156.3 (±10.0)	232.8 (±70.2)	117.6 (±11.4)
21	-40.9	-30.3	-65.4	5.2	5.9	3.9	85.6	102.4	65.9
22	-27.3	-13.4	-46.0	7.0	7.5	6.3	451.0	553.9	354.9
23	-27.0 (±1.0)	-13.6 (±0.2)	-46.7 (±6.4)	7.0 (±0.6)	7.5 (±0.3)	6.2 (±0.2)	360.3 (±59.3)	439.6 (±68.1)	251.8 (±81.1)

NOTE: Where no standard error is indicated the data are based on the observations from one sample of that community type.

Analyses of variance (ANOVA) of the mean, maximum and minimum values for the marginal sites were carried out. Only 10 community types were included in the analyses as there was a lack of sufficient replicate data for some types. This was owing to: the restriction in size of some communities; the reclamation of some marginal areas during the course of the fieldwork; the destruction of some phreatic pipes by cattle. Of the communities which could be included, the ANOVA of mean, maximum and minimum water table gave very significant statistical differences between communities, $P < 0.01$ in all cases (summary tables are shown in Fig. 6.3).

t-tests were carried out on the annual mean, minimum and maximum water table depths to determine which communities were statistically different from others. Communities 4I, 14C and 14D are the least species rich of the marginal (rather than the obvious cut-away types) communities and occupy the drier niche with maximum water table depths significantly lower than in the community groups 15 and 16 ($P < 0.05$). Statistically the average water table depths within the 15 group do not differ significantly. However maximum water table heights separate 15C ($P < 0.01$) from 15B and 15D ($P < 0.05$), which have higher maximum water table heights. There is no statistical difference between 15B and 15D. The mean water table depth is lower in the 16 group than in the 15 group ($P < 0.05$). Within the 16 group there is a difference in minimum water table height, 16B having a significantly lower minimum water table depth ($P < 0.05$).

ANOVA summary table of Mean Water table.

SOURCE	DF	SS	MS	F	P
Between	9	2374	263.8	2.87	0.0082
Within	51	4688	91.92		
Total	60	7062			

ANOVA summary table of Maximum Water table.

SOURCE	DF	SS	MS	F	P
Between	9	1305	145.0	3.7	0.0013
Within	51	1995	39.12		
Total	60	3300			

ANOVA summary table of Minimum Water table.

SOURCE	DF	SS	MS	F	P
Between	9	17490	1943	5.31	0.003
Within	51	29900	586.3		
Total	60	47390			

DF (degrees of freedom), SS (sums of squares), MS (mean square), F (variance ratio) and P (probability).

Fig. 6.3 Summary tables of the ANOVA of the mean, minimum and maximum water table heights in the marginal and cut-away communities.

An examination of the mean monthly water table depth over the year shows a number of community groupings. The communities 3G and 9B are wet sites with little water table fluctuation throughout the year, compared to the other marginal sites (Fig. 6.4). The plots included in the community types 4H and 20 have very variable water table depths. This may imply that water table depth is not an important factor in the distribution of these communities..

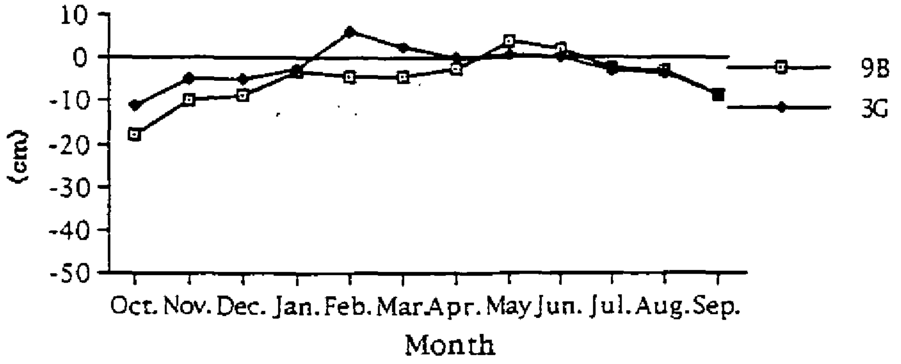


Fig. 6.4 Mean monthly water table depths of the wet cut- away communities.

4I and 14C have similar mean monthly water table depths throughout the year, those of 14C being just slightly lower. (Fig 6.5).

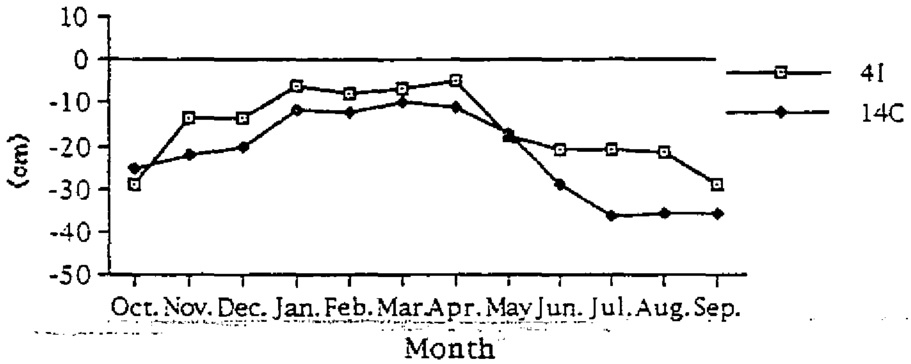


Fig. 6.5 Mean monthly water table depths in the dry cut-away communities.

The communities 17, 22 and 23 follow very similar trends throughout the year with relatively low water table depths at all times (Fig. 6.6).

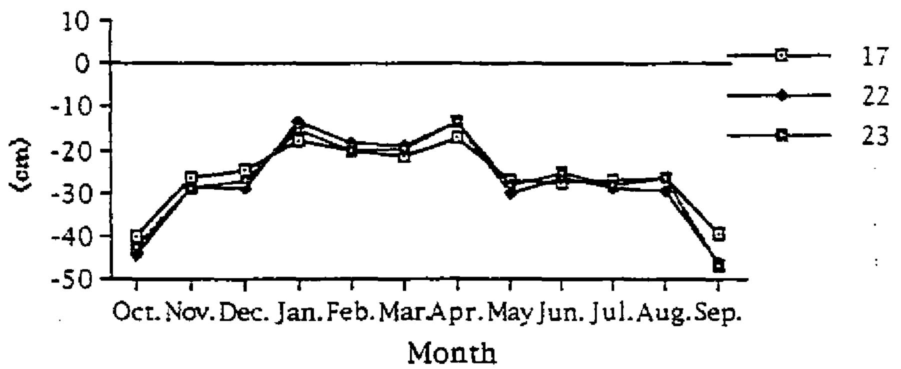


Fig. 6.6 Mean monthly water table depths in the drier cut- away communities.

The communities in group 15 follow similar patterns. 15B and 15D have greater water table fluctuations than 15 C. However 15C is a drier community type (Fig. 6.7).

109

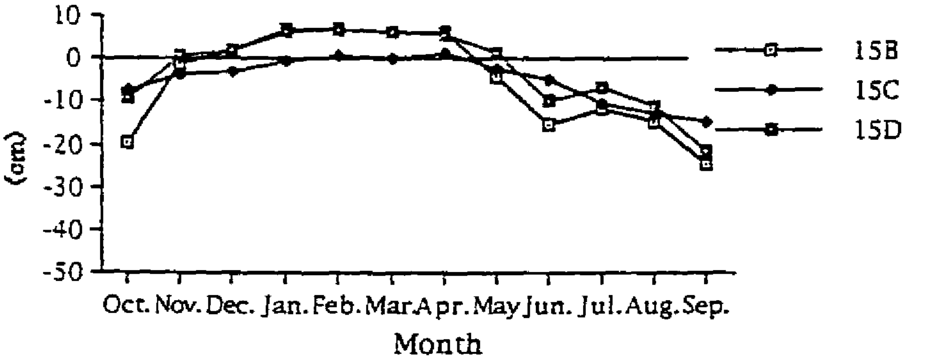


Fig. 6.7 Mean monthly water table depths in the group 15 communities.

The community types 16A and 16B follow similar patterns but variant 16B experiences much larger fluctuations in water table depth (Fig. 6.8). The difference between the two variants may also be illustrated in an examination of the duration lines for these two community types (Fig 6.9). These show that the water table in varaint 16B spends much longer below surface level and than it does in 16A. This suggests that more peat mineralisation could occur under the more aerobic conditions that the lower water table levels would provide.

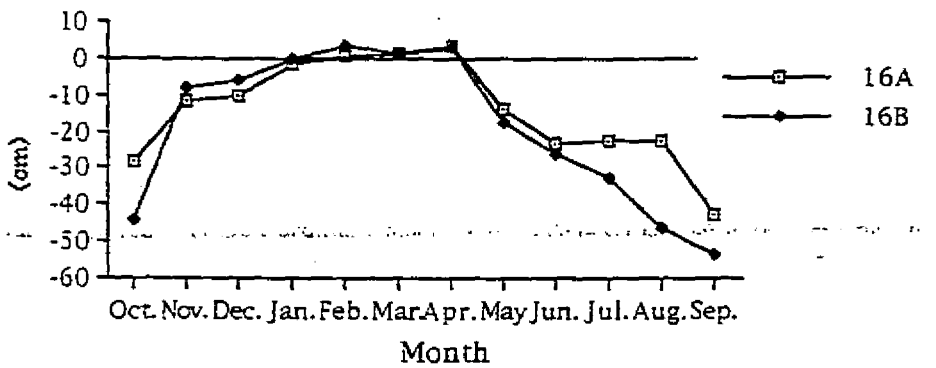


Fig. 6.8 Mean monthly water table depths in the group 16 communities.

6.3 K_{corr} and pH MEASUREMENTS.

K_{corr} and pH measurements of water samples were also made monthly within the same plots as water table measurements were taken. Average mean, maximum and minimum values are shown in Table 6.1. The K_{corr} values are illustrated in Fig. 6.10. Major differences in K_{corr} values between the different communities are apparent. ANOVA on the mean data from the 10 communities, which could be statistically analysed, showed a very highly significant difference ($P < 0.001$). t-tests, to statistically test which communities were different, showed that it was possible to divide the marginal and cut-away communities into three main groups. The first of these encompassing the communities with relatively low K_{corr} values, community types 3G, 4H, 4I, 9B, 14C, 17 and 21. The second group with intermediate K_{corr} values, differs statistically from the previous group ($P <0.01$, $P <0.001$) and encompasses the community types 15C, 14D, 16A and 20. The final group of communities with high K_{corr} values, differs statistically from the previous group ($P <0.05$) and includes the community types 15B, 15D, 16B, 22 and 23.

Prior to a more detailed hydrochemical investigation, these three groups indicate that there is a group of communities, of the cut-away, which are not influenced by ground water, a group which may be partly affected by up-welling ground water and finally a group which are almost certainly under the influence of ground water.

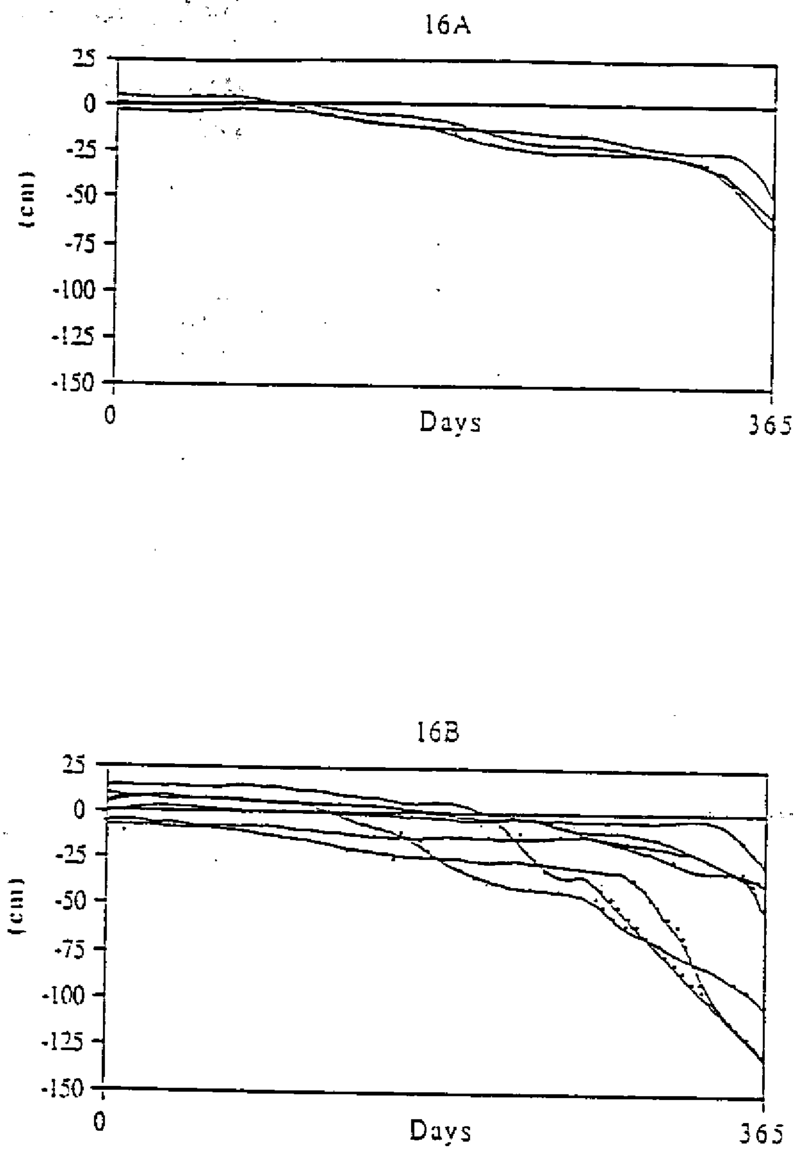


Fig. 6.9 Duration lines of community variants 16A and 16B.

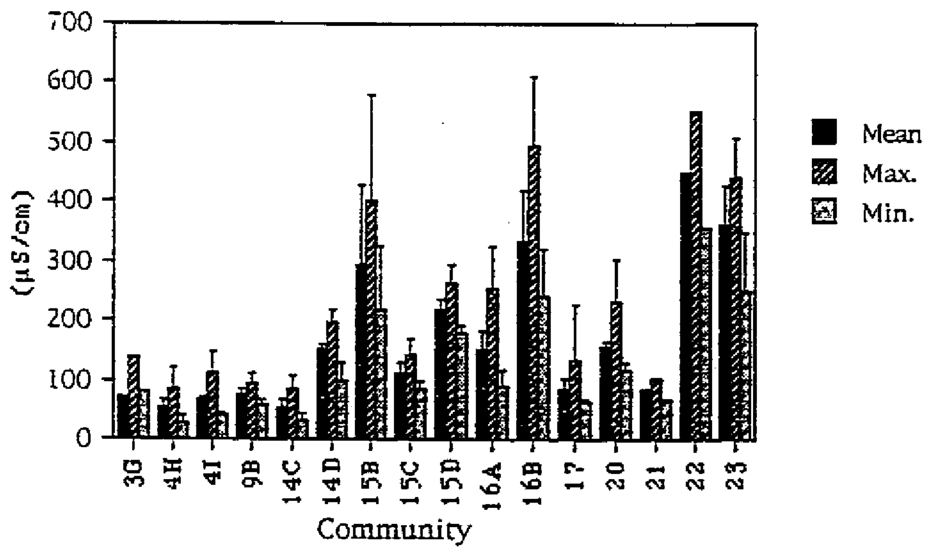


Fig. 6.10 Annual mean, maximum and minimum K_{corr} ($\mu S\ cm^{-1}$) ($\pm$ 2 S.E.) in the marginal and cut-away communities.

Average mean, maximum and minimum pH values for the marginal communities are shown in Fig. 6.11. In common with the K_{corr} data, ANOVA of the annual mean levels shows a very highly significant difference between the communities ($P < 0.001$). Here, t-tests divide the communities into four groups: the group of communities with very low pH values, akin to raised bog pH levels, communities 4H, 4I, 14C and 21; communities 9B and 3G with low pH values; communities 14D, 15C and 20 with intermediate pH values; and finally those with high pH levels, communities 15B, 15D, 16A, 16B, 22 and 23. High pH values indicate a ground water influence as the Ca^{2+} ion in ground water is an antagonist of the H^+ ion and thus helps to regulate soil acidity (Kemmers, 1986). Ground water in the region of Clara and Raheenmore bogs is rich in Ca as it has a long residence time in the mineral soil (limestone derived) thus becoming enriched with minerals. Hydrochemical analysis of samples from boreholes into the limestone bedrock at Clara and Raheenmore show concentrations of Calcium of approximately 140 mg l^{-1} (Flynn, 1993). In contrast waters which have recently infiltrated or short residence time have a similar chemistry to rainwater and thus have low pH values.

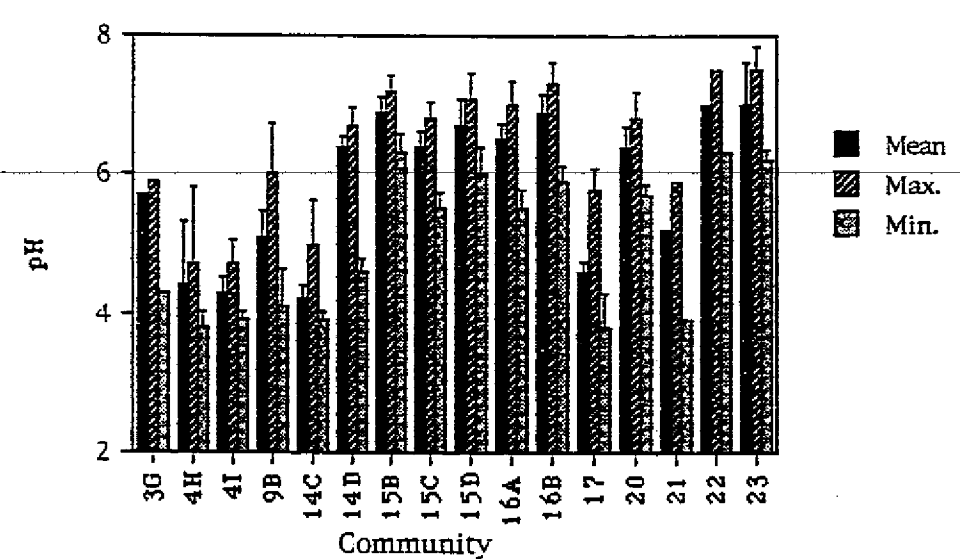


Fig. 6.11 Annual mean, maximum and minimum pH ($\pm$ 2 S.E.) in the marginal and cut-away communities.

112

6.4. HYDROCHEMISTRY AND CCA OF THE MARGINAL AND CUT-AWAY SITES.

More detailed hydrochemical analyses were carried out on a number of selected water samples. The chosen sites were sampled every second month for at least one year and in some instances for two years. Not all community types were incorporated in this analysis as it was not possible to sample all sites for detailed hydrochemistry, due to the restraints of time available for field work and laboratory analyses. These data were analysed using canonical correspondence analysis. The data from the two different years were analysed separately and no significant differences were detected between the different years. The 1990-1991 data are discussed, as a greater number of marginal communities were sampled during that period. The 1990-1991 ordination plots are shown in Fig. 6.12. The eigenvalues for the axes in this ordination were 0.860, 0.759, 0.734 and 0.666, indicating that the third ordination axis is almost as important as the second in separating the species data. The environmental parameters used in the analysis were water table (WT) water fluctuation (WTFL) pH, K_{corr} (KC), Na, K, NH_4, Ca, Mg, NO_3, Cl, SO_4, Total Phosphate (TP), Orthophosphate (OP), Fe and Mn. Alkalinity values were not included as some data were missing. However, the parameter of alkalinity is closely related to pH in all other CCA plots including the ordination plot of the second year's data. The most important variables separating these marginal communities are those related to pH, incorporating the variables pH, K_{corr} and Ca (and alkalinity). These are the indicators of ground water as mentioned above. The communities 22, 16A, 15B plot out to the high pH side of the ordination. Communities 16B, 15C, and 20 are also on the ground water side of the ordination but their position does not indicate such a strong ground water influence. The left side of the ordination shows a drier more ombrotrophic set of communities. Communities 17, 4I, 14C, 21 and 14D are related to water table fluctuation and higher levels of NO_3, suggesting peat mineralisation.

Recycling of P and N in marginal areas is quicker than in the raised bog communities, as conditions are more favourable for mineralisation (Malmer, 1986). The conditions for decomposition at the bog margins are more favourable due to greater aeration and lower acidity compared to the vegetation types on the mire expanse.

In summary three vegetation groups, with sub-sections, can be established from the communities examined during the investigation of the marginal communities at Clara and Raheenmore:

Cut-away communities

These are characterised by low Ca levels (Fig.6.13), low pH and low K_{corr}. They are very similar to high bog communities in relation to the pH and Ca (Fig. 6.14) content of their interstitial water.

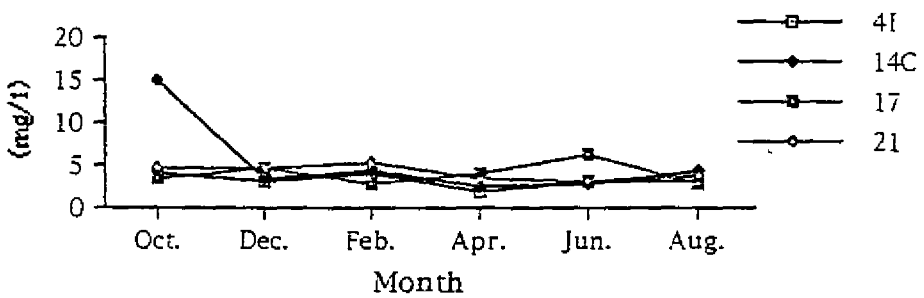


Fig.6.13 Ca concentration in water samples from within the cut-away communities.

113

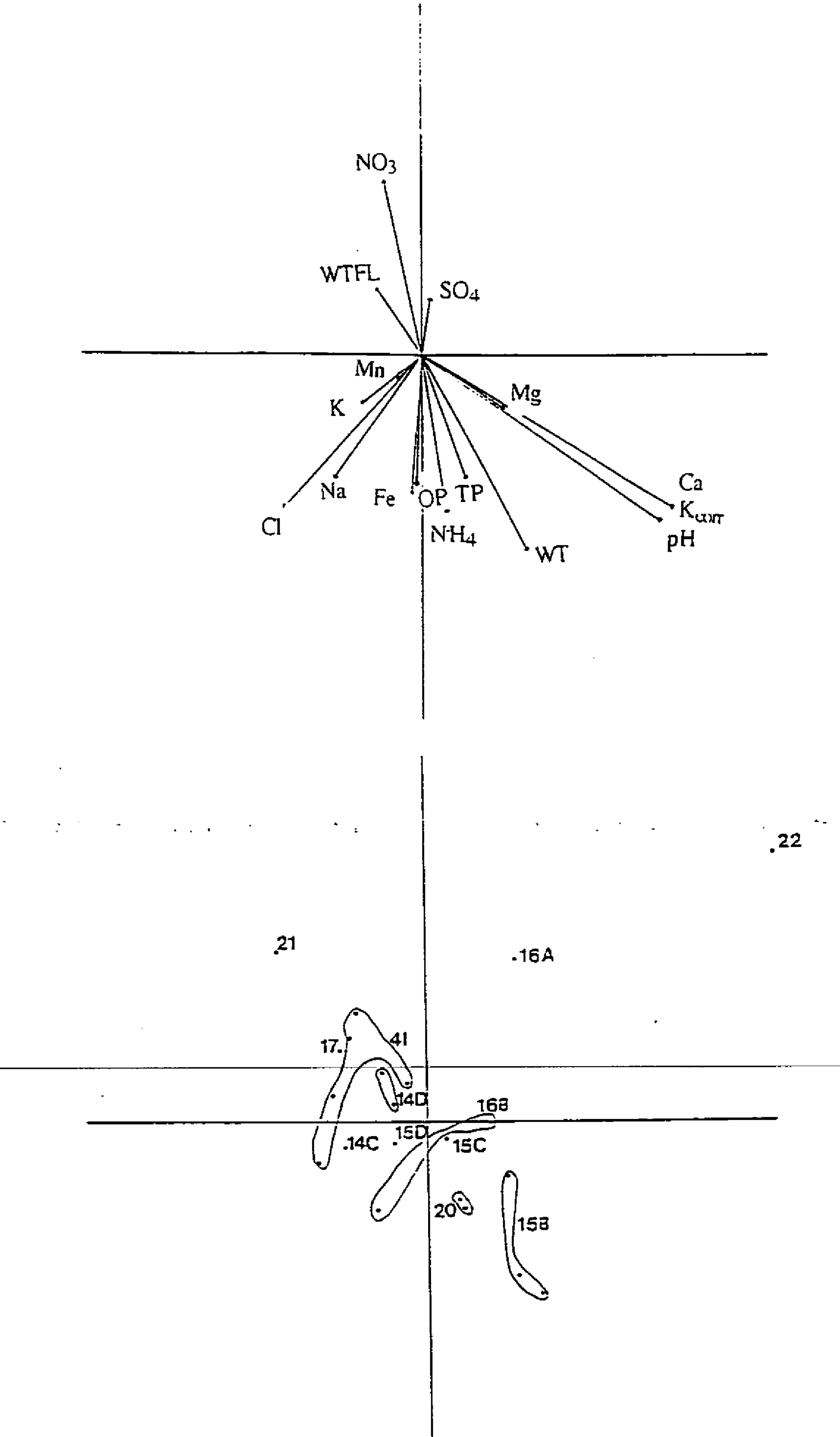


Fig. 6.12 Ordination plots of the marginal sites obtained from CCA of the average values of the 1990-1991 data.

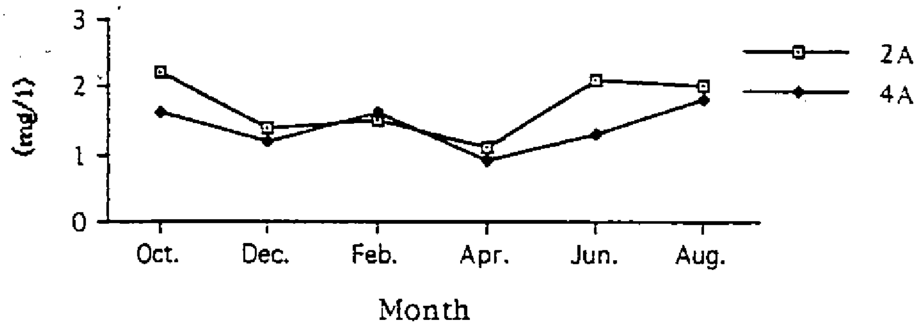


Fig.6.14 Ca concentration in water samples from within the two typical high bog communities.

a. Wet
3G and 9B: both communities are found in wetter areas of the cut-away. They are relatively species diverse in comparision to the typical high bog communities. Some mineral enrichment is suggested with elevated phosphate levels (annual average of 0.043 mg l^{-1}) compared to those levels recorded in samples from high bog communities (annual average of 0.016 mg l^{-1}). Although they have high water table levels, they fall below surface level for sufficient periods for peat mineralisation to occur.

b. Dry
4I, 4H, 14C, 17 and 21: all have indications of increased mineralisation, that is higher phosphate concentrations (annual average 0.057 mg l^{-1}). This would be expected as low water table levels ensure enhanced aeration and thus higher turnover of plant litter. No ground water influence is indicated.

Intermediate communities
These are characterised by relatively high pH, K_{corr} and Ca (Fig. 6.15) indicating some influence of ground water

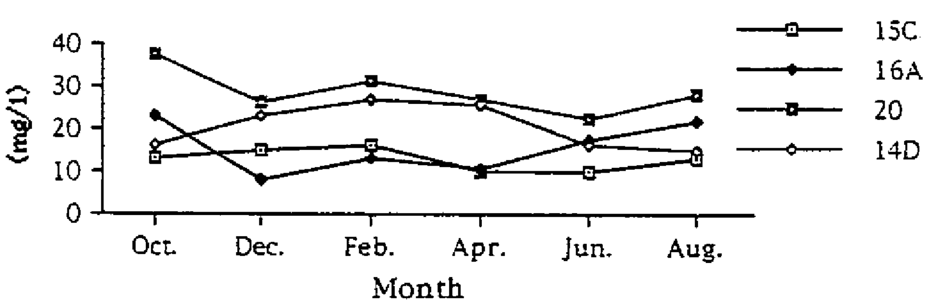


Fig.6.15 Ca concentration in water samples from within the intermediate marginal communities.

a. Wet
15C and 20: both communities are close to ombrotrophic conditions, that is the ions Na and Cl are important, but there is some indication of mineralisation or a low ground water input. This ground water influence may occur at certain times of the year although no significant seasonal differences could be established.

b. Dry
14D, 16A: water table levels are low in these two communities, some mineralisation is indicated with slightly elevated phosphate levels.

Lagg communities
15B, 15D, 16B, 22 and 23: these communities are all associated with high pH, elevated K_{corr}, Ca (Fig. 6.16) and Fe values. This indicates ground water influence. These are the communities which could form the core of lagg vegetation at both sites. They are still relatively dry due to drainage and if lagg sedge communities are to be established an increase in the height of the regional ground water level is required.

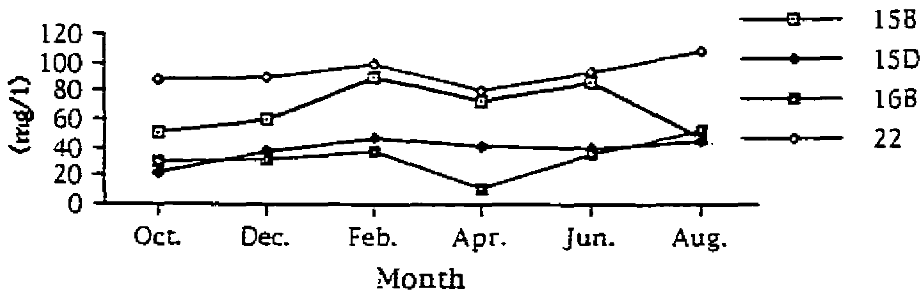


Fig.6.16 Ca concentration in water samples from within the 'lagg' communities.

6.5 CONCLUSIONS

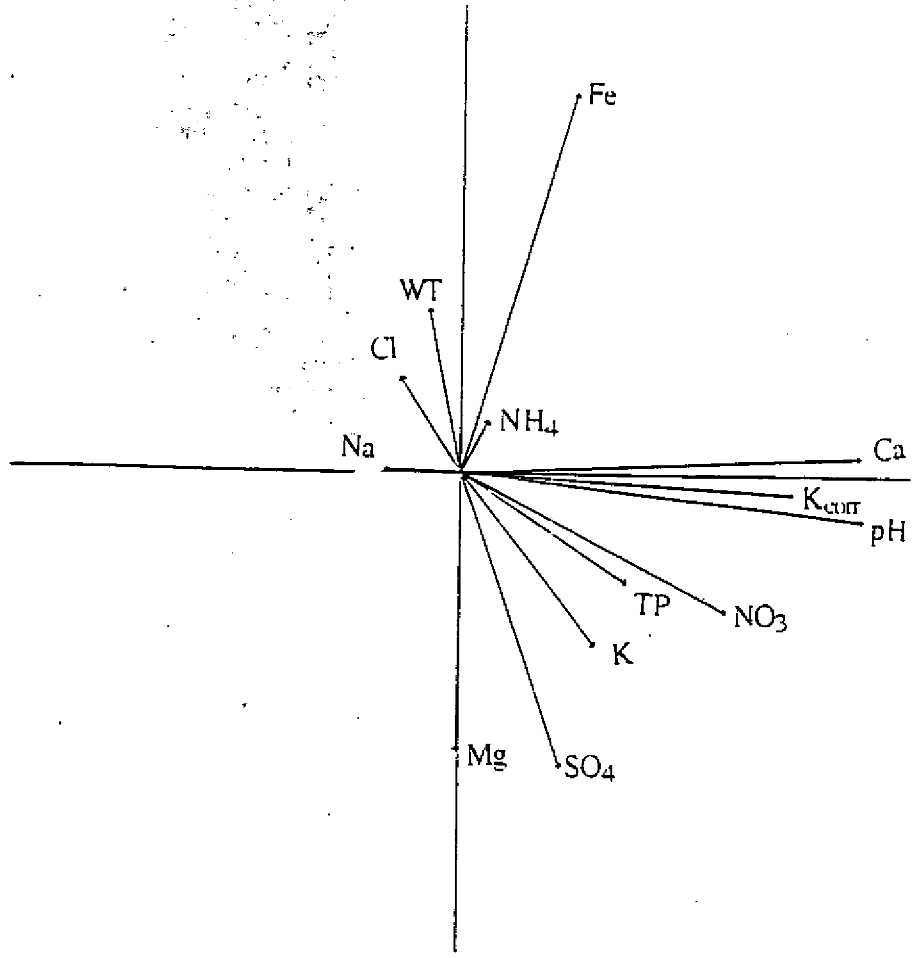
The main conclusions that can be made from the examination of the marginal and cut-away communities on Clara and Raheenmore are:

1. That there are still areas of vegetation on the margins of both bogs that indicate poor fen conditions (lagg communities) which are influenced by ground water. These are situated on Raheenmore north-west, some small areas on the southern edge of Raheenmore and on the northern edge of Clara East (the latter area has been recently disturbed but could still be rehabilitated). The water table level in these communities is still relatively low and if an increase in sedge communities is desired the regional ground water table will need to be raised. As well as creating wetter conditions the impact of ground water would be greater.
2. These existing areas can now, in theory, be protected as their hydrological and hydrochemical characteristics are known. This knowledge could result in the ability to extend existing communities if suitable conditions could be created in other areas.
3. Creation of suitable conditions may include (a) the removal of ombrotrophic peat in cut-away areas so that fen peats are exposed for recolonisation by fen peat species or (b) an increase of water table levels by impeding drainage.
4. That the wet cut-away communities add to species diversity and do not require any conservation measures apart from ensuring that the peat does not become desiccated. This may be achieved by controlling marginal drainage of adjacent land. The indications of nutrient enrichment which are seen in these areas are probably related to the mobilisation of certain minerals caused by the oxidative decomposition of the peat after exposure to air.
5. If any marginal communities are to be conserved, then existing areas of lagg vegetation, which are not already owned by the National Parks and Wildlife Service (O.P.W.), should be purchased as soon as possible.

6.6 RELATIONSHIPS BETWEEN BOG, MARGIN AND SOAK COMMUNITIES.

A summary comparison of the three main habitat types associated with these two raised bog systems is shown in Fig. 6.17. This ordination plot is based on the data from the bog and lagg sites sampled in October 1990 and the data from the soak sites sampled in October 1991. The variable Ca was analysed passively as it was correlated with the variables pH and K_{corr}. The eigenvalues for the axes in this ordination were 0.667, 0.493, 0.375 and 0.267.The following variables were shown to be correlated in the correlation matrix in the output from CCA: K_{corr} and pH, Na and Cl and SO4 and Mg. The Monte-Carlo statistical test showed both the first axis and the overall test to be statistically significant.

In this Canonical Correspondence analysis, the hydrology and hydrochemistry of the bog, marginal and soak communities are compared (the soak systems of Clara are examined in more detail in the following chapter). Here the overall relationships of the three main vegetation divisions may be seen. The bog sites, as mentioned previously, are associated with the vectors of Na and Cl. This indicates their ombrotrophic nature. The water table vector indicates the wetter bog communities, such as pools and lawns, whereas the hummock and flat communities are in a negative position to the water table vector. The soak communities plot out, in some instances to the ombrotrophic site of the ordination and others to the Fe, K_{corr}, pH and Ca side (ground water influence). The marginal communities, including some of the cut-away types, are also associated with the ground water indicators of high Ca, pH and K_{corr} values. However they are also associated with indicators of mineralisation such as higher total phosphate levels (TP) and elevated NO_3. NO_3 is negatively related to water table, as the NH_4



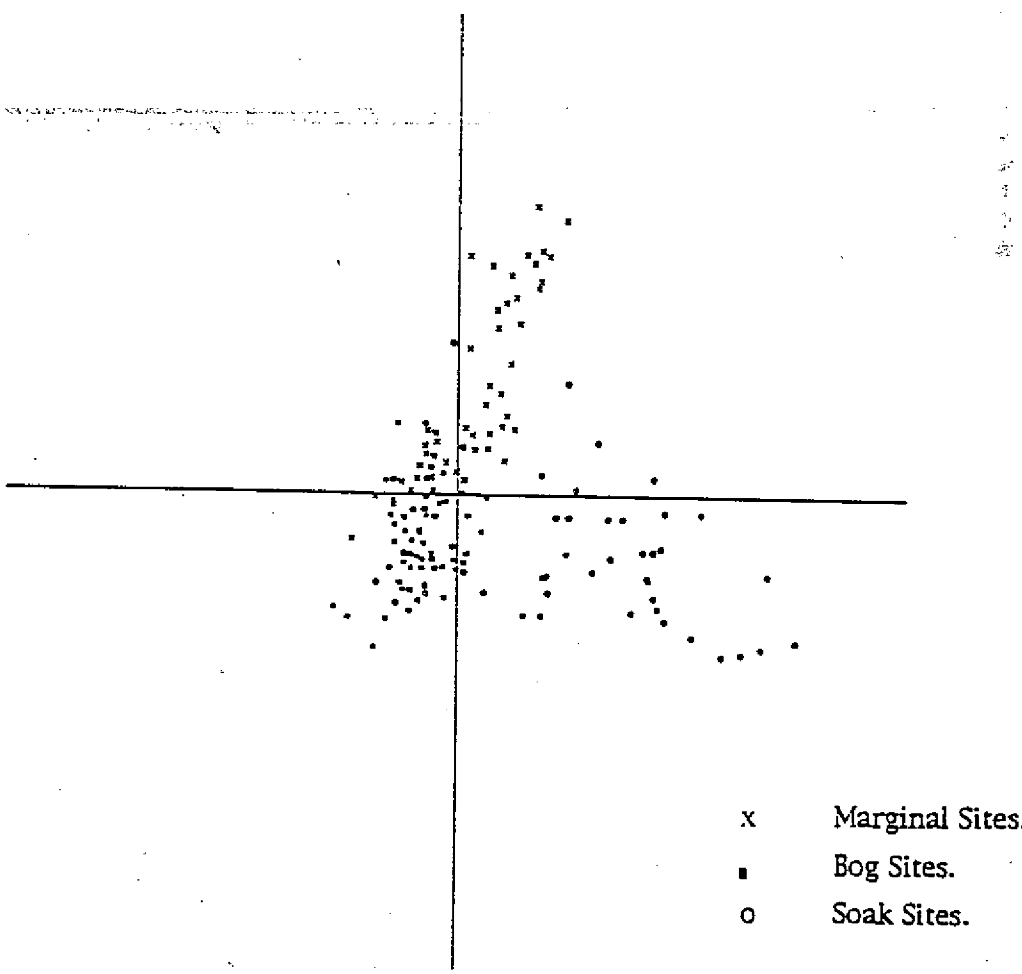


Fig. 6.17 Ordination plots of the bog, soak and marginal sites obtained from CCA of October 1990 (bog and margins) and October 1991 (soak) data.

form of nitrogen is more common under waterlogged conditions (Armstrong, 1985). Some cut-away sites are closely related to the drier side of the ombrotrophic section of the system. This ordination plot proves that the three main vegetation divisions that have been identified during this investigation are based on hydrological and hydrochemical differences.

118

CHAPTER SEVEN: SOAK SYSTEMS.

7.1 INTRODUCTION.

Soaks have been described as areas of mesotrophic or minerotrophic vegetation, occurring on an otherwise ombrotrophic bog, which are usually associated with internal drainage systems (Osvald, 1949; Moore, 1955; Cross, 1990). Moore (1955) states that almost all midland raised bogs of over one square mile (2.59 km^2) in area had features such as these. Since the 1950s, practically all larger bog complexes of the midlands have been exploited and consequently these soak systems have been destroyed. Today only three raised bogs with large open water soak systems remain, namely Clara Bog, Co. Offaly, Addergoole Bog, Co. Galway and Shanville, Co. Roscommon (Cross, 1990). The exact processes by which these systems were formed and maintained are not fully known, although some hypotheses were put forward in the past (Bellamy, 1986; Cross, 1990). If Clara bog is to be conserved with its soak systems intact, further investigations into soak characteristics and functioning are necessary. One of the primary aims of the Irish and Dutch project is the conservation of Clara's soak systems. As apparently naturally occurring phenomenon, they are an important part of the mire system as they not only add significantly to the diversity of plant species within the mire but also are now extremely rare features of raised bogs.

This investigation into the soak systems on Clara Bog will add to the present knowledge of soak systems by mapping the vegetation patterns of the main soaks, by collating information obtained by other workers during the project and by carrying out a series of hydrochemical investigations.

7.2 SOAKS ON CLARA BOG.

Three main soak systems have been identified on Clara Bog (Fig 7.1). These are as follows:

i. Lough Roe on Clara East (A).
ii. Shanley's Lough on Clara West (B).
iii. The long North-South soak on Clara West (C).

In addition to these, other minor areas which could be described as soaks or partial soaks were identified during the vegetation survey and mapping of the bog. These were:

iv. Small soak to the south of Lough Roe (D).
v. Small area of *Betula* and *Molinia caerulea* on Clara West (E).
vi. Small area of *Betula* and *Molinia caerulea* on Clara West (F).

7.2.1 Lough Roe.

History

This soak site is located on the eastern drained section of Clara Bog. The stratigrapical investigations of Connolly (1992) show that this feature has probably existed since the initiation of raised bog formation (Fig. 7.2). The ordnance survey map of 1838 shows Clara Bog in a relatively undrained state with only two long drains on either side of the bog, running parallel to the road. Lough Roe is shown as a open water body, approximately 220 metres long by 50 metres wide (Fig.7.3 A). By the time of the 1910 survey Lough Roe had a large drain leading from its western end to the road-side drains. Lough Roe is still shown as an open water body but is reduced slightly in size to 210 m long by 50 m wide (Fig.7.3 B). Zoological and botanical work on Lough Roe in the early 1980s shows that the area of open water had been much reduced, to approximately 5 metres by 20 metres, as the lake had become progressively infilled by a floating raft of vegetation or scragh (Reynolds, 1985). The central area at this time still supported plant communities of open water conditions (M. Schouten, pers. comm.).

Present Day

The vegetation work carried out in this area during the survey of the soak systems showed that practically no open water remains now, although the central area is still very wet and quaking and is surrounded by a scragh of vegetation. This rapid overgrowth was probably aided by the extensive surface drainage of Clara East in 1983/84 in preparation for peat extraction (Fig. 7.4). This would have resulted in a general lowering of the water table in the area and thus created drier conditions and allowed the encroachment of less aquatic species. It is also possible that the blocking of the exit drain to the west in the 1980s may have increased the impact of acid water, from the surrounding ombrotrophic bog, and increased the impact of mineral poor precipitation, by diluting the more mineral rich waters of the soak, which could no longer overflow so rapidly due to the blockage of the exit drain.

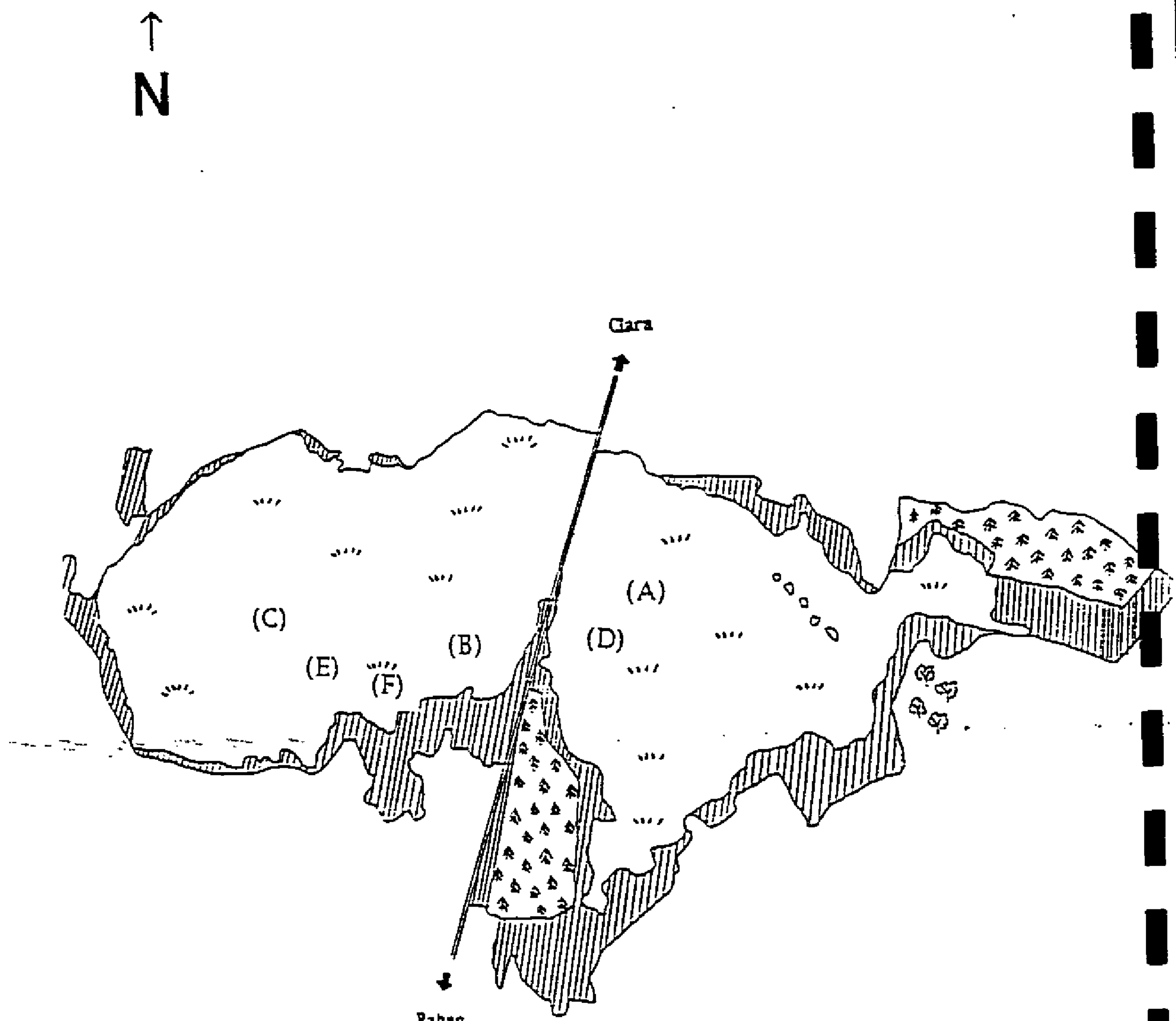


Fig. 7.1 Map of Clara Bog showing soak and minor soak locations.

(A) Lough Roe, Clara East.

(B) Shanley's Lough, Clara West.

(C) North/South Soak, Clara West.

(D) Small Soak south of Lough Roe.

(E) Small *Betula/Molinia* soak, Clara West.

(F) Very small *Betula/Molinia* soak, Clara West.

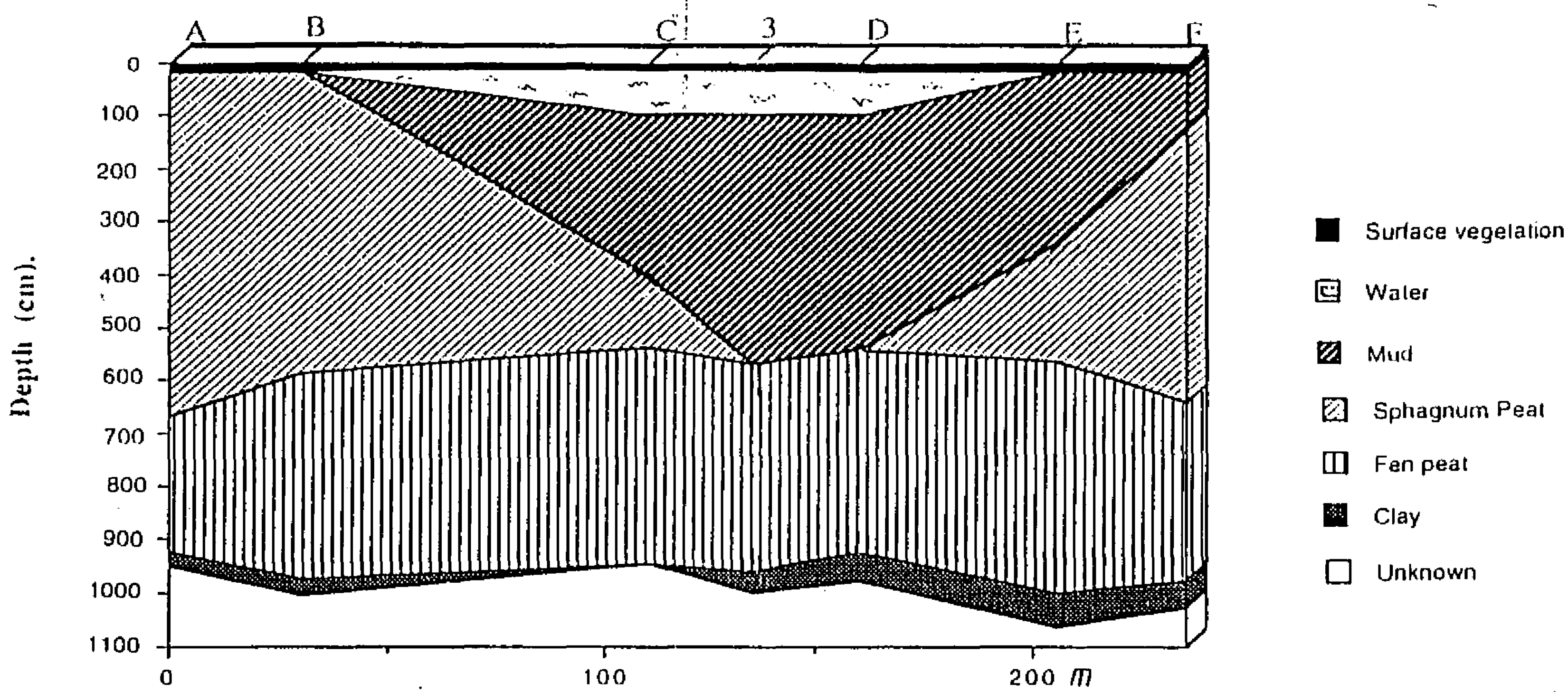


Fig. 7.2 Stratigraphical section of the east-west axis of Lough Roe.
Source: Connolly (1992).

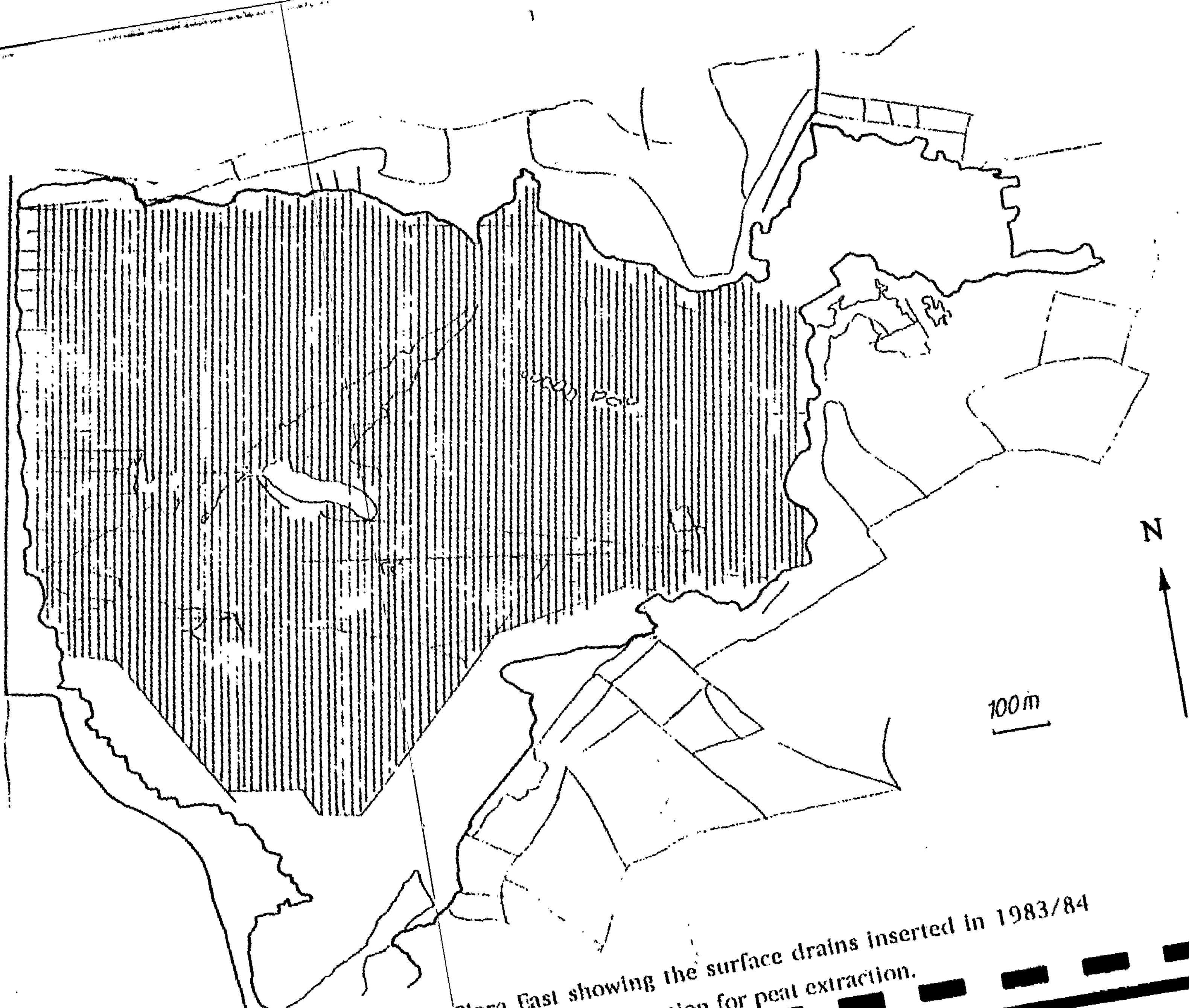


Fig. 7.4 Map of Clara East showing the surface drains inserted in 1983/84 by Bord na Móna in preparation for peat extraction.

Mapping of the feature followed the vegetation survey and this vegetation map shows a zonation in vegetation types from a wet central core, with remnant open water plant communities, to progressively drier more ombrotrophic conditions at the edges of the feature (Fig. 7.5). The vegetation of the central area is indicative of poor fen conditions with vascular species such as *Carex rostrata*, *Lychnis flos-cuculi*, *Hydrocotyle vulgaris*, *Potentilla palustris*, *Menyanthes trifoliata* and *Succisa pratensis* occurring frequently (Plate 9). This corresponds closely to the *Carex rostrata* and *Sphagnum squarrosum* mire of Rodwell (1991).

Hydrochemistry

Samples for detailed hydrochemical analyses were collected from this site every second month for one year and water table, pH and electrical conductivity measurements were made each month for one year. The sampling points within the Lough are shown in Fig. 7.6.

The annual average mean, maximum and minimum values (± 2 S.E.) for watertable (cm), pH and K_{corr} of the soak communities are shown in Table 7.1. These were calculated from the monthly measurements taken between August, 1991 and July, 1992. The community types 5A, 5C, 5B (Plate 10), 6 (Plate 11), 8Aa, 8Ab (Plate 12), 8B (Plate 13), 8C (Plate 14), 11, 12Ab (Plate 15) and 13 occur in Lough Roe (see Chapter 4 for detailed community descriptions).

The K_{corr} data from the Lough Roe communities shows definite patterns. The communities may be divided into three groups on the basis of their average monthly K_{corr} values (Fig. 7.7). The first group (Fig. 7.7 (A)) are situated in the central area of Lough Roe and are associated with high K_{corr} values throughout the year. The second group of communities (Fig. 7.7 (B)) have intermediate K_{corr} values and are generally seen in the sub-central section of the soak. The final group (Fig. 7.7 (C)) have low K_{corr} values, similar to values measured in the ombrotrophic communities of the high bog, and are mostly found at the margins of Lough Roe.

Similar groupings of communities may be seen in an examination of the pH values (Table 7.1).

These K_{corr}, pH and other more detailed hydrochemical data from this area support the suggestion that this is a poor fen system, as the water samples from this area (particularly from the central section) are not typical of ombrotrophic bog situations.

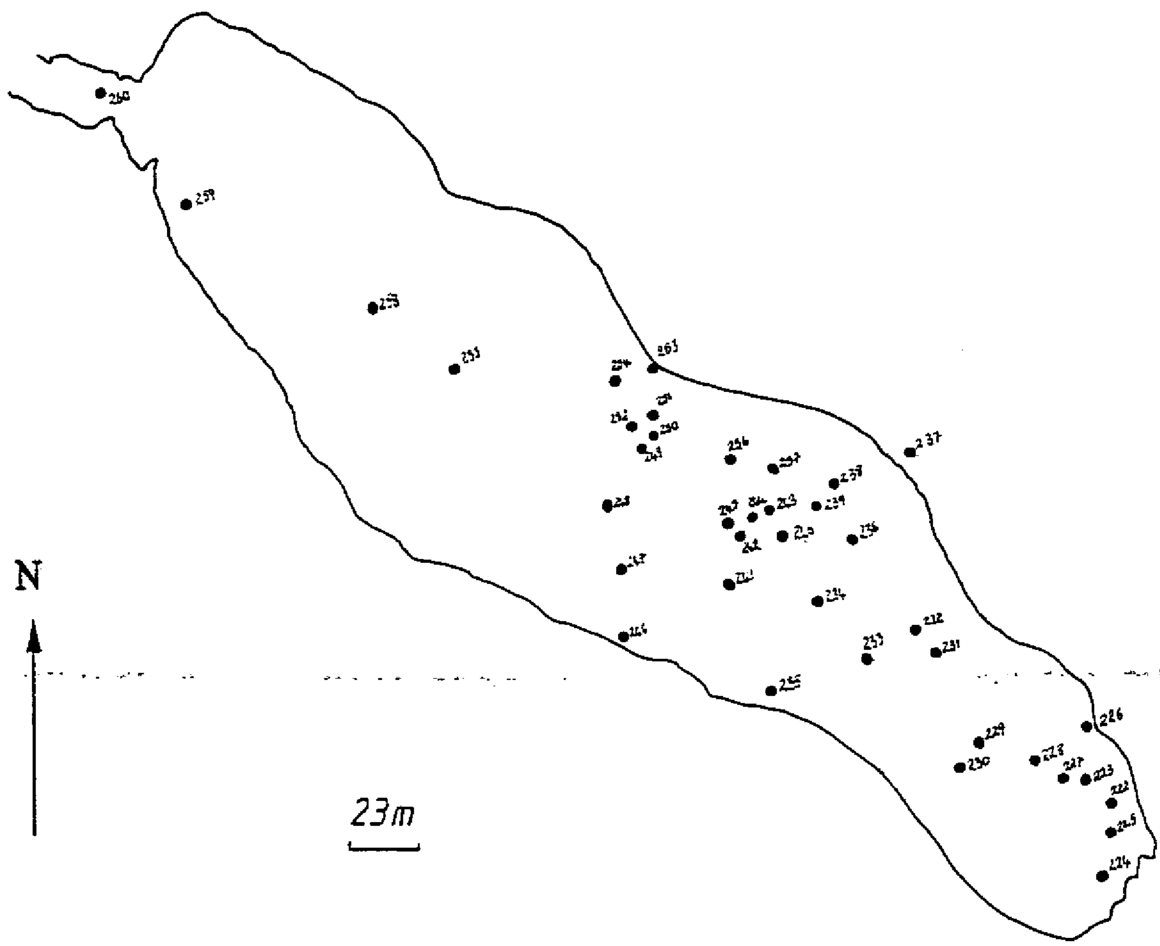


Fig. 7.6 Map of Lough Roe showing sampling points of hydrochemical, hydrological and vegetation investigations.

Table 7.1. Summary of some hydrochemical and hydrological characteristics of the soak plant communities. The annual average of the mean, maximum and minimum values (± 2 S.E.) are shown for water table depth (cm), pH and K_{corr} (μ S cm^{-1}).

	Water table			pH			K_{corr}		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
3F	-21.1 (±10.6)	4.2 (±6.6)	-5.2 (±7.2)	3.6 (±0.1)	4.3 (±0.1)	4.0 (±0.0)	20.1 (±8.8)	80.5 (±16.0)	52.5 (± 6.4)
5A	5.3 (±0.8)	30.6 (±1.0)	25.5 (±0.6)	4.3 (±0.2)	5.2 (±0.3)	4.9 (±0.3)	62.4 (±12.4)	139.0 (±36.8)	98.1 (±18.2)
5B	30.7	54.2	46.0	4.7	5.5	5.1	56.4	167.1	102.7
5C	6.2	35.8	28.0	4.7	5.7	5.3	75.1	142.0	111.7
6	-0.6 (±1.4)	23.9 (±8.2)	14.5 (±5.4)	4.5 (±0.2)	5.3 (±0.2)	5.0 (±0.2)	72.6 (±15.6)	115.0 (±25.6)	94.1 (±20.8)
7	3.0 (±0.6)	27.0 (±3.0)	19.0 (±2.6)	3.5 (±0.0)	4.4 (±0.1)	4.0 (±0.0)	25.5 (±1.4)	69.0 (±2.6)	48.8 (±3.6)
8Aa	-5.2 (±4.6)	15.6 (±5.0)	9.0 (±4.0)	3.7 (±0.1)	4.3 (±0.1)	4.0 (±0.1)	23.3 (±2.8)	68.9 (±1.9)	44.9 (±1.3)
8Ab	-3.2 (±2.2)	13.4 (±2.6)	8.0 (±2.4)	4.2 (±0.2)	4.8 (±0.2)	4.5 (±0.2)	51.1 (±8.8)	94.8 (±11.6)	73.7 (±9.0)
8B	-0.5 (±4.6)	11.6 (±6.6)	5.9 (±6.8)	4.2 (±0.1)	5.0 (±0.1)	4.5 (±0.1)	52.8 (±7.6)	86.7 (±7.9)	70.4 (±5.8)
8C	-6.7 (±2.2)	9.1 (±2.0)	3.4 (±2.2)	4.1 (±0.1)	5.0 (±0.1)	4.6 (±0.1)	46.1 (±4.9)	94.7 (±4.9)	71.0 (±4.5)
9A	-10.3 (±2.2)	5.5 (±2.6)	0.9 (±2.8)	3.6 (±0.1)	4.2 (±0.0)	3.9 (±0.0)	19.0 (±4.0)	85.4 (±22.2)	44.2 (±3.6)
11	-13.0 (±2.6)	4.7 (±2.0)	-1.4 (±1.4)	3.8 (±0.2)	4.5 (±0.3)	4.2 (±0.3)	34.4 (±10.0)	91.0 (±11.2)	59.7 (±10.2)
12Aa	-18.8 (±2.0)	2.4 (±3.8)	-5.6 (±1.4)	3.7 (±0.1)	4.2 (±0.1)	3.9 (±0.0)	26.3 (±1.0)	81.4 (±18.0)	52.1 (±4.2)
12Ab	-16.5 (±7.2)	5.4 (±1.6)	-1.7 (±3.8)	3.5 (±0.1)	4.2 (±0.0)	3.9 (±0.0)	33.6 (±16.5)	89.3 (±47.4)	55.2 (±22.6)
12Ac	-10.9 (±3.6)	6.9 (±2.8)	0.2 (±2.8)	3.7 (±0.1)	4.3 (±0.1)	4.0 (±0.0)	19.5 (±4.6)	65.0 (±1.4)	44.4 (±1.2)
12Ba	-6.4	11.5	5.3	3.7	4.3	4.1	27.0	63.8	47.3
12Bb	-19.4 (±9.4)	5.7 (±8.6)	-2.0 (±8.8)	3.5 (±0.1)	4.2 (±0.0)	3.9 (±0.0)	28.8 (±3.0)	96.2 (±33.2)	51.9 (±3.4)
13	-4.6	10.6	6.1	4.5	6.1	4.5	54.9	98.3	69.6
14A	-20.3 (±9.4)	1.3 (±5.6)	-6.1 (±5.8)	3.5 (±0.1)	4.2 (±0.0)	4.0 (±0.0)	25.2 (±4.2)	76.1 (±2.0)	51.4 (±2.0)
14B	-2.5 (±5.2)	18.6 (±5.8)	11.5 (±6.4)	3.7 (±0.0)	4.4 (±0.1)	4.1 (±0.0)	28.4 (±3.4)	68.6 (±2.6)	47.1 (±0.8)

Note: Replicate samples were unavailable where no standard errors are indicated.

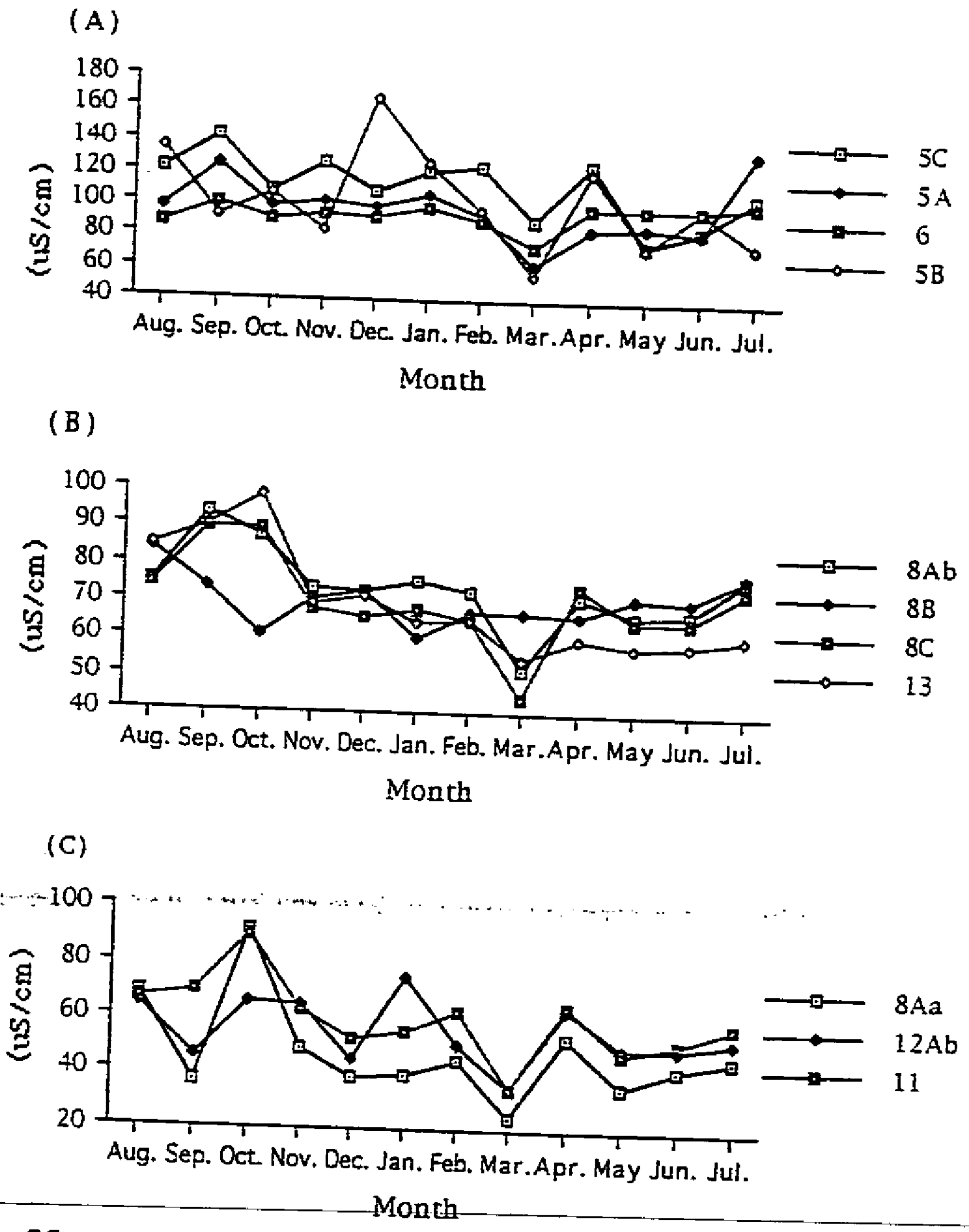


Fig. 7.7 Average monthly K_{corr} values for the Lough Roe sites. (A) communities with high K_{corr} values, (B) communities with intermediate K_{corr} values and (C) communities with low K_{corr} values.

Water classification, using the computer program of Stuyfzand (1990), shows that waters of CaCl type are common, with $CaHCO_3$ water types also occurring (Table 7.2). This indicates that there is a source of mineral enriched water coming into the site, as the high levels of Ca and HCO_3, necessary for the waters to be classified as CaCl and $CaHCO_3$, cannot be derived totally from precipitation (see Chapter 5). An examination of Table 7.2 shows that there is a variation in water chemistry over the year. This is related to the amount of dilution that is occurring. When precipitation is high, the Ca and HCO_3 in the soak waters will be diluted by the incoming rain, which has high levels of Na, SO_4 and Cl and low HCO_3 and Ca .

Table 7.2 Hydrochemical Data from Lough Roe (selected sites) for the period August, 1991 to June, 1992 at two-monthly intervals.

	SAMPLE TIME					
Site	Aug'91	Oct '91	Dec '91	Feb '92	Apr '92	Jun '92
230	CaCl	NaCl	CaCl	NaCl	NaCl	NaCl
231	CaCl	CaCl	CaCl	NaCl	CaCl	CaCl
236	CaCl	CaCl	NaCl	NaCl	CaCl	CaCl
244	CaCl	CaCl	CaCl	$CaHCO_3$	$CaHCO_3$	$CaHCO_3$
251	CaCl	CaCl	CaCl	CaCl	CaCl	CaCl
252	CaCl	CaCl	CaCl	CaCl	CaCl	CaCl
256	$CaHCO_3$	CaMiCl	CaCl	NaCl	$CaHCO_3$	$CaHCO_3$
257	$CaHCO_3$	CaCl	CaCl	$CaHCO_3$	$CaHCO_3$	$CaHCO_3$

Water types may be characterised by their ionic ratio (Van Wirdum, 1980). The ionic ratio of a water sample is calculated using the following formula:

$$Ca^{2+}/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})\ (\text{meq } l^{-1})$$

The ionic ratio may be plotted against the electrical conductivity to illustrate the hydrochemical characteristics of the water sample. If atmospheric (precipitation) and lithographic (ground water) samples are also indicated, water source may be derived (data used from Clara Bog for samples of ground water and precipitation). This type of plot is known as a Van Wirdum diagram (Van Wirdum, 1980).

A typical lithotrophic or ground water sample from the Clara bog area has the following chemistry: Ca 140 mg l^{-1}, Mg 8.3 mg l^{-1}, K 1.1 mg l^{-1}, Na 9.7 mg l^{-1}, Cl 20.0 mg l^{-1}, SO_4-S 16.1 mg l^{-1}, NO_3-N 3.6 mg l^{-1} and NH_4-N 0.16 mg l^{-1} and an electrical conductivity of 747 μS cm^{-1} (R. Flynn, pers. comm.).

The ionic ratio of the atmospheric sample was calculated from the mean monthly values for each of the ions from the year of sampling of precipitation from Clara. The EC value used was also the monthly mean value for the year.

The Lough Roe samples plotted on the diagram are the sites which were chosen to be monitored for a full year. The samples from February and June are plotted to illustrate the winter and summer situation respectively.

Typically most water samples from this site plot out toward the lithotrophic rather than the atmospheric end of the Van Wirdum diagram, which suggests a regional ground water source (Fig. 7.8). However hydrological investigations in this area show only vertical downward gradients of water movement, indicating that a hydraulic head, necessary for inputs from regional ground water, is absent (Flynn, 1993). During the winter period more sites are situated close to the atmospheric section of the diagram. This suggests that during periods of high rainfall and low evapotranspiration the dilution effect of rainfall is greater and that it is only the central sites of Lough Roe that plot towards the lithotrophic section of the diagram.

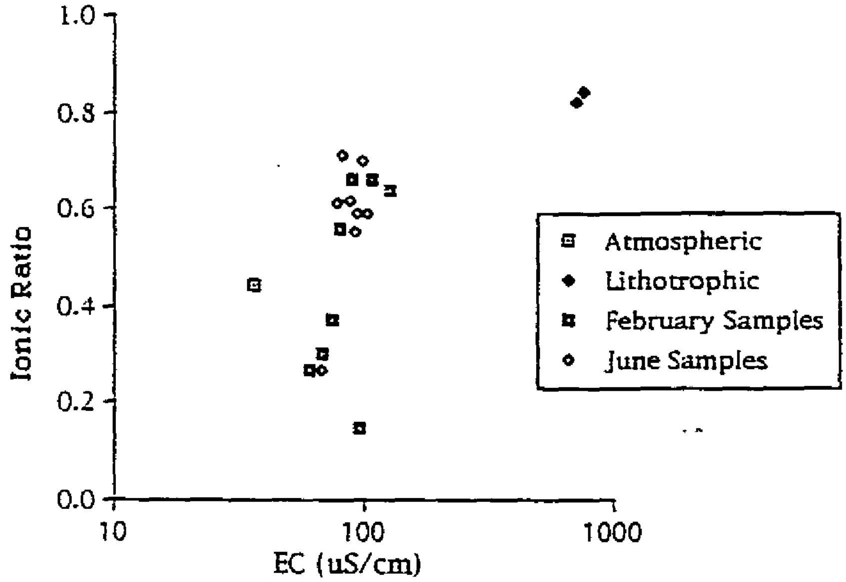


Fig. 7.8: Van Wirdum diagram of Lough Roe water samples in February and June, 1992, with atmospheric and lithotrophic reference points.

It has been suggested that, as soaks are usually associated with internal drainage systems of the bog, focused flow of water within the feature can explain the vegetation anomalies which occur (Sparling, 1966; Armstrong and Boatman, 1967). Ingram (1967) states that waters, which when stagnant support ombrotrophic vegetation, can if they flow, support a more mesotrophic vegetation. The water would only be NaCl type, typical of bog waters, but the rate of delivery of ions to the plant roots would be increased with the added advantage of greater aeration. This theory was suggested for a previous soak system at Pollagh Bog, Co. Offaly (Moore, 1955) and applies to some flushed sites on blanket bogs. Nevertheless the hydrochemical data from Lough Roe shows the water in most situations to be atypical of ombrotrophic bog waters and more representative of those suggesting a regional ground water input. Therefore the above theory is not plausible. Furthermore levelling information shows that Lough Roe is situated on a topographically high point of the bog (Hussey, 1992) and thus water flows are unlikely to be focused into the area.

Other Investigations

Since the initiation of this project, some minor studies (hydrological) were carried out on Lough Roe and some further theories proposed as to the origin of enriched waters. Van den Boogaard (1993) proposed that Lough Roe was under the influence of upwelling water held in fen peats below the site, as gradients in ionic concentrations were observed in waters at different depths beneath the site; deeper peat waters having higher concentrations of Ca and Mg. However the hydraulic head required for fen waters to upwell has not been detected.

Another theory was proposed by Flynn (1993). He suggested that the process of corrosive oxidation may be important, where the dissolved oxygen present in surface waters of the lake would enhance plant decomposition and thus recycling of nutrients. The wind exposed edges of bog pools over 2-4 m in size have been shown to support a slightly more enriched vegetation than smaller pools, as aeration is increased and so peat decomposition is faster with a consequent increase in nutrient availability for plant growth (Verhoeven, 1992). However this process has not been shown to result in poor fen vegetation. Flynn (op. cit.) suggested that the larger nature of this feature, compared to typical bog pools, means that the fetch is longer for oxygen to be incorporated into the water. Yet measurements carried out by Flynn showed dissolved oxygen to be absent from all but the top few centimetres of Lough Roe.

J. Streefkerk (pers. comm.) suggested that thermal convection currents could be responsible for cycling waters from the fen peats to the Lough surface. This hypothesis was investigated by Scheffers and Van der Meer (1993). Temperature measurements across Lough Roe during the summer of 1992 showed warmer waters at the surface. This implied that no convection currents were possible at that time as would be expected. Flynn (1993) studied this theory further by taking temperature profile measurements in winter, which showed that warmer waters were present at depth below a layer of cooler water and thus convection cycling was possible.

Small soak to the South of Lough Roe

This feature appears as an open water body on the 1838 and 1910 maps of the area. It was probably drained at the same time as Lough Roe and because of its smaller size and closer proximity to the road was overgrown by a scragh more swiftly and the transition to ombrotrophic vegetation has been more rapid. At the time of the vegetation survey, no open water remained but the wettest central section still supported *Sphagnum recurvum* and *Menyanthes trifoliata* with some *Aulacomnium palustre* and *Empetrum nigrum*. No hydrochemistry samples were collected here but A. Connolly (pers. comm.) intends to investigate the stratigraphy to examine if it is similar to Lough Roe. Its history and the presence of some indicator species, such as *Sphagnum recurvum*, *Empetrum nigrum* and abundant *Vaccinium oxycoccus*, implies that it may have a similar origin to Lough Roe.

No other bog with features such as these has been described in the literature. Other soak systems which have been previously recorded are more similar to the soak sites described below.

Lough Roe Conclusions

It would appear from these investigations that Lough Roe is a relict feature. A possible suggestion is that the regional ground water level was lowered due to arterial drainage. Prior to this probable lowering of the regional ground water table, adequate artesian pressure may have existed to provide ground water to this area in the form of a spring. This is suggested by the findings of Connolly (1992). Since extensive peat cutting and drainage, both regional and local, were carried out and the water table lowered, this artesian pressure was removed and the Lough was no longer fed by spring water. Flynn (1993) further investigated this theory and hypothesized on the paleohydrology of the area. He suggested that a former lake within a dip in the esker to the north of the bog may have provided the head of water required for the spring under Lough Roe. When the Brosna river catchment was drained, this lake dried out and the head of water was lost.

It appears that this soak system is now under the influence of convective currents which are at present supplying ions from old ground water held in peat pores below the Lough. This supply is limited and will eventually be exhausted. This hypothesis is supported by the fact that, although the hydrochemistry from Lough Roe suggests a ground water influence, it is very dilute in comparison to ground water samples from boreholes in the area. The average Ca content of the central Lough Roe waters is in the region of 9.0 mg l^{-1}, while that of bore hole samples is approximately 140 mg l^{-1}.

Ingram (1967) suggests that after a long period of accumulating ions, a mature vegetation community may be independent of further supply. In other words it may be self perpetuating. This does not appear to be the case in Lough Roe. Recycling may not be complete and losses from the system may be too great. The rapid overgrowth in the last ten to twenty years has been probably the result of further drainage and a deterioration in the conditions necessary for open water, lake vegetation.

This implies that Lough Roe will eventually be completely infilled with vegetation, which will gradually become more ombrotrophic as the mineral ion supply is diminished and will be similar to the small soak, which lies to the south of it. Possibly the only way to reverse this process would be to raise the regional ground water level by a number of metres and re-establish the hydraulic head. This is a virtually impossible task. It has also been suggested that, by re-opening the exit drain from the soak, the influence of the acid and mineral poor water from the surrounding area may be reduced.

7.2.2 Shanley's Lough.

History

Shanley's Lough is located on Clara West and in contrast to Lough Roe, is a relatively recent phenomenon. This is apparent from Fig. 7.3 (a) and (b) where an open water body, in the region of the present day soak, is absent from the ordnance survey map of 1838 but is shown on the map of 1910. Investigations by Bloetjes and Van der Meer (1992) show a similar stratigraphical succession beneath this soak to that which is seen beneath the typical ombrotrophic bog vegetation. This is in contrast to the Lough Roe soak, where the stratigraphy suggests the presence of a spring from the initiation of ombrotrophic peat development (Connolly, 1992). There is no indication from the peat stratigraphy under Shanley's Lough that the present vegetation has existed since ombrotrophic peat development (Bloetjes and Van der Meer, 1992).

Present Day

Shanley's Lough now consists of an almost circular open water body of approximately 60 metres in diameter (Plate 16). The vegetation of the site is more typical of those soak systems described in the literature (Osvald, 1949; Moore, 1955). It is a linear feature with an open water pool at its head, which is surrounded by *Carex rostrata*, *Eriophorum angustifolium* and *Juncus effusus* with some small areas dominated by *Menyanthes trifoliata*, *Juncus bulbosus* and *Hydrocotyle vulgaris*. To the south of the open water pool, that is towards the bog edge, stands of *Betula pubescens* occur (Plate 17) and closer to the bog edge again, the vegetation is dominated by *Molinia caerulea* and *Myrica gale* (Plate 18). The vegetation patterns of this site are shown on the vegetation complex map of Clara West (Appendix 8. 1(b)). The soak community types which have been recorded at this site are 3F, 7, 8Aa, 9A, 12Aa, 12Ab, 12Ac, 12Ba, 12Bb, 14A and 14B (for detailed community descriptions see Chapter 4).

A similar pattern of vegetation is described by Osvald (1949) on a bog close to Edenderry, Co. Offaly (this site has since been cut-away). A large pool at the head of the Edenderry soak was fringed with *Juncus effusus*, followed by an area of tall *Betula pubescens* trees with *Pteridium aquilinum*, *Dryopteris carthusiana* (*D. spinulosa*) and *Osmunda regalis*. This was followed by a section dominated by *Molinia caerulea* and *Myrica gale*. At the borders, Osvald describes the presence of *Polytrichum commune* hummocks overgrown with *Vaccinium oxycoccus* (*Oxycoccus quadrapetalus*). This community type also occurs at the edges of Shanley's Lough.

One of the other remaining raised bog sites with a soak system, Addergoole Bog, Co. Galway, located on the eastern shores of Lough Corrib, 9 km north of Galway city, (M 310 340) was visited in June, 1993. Again it is a recent feature, as the pools associated with it are not indicated on the 1910 map of the area (6" map Galway 69). It has a linear form, with two large open water pools occurring at the head of the soak, colonised by species such as *Menyanthes trifoliata*, *Hydrocotyle vulgaris*, *Juncus effusus* and *Carex rostrata*, in common with Shanley's Lough. These pools are followed by wet *Betula pubescens* (7-10 metres tall) woodland with an understorey of predominantly *Juncus effusus*, *Osmunda regalis* and *Molinia caerulea* with some *Pteridium aquilinum* and *Sphagnum palustre* dominating the bryophyte layer (Plates 19 and 20). The soak then grades into a band of vegetation, dominated by *Molinia caerulea* with *Myrica gale*. This area drains to the west into Lough Corrib. The only noteworthy difference between Shanley's Lough and the Addergoole soak is the abundance of *Carex limosa* which grows at the latter, presumably influenced by proximity to the sea.

The Addergoole site was surveyed by Douglas and Grogan (1985) who recommended that it should be conserved.

Investigations into the vegetation at two other soak systems at Shanville, Co. Roscommon (M 750 910) and Trien Co. Roscommon (M 655 76) showed similar vegetation patterns. This information was collated from the reports of Douglas and Mooney (1984) and Douglas and Grogan (1985). Shanville is described as having a large *Betula* dominated soak with other soak associated species. The 1910 6" map of the bog (Roscommon 15) shows two open water bodies (Friars holes) at the northern margin of the site associated with the soak. Trien is described as having a large wooded *Betula* flush in its centre. The bryophyte layer consists of large *Sphagnum* hummocks with species such as *Sphagnum recurvum* var. *mucronatum*, *S. palustre*, *S. fimbriatum* and *S. squarrosum* occurring, with the rare liverwort *Cephaloziella elachista* also recorded. On the south-western side of the soak a channel emerges which is dominated by *Molinia caerulea*. Again this is a similar pattern to the other soak sites described. The vegetation of these four sites could not be described as typical of a poor fen, as they lack the poor fen indicators that Lough Roe possesses. Yet they do support vegetation communities which indicate slight enrichment. The similarity of vegetation patterns (Fig. 7.9) and the species occurrence of these features suggests that their origins and functioning may be similar.

The heads of these soak systems are all located towards the centre of each of the sites, the area which would correspond to the central dome of the bog. All lead towards a road, a river, a lake or cut-away. This suggests that they are drainage features.

A possible suggestion for their origin is based on anthropogenic effects. The top layer of the centre of a raised bog is composed of poorly decomposed peat with a very high water content. If drainage or peat cutting is carried out at the edge of the bog, this area will lose a proportion of its water content and may sink in relation to the surrounding peat, which may not have as high a water content. This could result in a sunken area in the central section of the bog, where water may pond and then drain towards the lowest point. This hypothesis is supported by the fact that these soaks are all recent features, which have appeared since the start of major bog exploitation. The second soak on Clara West may also be explained by this sequence of events, as Spieksma (1993) states that Clara West probably developed as

132

two domes which coalesced. The head of the North /South soak is positioned in the central area of the western basin, as the extent of the bog in that area was limited by the till mound to the south. Shanley's Lough is now at the edge of the raised bog, but there has been large scale cutting in that area and the original extent of the raised bog suggests that it would have been situated towards the centre of the original bog basin (Bloetjes and Van der Meer, 1992).

Hydrochemistry

Water table heights, pH and K_{corr} were measured monthly, during the same period as sampling at Lough Roe. The annual average mean, maximum and minimum values are shown in Table 7.1. These results show that the Shanley's Lough community type water samples have much lower pH and K_{corr} values than those measured in the communities at Lough Roe and are more typical of the raised bog community hydrochemistry (see Chapter 5). Detailed hydrochemical work was also carried out at Shanley's Lough at the same time as Lough Roe. Sampling sites are illustrated in Fig. 7.10. Most water samples, from the year of sampling of the chosen sites, were classified as NaCl with some MgCl (Table 7.3). An NaCl water type indicates that precipitation is the major ionic source as there is no mineral enrichment by ions such as Ca. The MgCl water type indicates some disturbance in the local area, perhaps due to drainage. This hydrochemical analysis shows that there is no ground water influence at Shanley's Lough.

Table 7.3 Hydrochemical Data from Shanley's Lough (selected sites) for the period August 1991 to June 1992 at two-monthly intervals.

	SAMPLE TIME					
Site	**Aug'91**	**Oct '91**	**Dec '91**	**Feb '92**	**Apr '92**	**Jun '92**
272	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
281	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
282	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
284	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
286	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
296	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
300	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
306	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
307	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
308	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
310	MgCl	MgCl	NaCl	NaCl	NaCl	NaCl
311	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
314	NaCl	NaCl	NaCl	NaCl	NaCl	NaCl
315	NaCl	NaCl	MgCl	NaCl	NaCl	NaCl
323	NaCl	NaCl	MgCl	NaCl	NaCl	NaCl

As all ionic inputs are derived from precipitation, the samples plot out close to the atmospheric section of the Van Wirdum diagram (Fig. 7.11). The lithotrophic and atmospheric reference points are the same as those used in the Lough Roe plot. The hydrochemistry data from the February and June samples of the chosen sites are illustrated. Note that the samples plot out more to the right of the plot than the atmospheric sample, as their electrical conductivity (uncorrected) values are higher. This is due to the ion exchange activity of *Sphagnum*, as the K_{corr} values are low for these sites, indicating that high electrical conductivity values are due to elevated levels of the H^+ ion rather than high Ca levels. They also plot out lower than the atmospheric samples as their ionic ratios are lower. This is because the Na concentrations of the soak samples are mostly higher than those measured in precipitation and the Ca levels are lower.

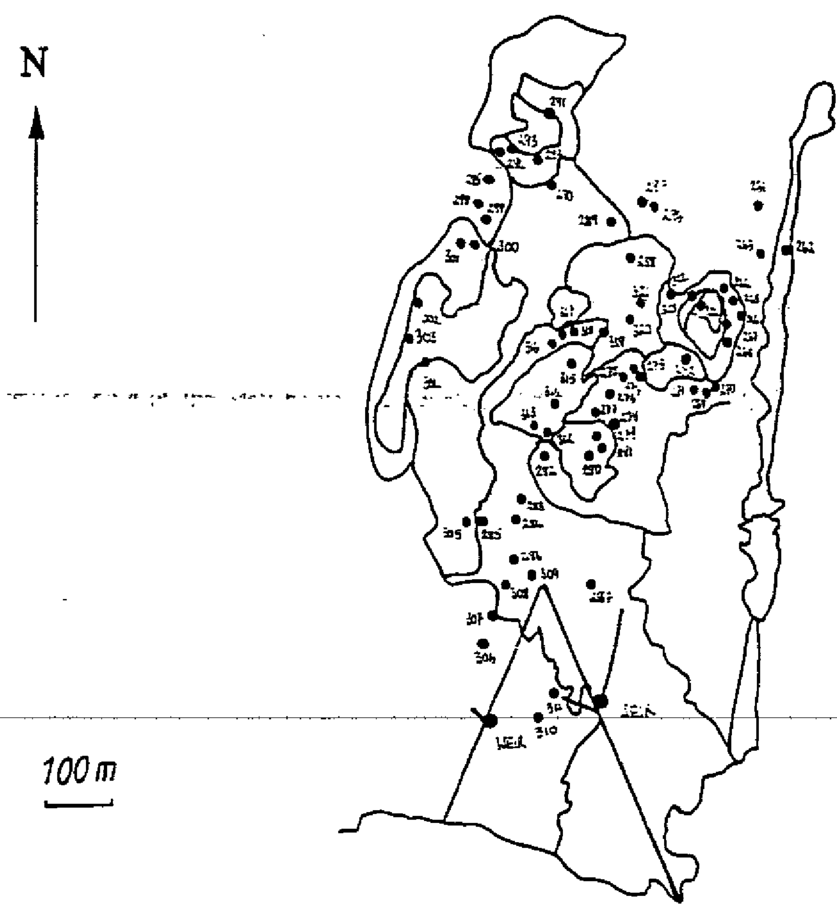


Fig. 7.10 Map of Shanley's Lough showing sampling points of hydrochemical, hydrological and vegetation investigations.

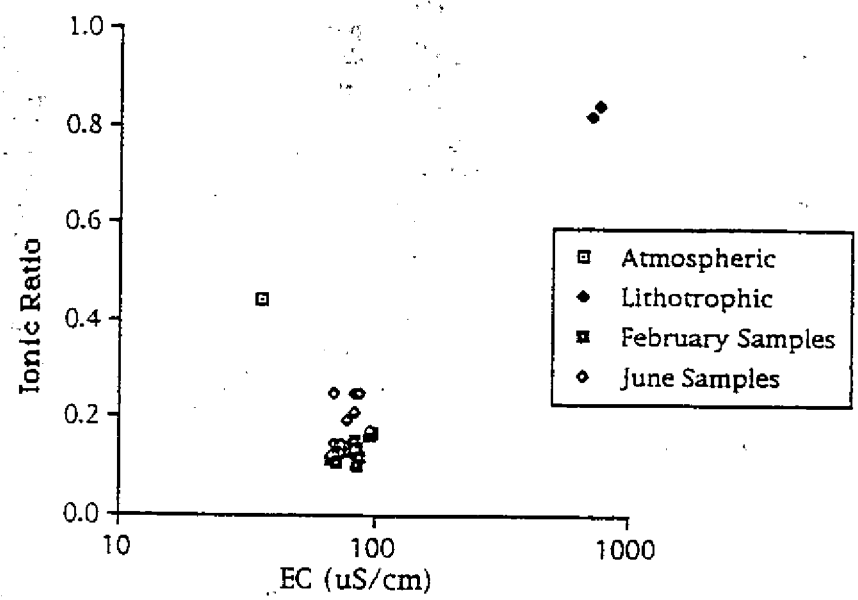


Fig. 7.11 Van Wirdum diagram of Shanley's Lough water samples in February and June, 1992, with atmospheric and lithotrophic reference points.

Some research work is currently in progress at the Addergoole soak. Hydrochemical analysis carried out there has shown no indication of upwelling ground water (A. Bleasdale and J. Conaghan, pers. comm.). Two surface water samples (250 ml) collected in June, 1993 from one of the open water pools and from within the *Betula* woodland confirm this, as they are both NaCl water type (Table 7.4). Owing to maritime influence, they have slightly higher Na values than samples from Shanley's Lough (sampled the following day).

Table 7.4 Addergoole and Shanley's Lough Hydrochemistry (mg l^{-1}).

	pH	EC	Na	K	Fe	Mn	Ca	Mg
Betula woodland	3.62	81.4	10.3	0.08	0.04	0.02	0.55	0.89
Large open water pool	3.73	67.6	8.8	1.13	0.08	0.01	0.52	0.74
Shanley's Lough	4.35	57.6	3.9	0.29	0.24	0.01	0.65	0.60
Shanley's Lough	4.31	56.1	4.6	0.31	0.23	0.01	0.58	0.60

(Cl and SO_4 were not analysed, as access to an ion chromatograph was no longer available).

7.3 OTHER SOAKS.

Two small areas of *Molinia caerulea* tussocks and *Betula* trees/scrub may be seen on Clara West (see vegetation map). Within each, at their south-eastern side, a hole of approximately 1-1.5 m deep and 0.5 m wide into the peat occurs. Observations showed that running water was constantly present, even in the dry summer of 1992. The similar orientation and position of the swallowhole in these features indicates that they are hydrologically interconnected.

The long North/South Soak on Clara West has a slightly different vegetation pattern to the Shanley's Lough-type soaks described above. The semi-open water pool occurs towards the outflow end (Plate 21) with *Betula* scrub at the head of the feature. The vegetation of this soak appears to be slightly more enriched than Shanley's Lough with the presence of *Typha latifolia*. The hydrochemistry of this soak was not investigated in detail, but some work by Van den Boogaard (1993) indicated no regional ground water input. Some concentration of ions, due to evaporation, may occur at certain times of the year. In addition this area is very attractive to bird life and it is often frequented by Mallard. It is possible that the semi-open water pool is where water ponds, as this soak may be connected to the two areas of *Betula* described above. It is situated in another topographical low point of the bog (Hussey, 1992). Water may flow through the system north to south and then eastwards, exiting at the face bank. This soak, like Shanley's Lough, appears to be a recent feature as stratigraphical investigations show the sequence of peat beneath the site to be similar to the rest of the high bog (Bloetjes and Van der Meer, 1992). This is in contrast to the peat stratigraphy at Lough Roe.

The similarity between the vegetation and hydrochemistry (where available) of these soaks and their association with drainage areas and topographic low points suggests that, unlike Lough Roe, they are focused flow features.

Shanley's Lough has a large surface water catchment area of approximately 120 ha and the water from this area is focused out through a very small sunken section of the bog. Two V-notches, to monitor water flow through this area, were installed by the hydrological section of this project. The average outflow focussed through this small area is approximately 2.656×10^{8} l $year^{-1}$.

Similarly, an outflow at a cut-a-way face bank at the southern edge of Clara West, which appears to be linked to the two areas of *Molinia* and *Betula* with the swallow holes and possibly also linked to the N/S soak, has an outflow of approximately 8.85×10^{7} l $year^{-1}$. The flow is focussed toward the southern edge of the bog as the bog slopes in that direction. Both Shanley's Lough and the North/South soak run parallel to the slope of the bog. This flow of water can have several ameliorating effects on the vegetation. The main effects that lateral water movement through an area may have on the associated vegetation are: increased ion supply, increased dissolved oxygen levels and the removal of toxic elements.

The rate of supply of mineral ions to the roots of plants, where there is lateral water movement, is greatly increased as ions are brought in from the surrounding area (Newbould and Gorham, 1956; Sparling, 1966; Ingram, 1967). This means that a more nutrient demanding vegetation may be supported in the soak area, although the ionic concentrations in the water are low.

In waterlogged soils, oxygen concentrations are generally low, as the rate of gaseous diffusion in water is 1/10,000 of that in air (Greenwood, 1961). Thus oxygen is quickly depleted in waterlogged peat. Dissolved oxygen levels may be increased where there is laterally flowing water through an area, owing to turbulence incorporating oxygen into the water (Sparling, 1966; Armstrong and Boatman, 1967). Elevated oxygen levels would increase root activity and the redox potential of the peat.

Under the anaerobic conditions that occur in waterlogged soils, iron and manganese are reduced to their more soluble forms and may reach toxic levels for some plant species (Jones and Etherington, 1970). Rutter (1955) suggests that lateral water movement may play a role in the flushing away of these toxins.

7.4 MINOR INVESTIGATIONS.

Some minor investigations were made to test the hypothesis that Shanley's Lough is a focussed flow feature. These included direct observations and some laboratory procedures.

Plant Species indicating water movement

Some plant species are known to indicate water movement. Species lists for the area included some such species, for example *Carex nigra*, *Molinia caerulea* and *Myrica gale*. The occurrence of *Carex nigra* in bogs is usually associated with some degree of water movement or mineral enrichment (Jermy et al., 1982). As no significant enrichment has been recorded at Shanley's Lough, the presence of this species at this soak suggests water movement through the area. This species was also recorded by Osvald (1949) (*Carex fusca*) at the Edenderry soak site. The tussock growth form of *Molinia caerulea* suggests a fluctuating water table or water movement through an area (Jefferies, 1915). The *Molinia caerulea* communities of Shanley's Lough consist only of the tussock growth form. *Myrica gale* is also thought to be associated with water movement when it is seen growing in water logged situations. This is because the mycorrhizal activity associated with the root systems requires a relatively high oxygen supply to function. This supply is provided, to a certain extent, by root activity (Armstrong, 1985). However *Myrica* tends to be located in areas where there is some degree of water movement and appears to thrive better in these areas. This water movement would increase the oxygen supply to the mycorrhizas.

Peat Properties

The basic factors which influence the plant community distribution on a bog are: the amount of seepage (rate of water movement), the water table level and fluctuation and hydrochemistry (Ivanov, 1981). The water chemistry of Shanley's Lough differs little from the surrounding area and water table levels and water table fluctuations are not notably different. Therefore the assumption is that seepage is the major influencing factor on community distribution. Seepage may be defined as the total amount of water moving through an area per unit of time (Ivanov, 1981). One of the determining factors on the rate of water movement through peat is the hydraulic conductivity or permeability of the peat (Rycroft et al., 1975). The hydraulic conductivity of the peat in water trackways or soaks has been shown to be higher than that in the surrounding area. Ingram (1967) showed that the hydraulic conductivity in a *Molinia/Myrica* water track (similar to that seen at the southern edge of Shanley's Lough) was 2×10^{-2} cm/day, as compared to 8×10^{-3} cm/day in the mire expanse. The hydraulic conductivity of peat is a difficult parameter to measure, as the variations in botanical composition and humification cause great differences in measurements and methods are complicated (Ingram, 1967; Rycroft et al., 1975). However a relationship between bulk density of peat and its hydraulic conductivity was established by Boelter (1970). This enabled a swift comparison to be made between the hydraulic conductivity of the soak area and bog expanse.

Three peat cores were taken from within the *Molinia* dominated community and three from outside. These were 40 cm long and were divided into four 10 cm sections for analysis.

Loss on Ignition (L.O.I.) was determined using the following method:
$1.0 \text{ g} \pm 0.01$ g of oven dried (70 ^{0}C) milled peat was ignited gradually for a period of 6 hours to 500 ^{0}C and then weighed, after cooling in a desiccator.
L.O.I. = Initial weight of sample - Final weight of sample.
Bulk density was then calculated using the correlation of %L.O.I to bulk density (Jeffrey, 1970): where Bulk Density = 1.482-0.6789 log X(g cm^{-3}) when X=% L.O.I.

This showed that samples collected from within the area of *Molinia* and *Betula* at the soak site had very similar bulk densities to those peats from outside the area of *Molinia*. The average bulk density values for the cores from the *Molinia* dominated area were 0.1350 ± 0.003 g cm^{-3}, while those from outside the area had an average value of 0.1342 ± 0.002 g cm^{-3}. However the top 10 cm of peat from within the *Molinia* dominated area had a slightly higher bulk density (0.1388 ± 0.005 g cm^{-3}) than the top 10 cm samples from the ombrotrophic peat outside the soak area (0.132 ± 0.001 g cm^{-3}). This may support the view that Shanley's Lough formed as the result of peat shrinkage causing a depression through which water is funnelled (J. Streefkerk, pers. comm.). It does not support the view that the hydraulic conductivity of the peat in these areas is higher. However it is possible that the layer of more permeable peat, through which greatest water flow occurs, is deeper than the samples examined. This is suggested by the swallowholes in the two small *Betula/Molinia* areas mentioned previously, where water is flowing at least 1 metre beneath the bog surface. Spieksma (1993) concluded, after a study on the subsidence of Clara West, that the bulk density of peat in the area of Shanley's Lough did not suggest strong local subsidence.

The second important influence on the rate of seepage is relief. In sloping areas of the bog the rate of water movement will be faster, owing to the gradient effect. This seems to be the main influence at the Shanley's Lough site, as the extensive peat cutting to the south of the soak has caused an increase in the slope of the bog surface towards the cut-away. This is due to peat subsidence at the bog edges caused by the drainage effect of peat cutting, reducing the water content of the peat and thus altering its structure.

Ion Supply

Newbould and Gorham (1956) compared the mineral content of *Schoenus nigricans* in a flushed area, to that of plants outside the soak area. The water flowing through the soak had similar ionic concentrations to the rest of the bog. However they found that the flushed site plant samples had 1.25 times as much calcium as the bog samples and almost twice the percentage of ash. This implies that the total mineral uptake per unit area is greater within the soak site and thus there must be a greater absolute supply.

To test whether this hypothesis is true in the case of Shanley's Lough, an estimation of the nutrient content of *Molinia caerulea* in the *Molinia caerulea* dominated communities at the Shanley's Lough soak site on Clara West was made. Three harvests of *Molinia caerulea* were taken on the following dates: 12th of May, 13th of September and the 14th of December, 1992. Three sites were sampled at each of these harvests. A 20 cm^2 area was clipped for above ground biomass and the material was placed in plastic bags for transportation to the laboratory. Below ground biomass was harvested by the removal of a 20 cm^2 monolith from beneath the clipped area to a depth of approximately 40 cm, or until no root mass was visible.

The above ground biomass was divided into the following categories:
1. Standing live (SL)
2. Standing dead (SD)
3. Culm live (CL) (the culm being the swollen leaf base).
4. Culm dead. (CD)

The below ground biomass was separated into a number of categories. *Molinia* roots are of two types: tough fibrous roots(>0.5 mm), which are easily separated and fine roots (<0.5 mm), which are difficult to isolate. In the larger root category, live and dead roots were distinguished using the following criteria: live roots, being those which were creamy yellow in colour and fully turgid; dead roots which ranged from light brown to black and were in various stages of decay. Adequate criteria could not be established for the separation of the finer root category into dead and live and they were therefore grouped into one category; roots < 0.5 mm. The root categories are:

1. > 0.5 mm roots live
2. > 0.5 mm roots dead.
3. < 0.5 mm roots live and dead.

All categories were oven dried at 70 ^0C for 24 hours and dry weights were recorded for biomass estimation. All plant tissues were then milled, using a Cyclotec 1093 Sample Mill with a mesh size of 0.5 mm, in preparation for nutrient analyses. The analyses carried out are described in Appendix 7.1.

As there are no areas on Clara outside the soak systems where *Molinia* grows, apart from cut-away sections, the mineral content of *Molinia* from Shanley's Lough was compared to that from other studies.

The nutrient content (mg g^{-1} of tissue) of the standing live material from May, 1992 is illustrated in Fig. 7.12, where it is compared to the nutrient content of *Molinia caerulea* from other sites. The results of Allen et al. (1974) correspond closely to those of the May harvest at Shanley's Lough. The concentrations of N, P, K, Ca and Mg are similar for all four studies, indicating that the *Molinia caerulea* at Shanley's Lough is not surviving under low nutrient conditions. The high level of nitrogen in the May samples may be accounted for by low biomass early in the growing season when tissue concentrations are still high. The later harvest in September shows lower levels of nitrogen, corresponding to higher biomass. However concentrations of calcium increase in the tissue later in the year, suggesting that calcium accumulation is occurring.

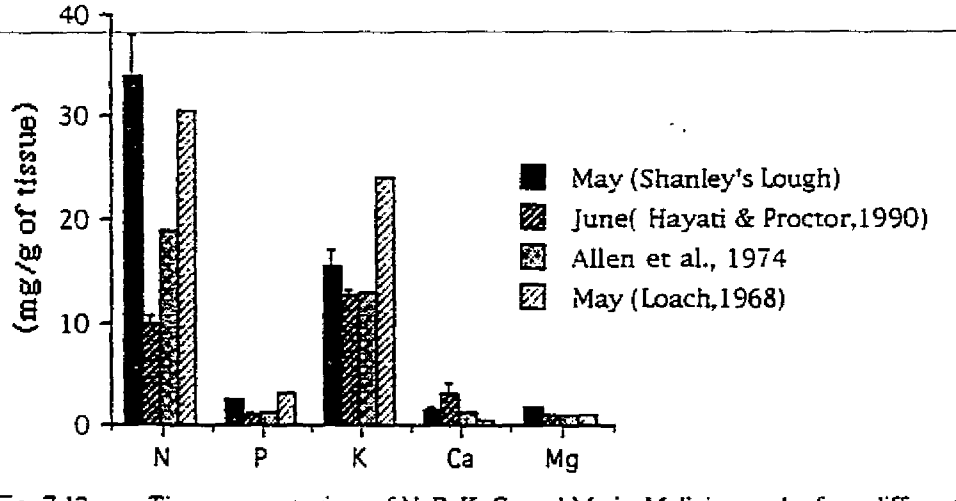


Fig. 7.12 Tissue concentrations of N, P, K, Ca and Mg in *Molinia caerulea* from different studies.

Research on heathlands in The Netherlands has shown that *Molinia* out-competes *Erica tetralix* under conditions of higher nutrient availability due to atmospheric pollution (Aerts, 1989). In a heathland

136

community dominated by *Erica tetralix* and *Molinia caerulea*. *Molinia* was shown to have an above ground biomass in September (maximum) of 520 g m^{-2}, while *Erica tetralix* had a net primary production of 376 g m^{-2} $yr.^{-1}$ (Aerts and Berendse, 1989). At Shanley's Lough, the above ground biomass in September, 1992 of an almost mono-dominant stand of *Molinia* was 820.6 g m^{-2} (below ground 835.8 g m^{-2}). The annual production of a raised bog has been estimated at 643g m^{-2} $yr.^{-1}$ (Madden and Doyle, 1990).

This area has not been examined in depth and thus the main conclusion that may be drawn is that the *Molinia caerulea* community at Shanley's Lough is characterised by high productivity and high turnover, which is in direct contrast to the communities of typical raised bog plant species. This suggests that although the hydrochemistry of Shanley's Lough is similar to the rest of the high bog, the plant communities have an increased absolute supply of nutrients due to focussed flow of water through the area.

7.5 SOAK PLANT COMMUNITY HYDROLOGY AND HYDROCHEMISTRY.

In addition to the investigations into the functioning of the main soak systems on Clara Bog, a more detailed study was made into the relationship between the different soak communities and their hydrological and hydrochemical parameters.

Initially the hydrochemistry and water table measurements from all the soak relevés (average values for August and October, 1991) were used, in conjunction with their associated vegetation data, to run a canonical correspondence analysis (CANOCO (CCA), see Chapter 4). The first CCA run indicated high collinearity between a number of variables. A second analysis was performed with the variable Fe excluded, as it had high correlations with other variables. It was later added to the ordination plot by passive analysis. The result of this analysis was, again, to exemplify the difference between the two soak systems (Fig. 7.13) (the species plot is shown in Appendix 7.2 (a)). The eigenvalues for the axes were 0.592, 0.331, 0.256 and 0.193. The first axis is positively correlated with the variables Ca, Mn, Fe, alkalinity, K_{corr} and pH and is negetavely correlated with Na. The second axis is most strongly correlated with the variables Cl and Mg. The variables Ca, Mn, alkalinity, Fe, K_{corr} and pH are all correlated with each other, while Cl, Mg and Na are all correlated with each other. Alkalinity is negatively correlated with SO_4. The ordination plots of the relevés and environmental variables show a division of most of the Lough Roe sites to the side of the plot, which indicates minerotrophic conditions, that is, with high values of pH, K_{corr} calcium, alkalinity, iron and manganese. In contrast, the Shanley's Lough sites plot out on the ordination diagram negatively related to the above parameters but positively related to sodium, chloride and sulphide, indicating the system's ombrotrophic nature. Due to the number of samples included in this analysis, not all relevés could be identified on the ordination plot. However with reference to the solution files from CANOCO, the situation of the community types has been indicated. This shows that the species assemblages of the central communities of Lough Roe (5C, 5B, 5A, 6 and 8Ab) are more closely related to the ground water indicators than the sub-central and marginal communities (8B, 8C, 11 and 8Aa). It also illustrates the point that the *Betula* woodland, *Betula* scrub and *Molinia* communities of Shanley's Lough are closely related to high levels of Na and Cl, with some influence of higher K values. The latter may be related to a higher turnover of plant litter as *Molinia* and *Betula* are both deciduous and K is easily leached from the dead leaves. High K values were found in water samples from bog pools by Boatman et al. (1975). They associated these high levels with the occurrence of *Molinia* leaf litter in the pools. The more ombrotrophic communities of Shanley's Lough occupy an intermediate position on the ordination.

A second canonical correspondence analysis was used with the average of one year's abiotic values of the selected soak sites (August, 1991-July, 1992). This included nine community types and showed that the above differences between the two soak sites are continuous and not affected by seasonality. Inflation factors were high, indicating collinearity or close correlations between variables, in the first run for a number of variables. In response to this, a second run was made with the following factors excluded: pH, SO_4, Fe, Mn, K_{corr}, Na and Alkalinity. These were later added to the ordination plot by passive analysis. The eigenvalues for the axes were 0.858, 0.691, 0.506 and 0.299. The first axis is most closely correlated with Ca, NO_3 and Cl and the second axis is correlated with NH_4 and water table fluctuation. The following environmental variables are correlated NH_4 and orthophosphate, Ca with Cl and NO_3 and NO_3 with water table depth. The ordination plots from this CCA are shown in Fig. 7.14 (the species plot is shown in Appendix 7.2 (b)). The pH and pH related parameters have the longest vectors. Thus they are most strongly correlated to the ordination axes and are therefore closely related to

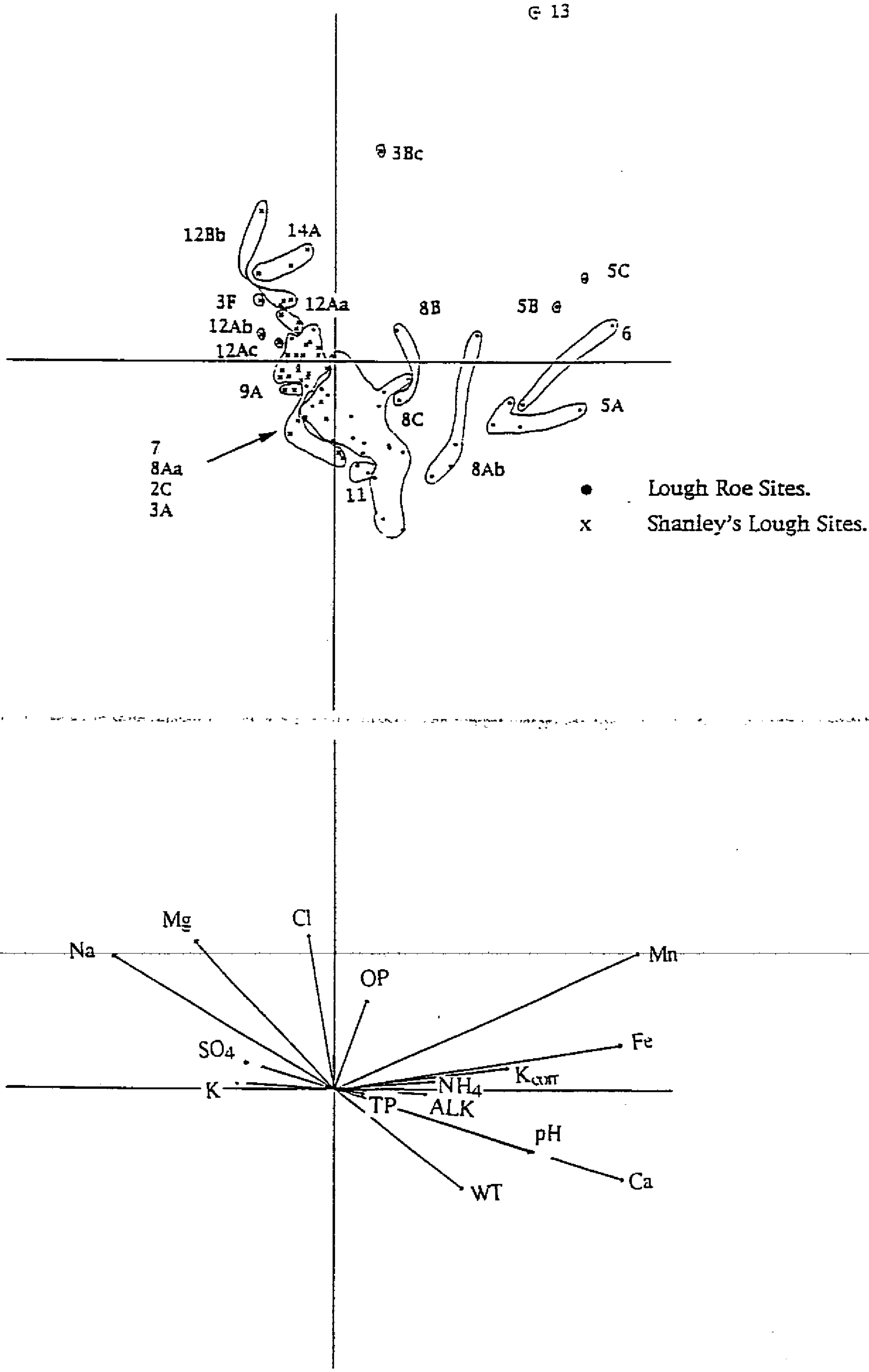


Fig. 7.13 Ordination plots of the soak sites obtained from CCA of the average values from the August and October, 1991 data.

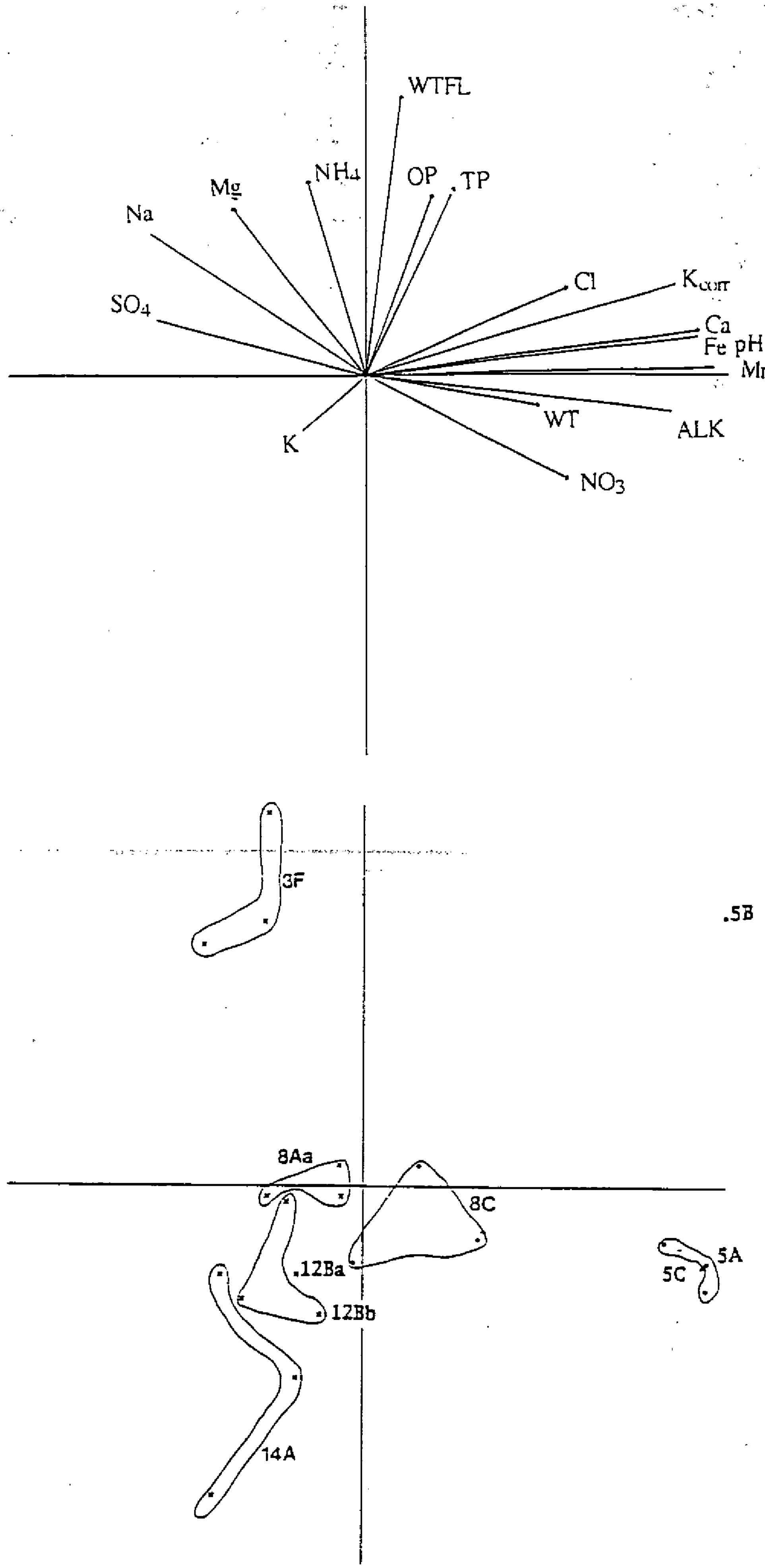


Fig. 7.14 Ordination plots of the soak sites obtained from CCA of the average values from August, 1991 to July, 1992.

the communities, or species composition, of the plots on that side of the ordination diagram. The central communities of Lough Roe such as the variant with *Nuphar lutea* (5B), the variant with *Sparganium erectum* (5C) and the typical variant of the community of *Carex rostrata* and *Drepanocladus fluitans* (5A) are associated with high levels of Fe, Mn, K_{corr}, alkalinity and pH, all of which indicate a ground water influence. The vector of NO_3^- also lies to the side of the Lough Roe communities. This was unexpected as the presence of NO_3^- is usually associated with non-flooded situations. However NO_3^- has been shown to be associated with flushed or poor fen vegetation by other workers (Hayati and Proctor, 1990). The community of *Aulacomnium palustre* lawns (8C) falls into an almost intermediate position on the ordination diagram. This confirms the suggestion made earlier, that the edges of Lough Roe are more ombrotrophic than the central section. The Shanley's Lough communities are all on the ombrotrophic side of the ordination. The *Myrica* and *Molinia* community sites are closely related to water table fluctuation. This may result in higher mineralisation rates, as phosphate levels are also higher. The *Molinia* dominated community type (14A) and the *Betula* communities (12Ba and 12Bb) are ombrotrophic and have low water table fluctuations and are again associated with higher K levels. The small fluctuations in water table height are unexpected, as the *Betula* trees in these communities can be tall (6 metres). Their presence, in this high water table, low water table fluctuation site, indicates that there must be a significant water flow through the area in order to provide sufficient oxygen to their roots. The *Betula* woodland at the Addergoole site is growing under similar conditions of high water table. The community of *Sphagnum recurvum* lawns (8Aa) occupies an intermediate position on the ombrotrophic side of the ordination.
The Monte-Carlo permutation test was applied to both these ordinations to test the significance of species and environment relationships. The test showed that for the mean data from August and October the first axis was statistically significant in its relation to species and environmental variables ($P < 0.05$). The overall test also proved be be highly statistically significant ($P < 0.01$). For the ordination plot of the mean values from the year's data of the selected sites the overall test was significant ($P < 0.05$). However the test of the first ordination proved not to be significant. This is often the case where the number of environmental variables is close to or greater than the number of samples.

In total twenty soak communities were identified and average water table depth, pH and corrected conductivity values (K_{corr} μS cm^{-1}) were calculated for each type. These data are summarised in Table 7.1. Using this information and the water classification of Stuyfzand (1990), the typical water type for each community is shown in Table 7.5.

Table 7.5 Soak community water type classification.

Community	Water Classification
3F	NaCl all year
5A	CaCl and $CaHCO_3$
5B	$CaHCO_3$ and CaCl
5C	$CaHCO_3$ and CaCl
6B	CaCl and $CaHCO_3$
7	NaCl all year
8Aa	NaCl and MgCl
8Ab	CaCl and NaCl
8B	NaCl all year
8C	CaCl and NaCl
9A	NaCl /$NaHCO_3$
11	NaCl/CaCl/$NaHCO_3$
12Aa	NaCl all year
12Ab	NaCl/MgCl/$NaHCO_3$
12Ac	NaCl all year
12Ba	NaCl all year
12Bb	NaCl all year
13	CaCl all year
14A	NaCl all year
14B	NaCl all year

The communities of Shanley's Lough are all classified as NaCl and MgCl types, whereas those of Lough Roe are more variable. The sub-central and central communities of Lough Roe, as mentioned above, are the most mineral rich of the soak communities.

The sub-central communities of Lough Roe correspond to the *Carex rostrata-Sphagnum squarrosum* mire described in the National Vegetation Classification (Rodwell, 1991). Rodwell states that this community type is commonly found in zonations related to variations in water table and cation status. This also seems to be the situation at Lough Roe, where there is a central point source of enrichment and high water table, corresponding to the position of the vegetation communities 5C, 5A and 5B. As the vegetation communities change towards the edges of the feature so does the water chemistry. This is illustrated in Fig. 7.15 (a) and (b) where the communities on the x-axis correspond to a transect across Lough Roe, east to west (See Lough Roe vegetation map). These illustrations highlight the differences between the marginal Lough Roe communities and the central communities. Average pH, K_{corr} (μS cm-^{1}) and water table level are all higher in the central Lough Roe communities.

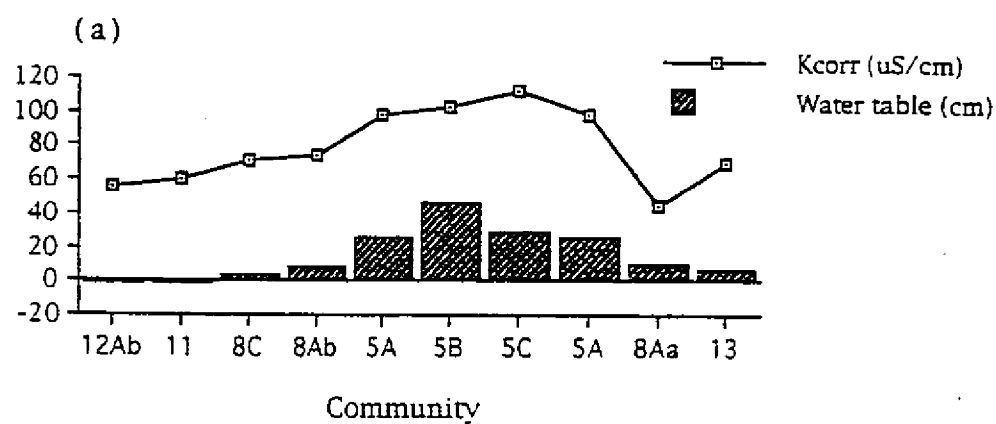


Fig. 7.15 (a) Water table (cm) and K_{corr} (μ Scm^{-1}) transect across Lough Roe.

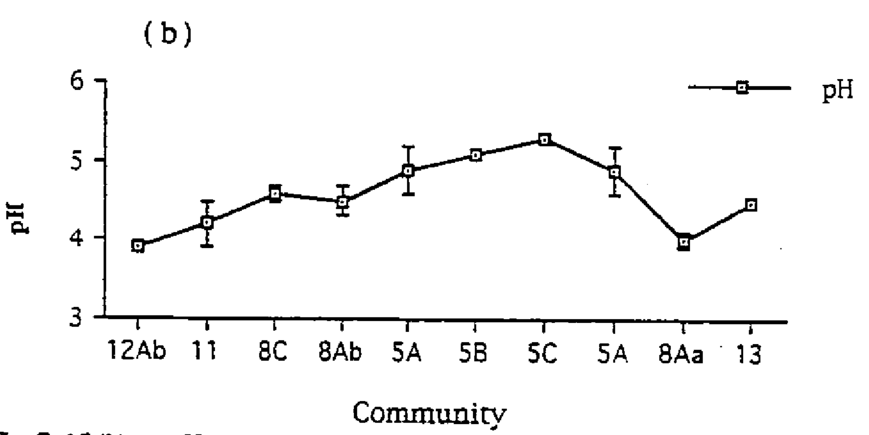


Fig. 7. 15 (b) pH transect across Lough Roe.

The average Ca levels measured in the central communities (5-12 mg l^{-1}) agree with those recorded in similar community types (5-16 mg l^{-1}) (Proctor, 1974). A transect of average calcium concentrations (± 2 standard errors) across Lough Roe shows the highest levels in the central area (Fig. 7. 16).

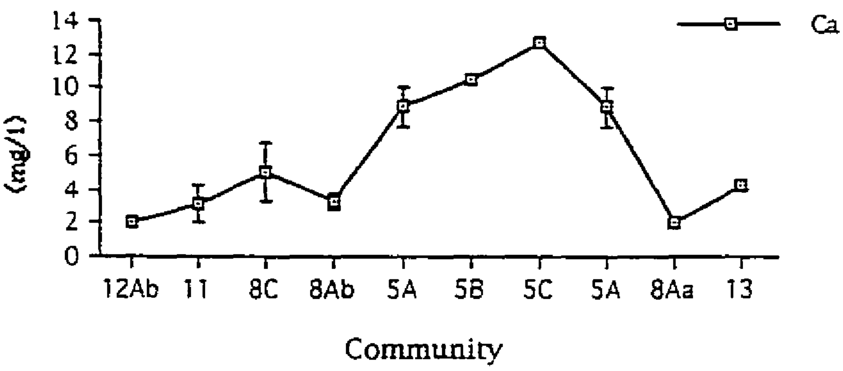


Fig. 7.16 Transect of the calcium (± 2 S.E.) concentration in waters across Lough Roe.

7.6 CONCLUSIONS.

The main conclusions that may be made from the investigation of the hydrology and hydrochemistry of the soak systems on Clara Bog are:

1. That Shanley's Lough and Lough Roe differ significantly, in their origins, vegetation and hydrochemistry. The former being a relatively recent feature of an ombrotrophic nature possibly resulting from a bog burst. A more likely explanation is that the sunken area in which it is situated, and through which the water flows, may be the result of drainage causing subsidence in what would have been areas of peat with the highest water content. This subsidence would have created a larger water catchment area, which may have resulted initially in the ponding of water in one area (the open water pool) and, as water flows increased, with the possible addition of an event such as a fire, the vegetation types that occur today became established. Lough Roe appears to have existed since the initiation of the raised bog and the vegetation indicates mesotrophic conditions.

2. That Lough Roe is a relict feature and is presently in transition to more ombrotrophic conditions. As the balance is tipped towards more oligotrophic or base poor conditions, ombrotrophic communities become dominant. Rodwell (1991) suggests that as this balance is tipped *Betula /Molinia* woodland (the *Sphagnum* or *Juncus effusus* sub-communitiy) takes over from the *Carex rostrata/Sphagnum squarrosum* mire. This process appears to be occurring in the sub-marginal areas of Lough Roe, where *Molinia* and scrub *Betula* are starting to encroach.

3. That the initial investigations into the bulk density (thus hydraulic conductivity) of Shanley's Lough peat shows that it has values similar to the surrounding ombrotrophic peat. This is supported by the findings of Spieksma (1993). The top layers of ombrotrophic peat normally have high hydraulic conductivity values in the region of 10^{-1} m s^{-1} (Hobbs, 1986), if the acrotelm layer is functioning correctly (see Chapter 8). Thus the area will have relatively high hydraulic conductivity anyway. The main point of interest is that the topographic maps indicate that it is a sunken area and is thus a focussed flow feature, with large volumes of water flowing through a restricted area.

4. That of the other, minor soaks on Clara, the one south of Lough Roe may have been similar to Lough Roe, while the others are more similar to Shanley's Lough.

5. That Shanley's Lough will probably survive as long as drainage through the area is not impeded. It is also possible that this type of soak system only represents a phase following disturbance, such as drainage and peat cutting. There are some indications that the open water pool is filling in, as *Sphagnum cuspidatum*, *Eriophorum angustifolium* and *Carex rostrata* continue to encroach.

42

CHAPTER: 8 VEGETATION AND COMBINED MAPPING.

8.1 INTRODUCTION.

The mapping of the vegetation cover on the two bogs was considered to be an integral part of this investigation, as a means of linking the patterns observed in vegetation with the prevailing environmental conditions. In addition, the knowledge of plant community distribution was considered necessary for the formulation of management proposals. The main objectives of the mapping exercise were as follows:

1. To illustrate, at an appropriate level of resolution, the present distribution of plant communities on the two bogs.
2. To provide a base for the extrapolation of the ecological (Chapter 3), hydrological and hydrochemical information (Chapters 5 and 6), gathered from within small sample units, to the whole bog.
3. To provide the hydrologists with the ability to link hydrological regimes to vegetation patterns.
4. To provide a base for work in the future, for example an investigation into vegetation succession after restoration work has taken place or, if restoration does not occur, to monitor further changes.
5. To highlight areas of special interest, such as soak systems or possible discharge sites.
6. To aid in the decisions concerning where restoration work is necessary and where it should take place.
7. To discover the possibility of using certain community complexes as indicators of particular environmental conditions.

The use of aerial photography was considered to be the most suitable method for mapping the vegetation, as it was the quickest and most accurate method available.

Little information was available on the mapping of peatland vegetation communities apart from the compilation of very small scale maps. Some work has been carried out in Northern Ireland on the use of aerial photography to distinguish different blanket bog peatland types, but not communities or community complexes within a peatland type (Tomlinson, 1984).

The main disadvantage of aerial photography in mapping peatland vegetation is that, because of the nature of bog vegetation, the bog surface appears almost smooth on aerial photographs. This is particularly the case when using black and white photography. This problem can be almost completely eliminated with the use of colour photography, as the colour contrasts of the vegetation help to separate community types. The other, most important, problem which also applies to the drawing of maps using other methods, is the drawing of vegetation boundaries. The variation between most plant communities is continuous and thus they gradually grade into their adjacent community (Mueller-Dombois and Ellenberg, 1974). Boundaries, drawn on maps during this study, correspond as closely as possible to boundaries in the field. However the assumption can be made that, in most cases, there is a gradual change between adjacent community complexes.

8.2 MAPPING METHODS.

Black and white stereoscopic pair aerial photographs of the two bogs were taken by the Ordnance Survey of Ireland on the 23rd of May 1991: Nos. 8134-8137 cover Raheenmore Bog; Nos. 8144-8150 cover Clara Bog.

Oblique colour photographs were taken by the Photographic Division of the Irish Army in April, 1992. The scale of the black and white stereoscopic pair aerial photographs is approximately 1:10,000 and the colour photographs vary from approximately 1:5,000 to 1:2,500, due to the altitudinal range of the aircraft during the photography.

Vegetation mapping was undertaken on the two bogs during the summer of 1992. This included the mapping of the high bog, including the soak systems and marginal areas.

Initial maps were drawn using the black and white stereo photographs to establish boundaries, such as face-bank edges, which were not illustrated on the Ordnance Survey map of the area. These outline maps were then corrected and scaled to match the Ordnance Survey map of the area. This was necessary, as all maps used during the project had to have the Ordnance Survey map as their baseline. The main distinct vegetation boundaries were also included at this time. The black and white photographs were useful for distinguishing different textures in vegetation types and, as they were vertical photographs, were more suitable for drawing scaled maps (Howard, 1970). The colour photographs, although oblique, were the most satisfactory as, in addition to the advantages of colour, they were on a larger scale. An extensive ground survey was then carried out to establish other, less distinct, boundaries and to ground truth the initial boundaries. Some types were easy to recognise on the photographs, but in all cases areas had to be visited to ensure their validity.

A classification of communities on the two bogs had been established from the vegetation work in 1990, 1991 and 1992 (Chapter 3). However, as most of these communities are restricted in size to less than one square metre, vegetation maps had to be drawn on a community-complex level, where a community type is treated like a species in a relevé (Mueller-Dombois and Ellenberg, 1974). Using this method, a community-complex type on the vegetation map is made up of a mosaic of community types. A percentage cover of a community type can be estimated within a community-complex. In this instance community types are just listed in order of importance after the community-complex name. This method has been shown to be the most suitable for raised bog vegetation (Schouten, 1990).

For convenience, Clara was divided into two for mapping purposes: Clara East, the drained section and Clara West, the relatively intact part. Raheenmore Bog is represented on one map.

A scale of 1:5,000 was considered to be the most suitable for the vegetation maps. Derivative maps, such as desiccation and ecotope maps, were reduced to 1:10,000 as less detail was required.

8.3 VEGETATION COMPLEX MAPS.

The following is a description of the plant community complexes, found on both bogs, which are illustrated on the black and white patterned vegetation maps (Appendix 8.1 Raheenmore (8.1a), Clara West (8.1b) and Clara East (8.1c) (see back pocket)). The key to these maps is in Appendix 8.1d.

The plant community types included in the descriptions below are from the vegetation analyses carried out during the summer seasons of 1990/1991/1992 on both Raheenmore and Clara bogs (See Chapter 3).
The acrotelm information was obtained from the acrotelm maps of Clara (Van der Cruijsen et al., 1993) and the acrotelm transects on Raheenmore of Van 't Hullenaar and Ten Kate (1991) (See section 8.7).
The complexes have been placed under a number of headings depending on their proximity to the bog edge.

The face-bank division includes only one complex, with a limited community diversity seen on the top of the cut-away banks. Although this complex surrounds most of the two bogs, it does not extend far into the bog expanse. It is a typical complex of raised bogs, where the edges have been exploited, leaving dry elevated sections. It corresponds closely to the *Calluna* heath described by Osvald (1949) and the *Calluna* community of Hammond et al. (1990).

The marginal complex division contains six community complexes, all of which indicate disturbance to the bog. The drainage disturbance and the effect of marginal peat cutting on Clara has increased the extent of these marginal complexes. On Raheenmore the deep marginal drain has ensured that they are also widespread.

The *Trichophorum cespitosum* complex was also described by Osvald (1949) as a marginal complex inside the *Calluna* heath, which is similar to where the *Trichophorum cespitosum* complex occurs on these two bogs.

The section of sub-marginal communities contains three complexes, which indicate some disturbance yet still contain some community types of less disturbed conditions.

The sub-central section has two divisions: those influenced by drainage and those which are not so affected by drainage. The former contains complexes whose communities have a high *Calluna* cover but still have a moderate *Sphagnum* cover. The undrained areas are mostly transitional complexes, where the gradual drying out of the bogs has caused a change in plant communities. They generally have a moderate to abundant *Sphagnum* cover, but are very variable.

The soak associated division contains two complexes, both of which are seen on Clara East. These complexes appear to be linked to or influenced by the Lough Roe soak.

The two community complexes in the central section are the hummock and hollow complexes that are typical of the central areas of raised bogs (Godwin and Conway, 1939; Osvald, 1949; Schouten, 1984; Cross, 1990). They correspond to the wettest areas, characterised by an abundance of *Sphagnum*.

The soak complexes can be included in two broad divisions: the Lough Roe complexes, which indicate a ground water influence and those which indicate enrichment but that enrichment not originating from ground water (See Chapter 7).

A: Face-bank.

1. Face-bank Complex (Plate 22).
   This complex consists mainly of the community type 4G in which *Calluna vulgaris* is the dominant species, reaching cover values of up to 100%. *Calluna* thrives here where the low watertable enhances mineralisation and aeration. Few typical bog species survive in this environment and the number of community types is restricted, apart from 4G, to predominantly *Narthecium* hollows (3A), *Trichophorum cespitosum* (3E), burnt flat communities (3D), occasional burnt and underdeveloped hummocks (4A & 4B) and *Rhynchospora alba* hollows (1).
   An acrotelm does not occur where this community complex is found and the whole complex is indicative of the disturbance of marginal areas due to peat cutting. This disturbance has caused subsidence of the bog edge and has increased the slope of the bog surface in these areas to more than 0.25%, over which no acrotelm is found (Van der Cruijsen et. al., 1993).

B: Marginal Complexes.

2. *Trichophorum cespitosum* Complex (Plate 22).
   This complex also indicates disturbance. The community of *Trichophorum cespitosum* (3E) is the most abundant. *Trichophorum cespitosum* with high abundance values is usually associated with past disturbances, such as burning or drainage. Again *Narthecium* hollows (3A) are an important element, with burnt community types and *Rhynchospora alba* hollows (1) also occurring. An acrotelm is mostly absent from under this complex but it occasionally occurs in the class 0-5 cm.

3. *Carex panicea*/burnt Complex.
   This is a common community complex on Clara bog, particularly on the northern and roadside areas. It is again a complex where disturbance has occurred and where fire has probably been an important factor. 3D and 4B are the dominant community types with *Rhynchospora* (1) and *Narthecium* hollows (3A) also frequent. *Carex panicea* is an indicator of mineralisation and tends to occur on the margins of raised bogs in the midlands (Doyle, 1982). It is interesting to note that this marginal complex type is absent from Raheenmore, the more easterly site. Doyle (op. cit.) mentions that it occurs on the more westerly of the midland raised bogs. No acrotelm occurs under this community type.

3a. *Carex panicea* /*Narthecium* Complex.
   In some sections of Clara the two former complexes are combined, where the burnt community types are co-dominant with the *Narthecium* hollow communities. Disturbance, fire and drainage have had an effect here and an acrotelm is usually absent.

4. *Rhynchospora alba* Complex (Plate 23).
   There are some areas on Clara where *Rhynchospora* hollows (1) are the dominant community type over a small area. This is also a marginal complex type indicating disturbance and consequently an acrotelm is rarely found under it.

5. *Rhynchospora fusca* Complex.
   Rhynchospora fusca hollows occur on the marginal areas of Clara West and in a large drained section of Clara East. This complex also has communities indicating disturbance, as the drainage of Clara East has had a serious effect on the community types of this area and most of the complexes found there fall into the marginal/disturbed category. The acrotelm depth in this complex is mostly 0 cm; occasionally it covers acrotelm in the category 0-5 cm.

5a. *Rhynchospora fusca*/ *Carex panicea* Complex.
   The above type also occurs with the addition of the *Carex panicea* type complex including many burnt community types. The acrotelm depth varies from 0-5 cm and occasionally can be 10 cm.

C: Sub-marginal Complexes.

6. *Narthecium* Complex (Plate 24).

This complex is dominated by the community of *Narthecium* hollows (3A). These tend to be elongated features, as they are focus points for surface water run-off. The *Rhynchospora* hollows (1) are also common. This complex has similar features to the *Trichophorum cespitosum* complex, with burnt community types occurring frequently. Although the community of *Narthecium* hollows occurs over the whole bog, *Narthecium ossifragum* flourishes best where water table levels are lower (Daniels, 1975).

6a. *Narthecium*/ *Calluna* complex.

This complex is found mainly on the southern section of Raheenmore, in the area between the Face-bank complex and the transitional *Sphagnum magellanicum* complex. *Narthecium* hollows (3A) are frequent as in the above complex but an higher cover of *Calluna* is found (4A and 4B). Probably a slightly drier version of the above complex.

3b. *Carex panicea*/ *Dactylorhiza maculata* Complex (see above).

One marginal area of burnt community types occurs, with *Dactylorhiza maculata* in noticeable amounts, on Clara west. In this section the acrotelm is not quite so degraded, covering the category 0-5 cm. The presence of *Dactylorhiza maculata* indicates some evidence of mineralisation, as it is only normally associated with bog margins (Webb, 1977). Its presence here is possibly due to decreased water levels, fire history and proximity to the soak.

D: Sub-central Complexes.

D1: Sub-central Complexes affected by Drainage.

7. *Calluna vulgaris* Complex.

On some marginal and high bog areas, *Calluna* has an high abundance but the complex does not consist of the community type 4G. The marginal areas where it occurs usually have no acrotelm, but occasionally it covers the 0-5 cm acrotelm depth class. When this community type occurs on the more central areas of the bog, it is usually associated with ridges or slightly elevated areas such as north of the mound on Clara West and east of the soak on Clara East. The community types 4A, 4B and 4E are important.

7a. *Calluna vulgaris*/ *Eriophorum angustifolium* complex.

The above complex can also occur with the addition of areas where *Eriophorum angustifolium* is abundant. This complex usually has no acrotelm but occasionally covers areas where the acrotelm reaches 10 cm in depth. The areas with a higher abundance of *Eriophorum angustifolium* tend to occur in the slightly wetter areas of this complex and are therefore the sections with some depth of acrotelm. As *Eriophorum angustifolium* is a coloniser of bare peat (Rodwell, 1991), its presence here may be associated with the drainage of the area which resulted in the exposure of bare peat.

8. *Sphagnum imbricatum* Complex.

This is a relict complex located on the north-west of Clara with many *Sphagnum imbricatum* hummocks. Very few pools occur and the intervening low lying areas are dominated by *Narthecium* hollows (3A). It is over grown by *Cladonia portentosa* with a cover of 90-95%. This complex has probably survived as a relict community as it has escaped burning for some time. This is suggested by the abundance of *Cladonia portentosa* and also by the fact that it is surrounded by complexes containing burnt community types. The complex covers an area with a poor acrotelm. This is unusual, as *Sphagnum imbricatum* hummocks are normally associated with areas of active *Sphagnum* growth.

D2. Sub-Central: No drainage effect.

9. *Eriophorum vaginatum* Complex.

This complex consists mainly of the community type 4A with a high abundance of *Eriophorum vaginatum* and the community types 4B and 3D, indicating a fire history. The acrotelm depth varies within this complex mostly in the classes 0 to 0-5 cm, where burning is indicated. In some areas the acrotelm depth can be 10 or 20 cm.

10. Transitional *Sphagnum magellanicum* Complex.

This is a very variable complex as regards acrotelm thickness due to the fact that it is a transition type. It consists mainly of the communities 3Bb and 3A but also 3Ba and 2A. It occurs extensively on the central section of Clara West where it spans great ranges in acrotelm depth. After hydrological consultation it was decided that the slope factor may be important in the areas where the acrotelm is absent. In these areas the complex is probably tending toward the *Narthecium* Complex type. This complex type should respond quickly to restoration measures as, before drainage effects reached into the bog centre, this area would most probably have been in the hummock, hollow and pool complex type.

11. Hummock/ Hollow orientated pool Complex.
Some hummock and hollow areas occur, where the hollows and pools have a definite linear orientation rather than the more typical rounded shape. The orientation may be related to the direction of surface flow. The acrotelm is generally rather poor under this complex.

E. Complexes Associated with Soaks.

12. *Sphagnum magellanicum/Eriophorum angustifolium* Complex.
This complex is developed on the eastern section of Clara East. Within this area there are many remnants of old pools. The majority of these are now infilled, particularly with *Sphagnum magellanicum* and *Eriophorum angustifolium*. There is a series of pools running east/west across the complex which appear to have undergone some direct human interference. It is a possibility that these were the largest in the series of pools in this area and were further excavated by hand to encourage ducks to frequent them for shooting purposes. As mentioned previously, the infilled pools are mainly colonised by *Sphagnum magellanicum* and *Eriophorum angustifolium* (3Ba and 3Bb), with some central wetter areas still with community type 2A. The larger pools have *Sphagnum cuspidatum* and *Carex rostrata* community type (7), with the addition of species such as *Menyanthes trifoliata*, *Hydrocotyle vulgaris*, *Juncus effusus* and, in two instances, *Carex limosa*. The edges are often colonised by scrub *Betula* and *Salix* with *Empetrum nigrum/Sphagnum capillifolium* (11) and *Polytrichum alpestre/ Aulacomnium palustre* (8C). The intervening areas have mainly 3Bb and *Narthecium* hollows (3A). The numerous north to south drains running through this area have caused a variation in the community types, with the inclusion of disturbance/burnt types (4B and 3D). The central section of this complex has a well developed acrotelm, but the northern and particularly the southern edges in many instances have no acrotelm. This is probably due to the effect of drainage and the increase in slope, where the vegetation may be lagging behind the hydrological changes.

13. *Calliergon cuspidatum* Complex.
This complex is associated with Lough Roe. It is located to the north of Lough Roe and consists of a series of curved low ridges, which are apparent on the aerial photographs but are too small scale to map. The ridges consist mainly of the community type 10, with the addition of the enriched *Sphagnum magellanicum* variant (3Bc). The intervening areas are covered with the communities 3A, 3Bb, 4A and, due to the drainage disturbance, 3D and 4B.

F: Central Complexes.

14. Hummock/Hollow frequent Pool Complex.
This complex consists mainly of the community types 3Ba, 2A and 3Bb, with the addition of 4C, 4E, 4F and 3A. It is the wettest bog complex apart from the complexes within the soak systems. It is also the least disturbed complex on the two bogs and is the indicator of the most 'healthy' areas. On Raheenmore this complex is situated in the very central area of the bog. On Clara its occurrence is more fragmented but it also tends to be located in the more central areas, except for two areas on Clara where the complex has developed, possibly due to the subsidence close to the bog edges, which has created a basin type effect. Usually these areas are associated with the presence of a deep acrotelm of 30-40 cm. Occasionally this may fall to 10 cm and very occasionally to 0 cm, where it may be in transition to another type. Restoration should cause few changes in this complex type, but conservation measures are required.

15. Hummock/Hollow scattered Pool Complex.
A similar complex to the above with less of the community type 2A and more 3Bb and 3Ba. It is probably a degenerate form of the above where pools are most likely becoming progressively infilled as the bogs drain in from their edges. This is particularly apparent on Raheenmore, whereas on Clara the effect has possibly reached a further stage, with the widespread occurrence of the transitional *Sphagnum magellanicum* complex. The acrotelm under this complex reaches depths of 20-30 cm but occasionally 10 cm and very occasionally 0 cm. This complex type should respond quickly to restoration.

G: Soak Complexes.

16. Enriched *Sphagnum magellanicum* Complex.
This occurs on the periphery of the long North/South Western soak and is similar to the hummock/hollow complex with scattered pools with the widespread addition of community type 3Bc. It mostly has an acrotelm with a depth of 40 cm.

17. Enriched *Sphagnum magellanicum* with *Sphagnum cuspidatum* Complex.
This is similar to the above community type, but more centrally located in the long North/South Western soak system and with a greater abundance of the communities 2C and 3Ba. Acrotelm thickness is mostly deeper than 40 cm.

18. *Myrica gale* Complex.
This is situated to the south of Shanley's Lough on a ridge leading out from the *Calluna vulgaris* dominated mound. It consists of the community types 3A, 4A, 4B, 3D and 3E with the addition of *Myrica gale*. This area has been burnt in the recent past. There is no acrotelm under this complex.

19. *Myrica gale* and *Sphagnum magellanicum* Complex.
A wet area found to the south of Shanley's Lough. It consists mainly of the community type 3F with 3Ba, 3Bb and some 3A. The acrotelm is usually 40 cm deep.

20. *Molinia caerulea* Complex.
A complex of *Molinia caerulea* tussocks which mostly consists of community 14B with 12Ab and 14A. It occurs around Shanley's Lough, the western North/South Soak and some small soak holes to the west of the mound.

21. *Molinia caerulea* /*Myrica gale* Complex.
This complex occurs mainly at Shanley's Lough where the presence of *Myrica* possibly indicates lateral water flow. It is dominated by the community 14A. The acrotelm depth varies from 30-40 cm and is occasionally less.

22. *Betula pubescens* scrub/ *Molinia caerulea* Complex.
This complex occurs in similar situations to the above complex. It is made up of the community type 12Ab with 12Ac and 12Aa also frequent. The acrotelm depth is variable within this complex.

23. *Betula pubescens* woodland Complex.
This complex is situated at Shanley's Lough and the western North/South Soak. It consists of the community type 12Bb, with trees up to 15 metres not uncommon. Additional community types include 12Ab, 12Ac, 14A and 14B.

24. *Betula pubescens* /*Juncus effusus* woodland Complex.
This complex occurs in one small area just south of the open water of Shanley's Lough and is dominated by the community type 12Ba.

25. *Juncus effusus* Complex.
This is situated in the central part of the southern section of the western North/South Soak. It is dominated by *Juncus effusus* which indicates some mineral enrichment, possibly eutrophication due to the attraction of this site to birds. The acrotelm is usually over 40 cm deep.

26. *Typha latifolia* Complex.
This occurs in a similar situation to the above complex. Its presence indicates some mineral enrichment and possible ground water influence. The acrotelm is usually over 40 cm deep.

27. Enriched western North/South Soak Complex.
This forms an extensive section of the western North/South Soak with a mixture of communities indicating enrichment such as 12Ac, 3Bc and 11, with 14B and 12Ab. The most noticeable feature is the widespread occurrence of *Dryopteris dilatata*. The acrotelm is usually over 40 cm deep.

28. Less enriched western North/South Soak Complex.
This is situated to the north of the above complex. It is very similar to it but the communities indicating enrichment are not as widespread, with more of the typical hummock communities like 3Bb and 4A occurring. The acrotelm is mostly in the region of 40 cm.

29. *Sphagnum recurvum* /*Sphagnum cuspidatum* lawn Complex.
This consists mainly of the communities 8Aa and 7 which form very wet quaking, flushed areas in the central areas of the soaks. The acrotelm is usually over 40 cm deep.

30. *Sphagnum recurvum* / *Eriophorum vaginatum* lawn Complex.
In some areas to the north of Shanley's Lough and south of the western North/South Soak, extensive lawns of *Sphagnum recurvum* occur with clumps of *Eriophorum vaginatum*. This complex consists mainly of the community type 8Aa. The acrotelm is usually over 40 cm deep.

31. Central Lough Roe Complex.
This is a very wet and quaking area consisting of a scragh of vegetation. In the central section a relict open water community 5C occurs, with the community types 5A, 5B, 6, 7, 8Aa, 8Ab, 8B and 8C surrounding it. The acrotelm is more than 40 cm deep in all parts of this complex.

32. Marginal Lough Roe Complex.
This complex covers the slightly elevated margins of Lough Roe. It consists mainly of the community 11 and 12Ab. The acrotelm is only 10 cm deep under this complex.

The area (ha) of each of the main community complexes was measured using a digital planimeter. Only those complexes covering an area of more than 5 ha were indicated individually. Small community complexes in the soak systems were combined, as were degraded complexes of less than 5 ha in area. The area of each main community complex type and the aggregate types are shown in Table 8.1.

Table 8.1 Area (ha) covered by different community complexes on Raheenmore, Clara West and Clara East.

Community Complex	Raheenmore	Clara West	Clara East
Hummock/ Hollow frequent pools (14).	16.1	7.4	5.0
Hummock/Hollow scattered pools (15).	18.9	9.9	12.6
Transitional *S. magellanicum* (10).	21.3	42.6	None
Eriophorum vaginatum (9).	5.5	9.2	None
S. magellanicum/*E. angustifolium* (12).	None	None	23.6
Soak Communities (16-32).	None	23.2	1.5
Narthecium/*Calluna vulgaris* (6a).	22.1	None	None
Narthecium (6).	37.8	58.1	33.6
Calliergon cuspidatum (13).	None	None	9.8
Narthecium/ *Carex panicea* (3a).	None	11.6	12.7
Calluna /*E. angustifolium* (7a).	None	None	17.5
Rhynchospora fusca (5).	None	None	15.8
Other degraded complex types (3b, 4, 7, 8 and 11).	1.1	21.0	14.4
Carex panicea (3).	None	20.7	39.6
Trichophorum (2).	8.0	4.9	3.8
Face bank (1).	4.3	6.9	9.3

The numbers indicated after the complex name correspond to those used in the text and in the vegetation map key.

8.3.1 CONCLUSIONS.

The vegetation maps of the two bogs fulfilled the main objectives of the mapping exercise. The present pattern of plant communities of the two bogs has been illustrated. Some preliminary links between community complexes and abiotic factors have been suggested and the basis for more detailed community and environmental relationships to be made has been established. However it was necessary to draw up derivative maps in order that hydrological and hydrochemical information could be combined in a more accessible form. This was an important requirement for management purposes.

8.4 DESICCATION MAPS.

Desiccation maps, to illustrate the levels of drying out of the bog surface, were constructed by the amalgamation of community types with similar hydrological regimes (See Tables 5.5, 6.1 and 7.1 for hydrological details). Five categories were considered necessary to fully illustrate the situation. The colours used to denote these five classes follow accepted guide-lines (Mueller-Dombois and Ellenberg, 1974).

Red indicates the driest areas of the bogs, which consist of the *Calluna vulgaris* dominated zone close to face-banks at the bog edge and the closely associated *Trichophorum cespitosum* complex.

Yellow indicates dry areas. This includes the *Narthecium* complex and the *Carex panicea* complex and areas with high *Calluna* cover, apart from face-banks.

Green indicates the first wetness class (moist), which includes the transitional *Sphagnum magellanicum* complex, the drained area on Raheenmore and some *Eriophorum vaginatum* dominated complexes on Clara.

Pale blue is the second wetness class (wet). This consists of the complexes of hummocks and hollows with scattered pools and the areas surrounding the soak systems on Clara.

Dark blue indicates the wettest (very wet) situations on the two bogs. It mainly indicates the complexes of hummocks and hollows where pools are numerous and also the wettest central areas of the soak systems.

(See Figures 8.1.1, 8.1.2 and 8.1.3 for desiccation maps).

These maps highlight the wettest central areas of the two bogs. They also illustrate the drying out of the two bogs that has occurred, inwards, from the drained and/or cut-away margins.

8.5 DISCHARGE MAPS.

Maps were also constructed, on the basis of indicator species or species composition, to illustrate areas of possible discharge or ground water influence. The following plant species, which were recorded during the vegetation survey, were considered to indicate seepage or ground water influence in a peatland situation (P. Schipper, pers. comm.): *Sparganium erectum, Nuphar lutea, Carex acuta, Lychnis flos-cuculi, Equisetum fluviatile, Senecio aquaticus* and *Carex disticha*. In addition, the presence of *Triglochin palustre* indicates the seepage of phreatic water, *Juncus acutiflorus* indicates ground water movement and the presence of *Nasturtium microphyllum* suggests eutrophic seepage due to agricultural practices. The occurrences of the former species are indicated on vegetation maps as sites of possible ground water influence. These maps indicate marginal areas, where ground water is thought to be influencing the vegetation and the soak sites on Clara, where a ground water influence is suspected. It is extremely important to be aware of the position of the former sites, as these are vital to any lagg restoration which may take place in the future.

Lagg is a Swedish term used to describe the zone surrounding a raised bog, where the mixing of ground water and precipitation takes place, so that a fen type vegetation can be supported (Moore and Bellamy, 1976) (see Chapter 6). It is known from stratigraphic studies that these poor fen systems existed around raised bogs in Ireland in the past and some small areas still remain (Cross, 1990). The vegetation of these areas varied considerably, depending on the amount of mineral water influence. No intact lagg areas exist in Ireland today because all raised bogs have undergone some interference by humans, in the form of cutting and drainage (Cross, 1990). The effect of these disturbances has caused major changes, as these areas are particularly sensitive to drying out (Streefkerk and Casparie, 1989).

In order to conserve plant species of any relict areas that remain or to increase plant species diversity at raised bog sites, restoration in these lagg areas is strongly recommended. The importance of lagg areas is not only that they enhance plant species diversity but also that they increase diversity and numbers of insects and birds, as these areas have a richer vegetation and can become wooded with species such as *Alnus* and *Betula*, thus increasing habitat or niche diversity.

The most suitable areas for initial restoration would be those marginal areas illustrated on the maps, where some evidence remains of poor fen vegetation. As is evident from the maps, these areas are rare and are probably under threat due to further land reclamation by farmers in the area. These sites could also act as source points for re-colonisation of marginal areas, subsequent to restoration measures, when conditions may be more favourable for their growth.

The restoration of lagg areas would be a long term undertaking as it requires regional changes in ground water levels or the extensive removal of surface peat layers. However it is an important aim of this project to investigate the possibilities of lagg restoration. It is strongly recommended that restoration should take place as soon as possible, before all possible sites are lost.
See Figures 8.2.1, 8.2.2 and 8.2.3 for maps of possible discharge sites.

8.6 ECOTOPE MAPS.

Using the vegetation maps as a baseline, with the addition of abiotic information, a series of ecotope maps were constructed where community complexes with similar hydrological and hydrochemical characteristics were combined (See summary Table 8.2). An ecotope is the abiotic environment or habitat of a particular biotic system (Küchler, 1967; Whittaker et al., 1973), in other words, it is an area which is homogeneous in respect to its vegetation structure and a number of abiotic factors. Twenty four ecotopes were identified, not all occurring on both bogs.

A range of brown colours was used for the high bog vegetation, ranging from black to yellow; black being the driest areas and yellow the wettest, most 'healthy' complexes of the bogs. A range of blues and purples was used for the soak systems on Clara, from dark blue to light violet. These indicate a suite of soak ecotopes, from minerotrophic to mesotrophic, in terms of vegetation and possible ground water influence. For the marginal or lagg areas a range of green colours, from dark green to light green, was chosen, again illustrating the patterns of vegetation from minerotrophic to mesotrophic, in terms of their species composition and ground water.
(See Figures 8.3.1, 8.3.2 and 8.3.3 for ecotope maps of both bogs).

These maps highlight areas with similar hydrological and hydrochemical regimes and are necessary for formulating management plans for the two bogs.

8.7 ACROTELM AND VEGETATION COMPLEX.

The acrotelm of a raised bog is the living, actively growing upper layer of the bog surface which is composed mainly of *Sphagnum* species. It has many characteristics, the most notable being the fact that is periodically aerobic, due to fluctuating water table levels (Ingram, 1983). Allied with this, it is where the highest rate of plant decomposition occurs and it has a large capacity to store water. The presence of an acrotelm is of paramount importance to a bog, as it is here that peat formation continues to occur; its main importance is its ability to conduct water, as it is a very permeable layer. If this living layer is disrupted, due to drainage or other damage, surface runoff of precipitation will become more widespread, leading to erosion of the upper peat layer (Ingram and Bragg, 1984).

Acrotelm maps of Clara bog were prepared by Van der Cruijsen et al., (1993) and on Raheenmore acrotelm transects were established by Van 't Hullenaar and Ten Kate (1991). A correlation between the vegetation complexes and acrotelm depth was undertaken jointly with the former. In most cases a satisfactory relationship between acrotelm depth and vegetation complex was established (Table 8.3). In some instances correlation was difficult and the following are possible reasons for the anomalies seen between vegetation and acrotelm maps:

1. Wide variation around the soak systems: the acrotelm tends to be zoned, whereas the vegetation is not.
2. The slope factor, which the hydrologists discovered may be an important factor on Clara East.
3. The drain effect on Clara East: occasional localised amelioration of acrotelm in depressions around drains (that is higher water table levels) and also enhanced drainage effect around others.
4. Grid differences: grid maps were used in the formulation of the acrotelm maps and in some areas, problems with the grid have been discovered where copying of grid maps has led to distortion.

Table 8.2 Shows the main Ecotope Divisions, the complex and community types they include and their major Environmental characteristics.

ECOTOPE	COMPLEXES	COMMUNITIES	CHARACTERISTICS
1. Face-bank	Face-bank	4G, 4A, 4B, 3D	Water Type NaCl Watertable low (X= -30.4 cm) WT fluctuation high (X= 42.7 cm/yr.) Mineralisation indicated as Total Phosphate levels increased (X= 0.075 mg l^{-1}) Acrotelm = 0 cm
2. Marginal	*Trichophorum* *Carex panicea* *Carex panicea/Narthecium* *Rhynchospora fusca* *Rhyncospora alba* *Carex panicea/ Rhynchospora fusca*	3E, 3A, 3D, 4A, 1,4B, 3Bb. 3D, 4B, 4A, 1, 3A, 3Bb, 3E. 3D, 3A, 4B, 4A, 1, 3Bb, 3E. 1, 2B, 3A, 4A, 4B, 3D, 3Bb. 1, 3A, 3D, 4B, 4A, 3Bb.	Water table low (-3.9) but far from as low as above. WT fluctuation 22.0. Some indications of mineralisation NO_3 (0.464 mg l^{-1}) K (0.8 mg l^{-1}) Mg (1.9 mg l^{-1}).Water type NaCl Acrotelm = 0, 0-5 and occasionally 10 cm.
3. Sub-Marginal	*Narthecium* *Carex panicea/Dactylorhiza maculata*	3A, 3D, 4A, 1, 4B, 3E. 3D, 3A, 4B, 4A, 1.	Variable depending on rainfall input. In a dry year some mineralisation is indicated but in a wetter year when WT levels higher, rainfall is the only influence. Always NaCl water type. Acrotelm = 0, 0-5, 10 and occasionally 20 cm.
4A. Sub- Central With Drainage effects	*Calluna* *Calluna/Eriophorum angustifolium* *Sphagnum imbricatum*	4A, 4B,.3D, 3A, 1, 3E. 4A, 3A, 4B, 3D. 3A, 4F, 4A, 3Bb.	WT low (-6.4) with a low nutrient status. Probably all transition or relict communities. Water Type NaCl Acrotelm = 0, 0-5 and occasionally 10 cm.

Table 8.2 cont. **Shows the main Ecotope Divisions, the complex and community types they include and their major Environmental characteristics.**

ECOTOPE	COMPLEXES	COMMUNITIES	CHARACTERISTICS
4B. Sub- Central With No Drainage effects	*Eriophorum vaginatum* Transitional *Sphagnum magellanicum* Hummock/Hollow orientated pools	4A, 4B, 3D, 3A, 3Bb. 3Bb, 3A, 3D, 4A, 4B. 3Bb, 3Ba, 3A, 4A.	Water chemistry little deviation from rainwater NaCl type: WT variable. Acrotelm = 0-5, 10 and occasionally 20/30 cm.
4C. Complexes associated with soaks. a. Large infilled Pools	*Sphagnum magellanicum/ Eriophorum angustifolium*	3Bb, 3Ba, 2A, 2C, 3Bc, 3C.	High WT 16.6 cm. NaCl type water but some suggestion of enrichment or higher turnover as Mg (0.25) slightly elevated in the wetter communities. Acrotelm = mostly 10/20 and occasionally 30 cm with some transition areas 0-5 cm.
4C. Complexes associated with soaks. b. Parallel Ridges	*Calliergon cuspidatum*	10, 3A, 3Bb, 3E, 4E.	WT low (-5.9 cm) for high bog community. KC slightly elevated (66.3) Acrotelm = 10/20 cm.
5.Central 5a. Scattered Pools	Hummock/Hollow Scattered pools	3Bb, 3Ba, 2A, 3A, 4A, 4F, 3C, 4E.	WT fluctuation low 16.6 cm/yr. and WT relatively high (X= 6.3 cm).Slightly higher nutrient status than below but still little deviation from rainwater. NaCl type.
5.Central 5b. Frequent Pools	Hummock/Hollow Frequent pools	3Ba, 2A, 3Bb, 3A, 4A, 4F, 3C, 4E.	WT fluctuation low 18 cm/yr. and WT high (X= 10.3 cm). Low nutrient status. Rainwater main influence NaCl type. Acrotelm 30 cm.

Table 8.2 cont. ***Shows the main Ecotope Divisions, the complex and community types they include and their major Environmental characteristics.***

ECOTOPE	COMPLEXES	COMMUNITIES	CHARACTERISTICS
6. Rich Soak 6a. Recently Terrestrialised	Recently Terrestrialised	5A, 5B, 5C,	Fe (3.1), Mn (0.13) KC (104) pH (5.0) Ca (10.7)and Alkalinity (2 meq.) all elevated indicating ground water influence.Wt high (X= 28.3 cm). Acrotelm > 40 cm.
6. Rich Soak 6b. Central Seragh	Central Lough Roe Central Western Soak	6, 8Ab, 8B, 8C.	WT lower than above (mean 5.8 cm). Ground water influence still indicated but not as strong. pH (4.7) KC (77) Fe (1.3) Mn(0.02) Ca (5.0) and Alkalinity (0.013 meq.). Acrotelm > 40 cm.
6. Rich Soak 6c. Marginal Seragh	Subcentral Lough Roe	8Aa.	Influence of ground water still evident but still further reduced. Fe (0.18) Mn (0.01) Ca (1.4) KC (45) and pH (4.0). K levels slightly elevated (0.14) suggesting a possible high turnover. Acrotelm > 40 cm.
6. Rich Soak 6d. Soak Margin	Marginal Lough Roe	9A, 13, 12Aa, 12Ab.	WT lower (-0.5 cm) Rainfall greatest influence as NaCl type water but still some indications of very diluted ground water Ca (2.0). Acrotelm 10 cm.
7. Poor Soak 7a. Open Water	Soak poor Open water	7.	No ground water influence. NaCl type water. Acrotelm > 40 cm.
7. Poor Soak 7b. Central Flushed	Soak flushed	9A, 7.	No ground water influence. NaCl type water. Acrotelm > 40 cm.

Table 8.2 cont. **Shows the main Ecotope Divisions, the complex and community types they include and their major Environmental characteristics.**

ECOTOPE	COMPLEXES	COMMUNITIES	CHARACTERISTICS
7. Poor Soak 7c. Soak Marginal	Soak marginal	12Aa, 12Ab, 12Ac, 12Ba, 12Bb, 14A, 14B.	WT fluctuation relatively low (20). KC slightly elevated (85.4) K also elevated (0.43) suggesting possible higher turnover. Acrotelm > 40 cm.
7. Poor Soak 7d.	*Myrica/ Sphagnum magellanicum*	3F.	Mg (1.33) slightly elevated (1.33) possible ground water influence. NH4 (0.232) OP (0.014) and TP (0.021) all up suggesting mineralisation which may be due to WT fluctuation (25.3) or mycorrhizal activity. Acrotelm 40 and occasionally 30/20/10 cm.
8A. Rich Lagg 8A. Ground Water	Rich Lagg Ground Water	15B, 22.	KC(220), pH (6.8), Fe (0.6), Mn (.04) Alkalinity (2 meq) and Ca (82) all elevated suggesting a ground water influence.
8B. Rich Lagg 8Ba. Mineralised	Rich Lagg Eutrophication/Ground Water Mineralisation	15D, 16B.	WT fluctuation high (Mean = 52.3 cm/yr). Fe (0.59), Mn (.015) and Ca (34) all elevated suggesting a ground water influence but not as strong as the previous group. Indication of some eutrophication also- NO_3 (0.9).
8. Rich Lagg 8Bb. Rain water/ Mineralisation	Rich Lagg Rain water/Mineralisation	3G, 9B.	WT fluctuation high 31.9 cm/yr. Some mineralisation suggested by increased levels of OP (0.011) and TP (0.06).

Table 8.2 cont. *Shows the main Ecotope Divisions, the complex and community types they include and their major Environmental characteristics.*

ECOTOPE	COMPLEXES	COMMUNITIES	CHARACTERISTICS
8. Rich Lagg 8Bc. Rainwater/Ground water	Rich Lag Rainwater/Ground water	14D, 15C, 16A, 20.	Influence of Rainwater increased Na (7-8) and Cl (13-15) with Ca levels lower (15-20). Area with mixing of ground and rain water. Mean WT -5.9 cm.
9. Poor Lagg 9a. Scrub	Poor Scrub		Cut-away peat areas with poor scrub. No data available for these but it can be assumed from the vegetation that there is no ground water influence.
9. Poor Lagg 9b. Dry- desiccated Peat vegetation	Desiccated peat with some mineralisation.	4H, 4I, 14C, 17, 21.	WT levels low with a mean value of -33.7 cm. Total Phosphate (0.057). Communities of desiccated peat with no ground water influence.
9. Poor Lagg 9c. Grassland	Grasslands		No data available for these areas but assumed to have low WTs. Grasslands on the surrounding eskers.

Values for water chemistry are:	Corrected Conductivity	(KC) $\mu S\ cm^{-1}$.
	Water table (WT)	cm (annual mean).
	Alkalinity	millequivalents.
	Elements	$mg\ l^{-1}$.

Table 8.3 Vegetation complexes of Clara and Raheenmore and their associated acrotelm thickness (cm).

VEGETATION COMPLEX	Mostly (>70%)	Also (up to 20%)	Occasionally (up to 10%)	V.Occasionally (up to 5%)
Face-bank.	0			
Trichophorum cespitosum.	0		0-5	
Carex panicea/burnt.	0		0-5	10
Carex panicea/Narthecium.	0	0-5	10	20
Rhynchospora alba.	0	0-5		
Carex panicea/ Rhynchospora fusca.	0-5		10	
Rhynchospora fusca.	0	0-5		
Narthecium.	0-5	0	10	20
Narthecium/Calluna.	0-5			
Narthecium/Myrica.	0	0-5/10		
Carex panicea/Dactylorhiza maculata.	0-5			
Calluna vulgaris.	0		0-5	
Calluna/Eriophorum angustifolium.	0	0-5	10	
Raheenmore drained.	0-5	10		20
Sphagnum imbricatum.	0			
Eriophorum vaginatum.	20	10/30		0-5
Transitional *Sphagnum magellanicum.*	0-5/10	20	30	
Transitional *S. magellanicum/Trichophorum.*	10	20/0-5	0	
Hummock/Hollow orientated pools.	0-5	10		
S. magellanicum/Eriophorum angustifolium.	10/20	0/30/0-5		40
Calliergon cuspidatum.	0-5	20/0		
Enriched *Sphagnum magellanicum.*	40	30	20/10	0-5
Enriched S. *magellanicum/S.cuspidatum.*	>40	40		
Hummock/Hollow scattered pools.	20	30	10	0-5
Hummock/Hollow frequent pools.	30	>40/40	30	20/10/0-5
Myrica gale/Sphagnum magellanicum.	40	30	20/10	
Molinia caerulea.	0	10/20	30	
Molinia caerulea/Myrica gale.	30	40	20/10	

Table 8.3 cont. Vegetation complexes of Clara and Raheenmore and their associated acrotelm thickness (cm).

COMPLEX	Mostly (>70%)	Also (up to 20%)	Occasionally (up to 10%)	V.Occasionally (up to 5%)
Betula scrub/*Molinia caerulea*.	>40(SL) 20(WS)		10(WS)	0-5(WS)
Betula trees.	>40	20/30		
Betula/*Juncus effusus*.	>40			
Sphagnum recurvum/*S.cuspidatum* lawns.	>40			
Less enriched Western Soak.	40	30/20	10	
Enriched Western Soak.	>40	40/30/	20	10
Eriophorum vaginatum /*S. recurvum*.	>40	30/40		
Juncus effusus.	>40			
Typha latifolia.	>40			
Lough Roe Central.	>40		40	
Marginal Lough Roe.	10			

SL = Shanley's Lough
WS = Western Soak on Clara West.

Vegetation complexes as on vegetation maps.
Acrotelm thickness derived from acrotelm maps of Van der Cruijsen et al. (1993).

5. Scale problems: some small scale vegetation types may not be represented on the vegetation map but are identified on the acrotelm map and vice versa.
6. Definition of borders: vegetation boundaries are just a representation of where a complex type begins and ends; vegetation boundaries are rarely definite as the variation between most communities is continuous. This situation also arises on the acrotelm maps.

This linking of acrotelm depth and vegetation cover is an important step in the management of a raised bog system. From this data it is possible to see that the marginal and sub-marginal areas in most cases have no acrotelm layer. This is due to peat cutting disturbance and the effects of drainage which have increased the slope of the bog surface in these areas to greater than 0.25% over which no acrotelm is found (Van der Cruijsen et al., 1993). The transitional areas such as the transitional *Sphagnum magellanicum* complex have variable acrotelm depths, reflecting the fact that they are in transition from an area of actively growing bog to a marginal or sub-marginal area where peat formation has more or less ceased. The deepest acrotelm layers of the high bog, apart from the soak systems on Clara, are the complexes of hummocks and hollows. These are the core community complexes of a healthy, actively growing raised bog. From the vegetation complex maps and from Table 8.1, one can see just how restricted in size these areas are now. The conservation of these remaining areas is vital. The soak complexes, as would be expected, have the deepest acrotelm layers as they are mainly central or are situated in sunken areas with a focused water flow.

The presence of an acrotelm usually indicates the occurrence of *Sphagnum* species. What is clear from this information is that, in areas such as the *Narthecium* complex, restoration is still possible, as focus points for *Sphagnum* re-growth remain. This is evident from the variability in acrotelm depths seen in these complexes.

This linking of vegetation and acrotelm depth helps to identify areas which have priority as regards restoration and shows that transitional areas should be included in restoration works.

A direct relationship between acrotelm depth and vegetation cover is illustrated in Fig. 8.4 Here the percentage cover of vegetation types which are usually associated (>70% of the time) with a particular acrotelm depth are shown for Raheenmore, Clara West and Clara East.
Five categories were considered adequate. These were:

1= the % of vegetation complexes associated with depths of acrotelm >30 cm. This includes the hummock/hollow complex and the soak complexes.
2= the % of vegetation complexes associated with depths of acrotelm >20 cm. This includes the hummock/hollow complex with scattered pools, the *Eriophorum vaginatum* complex and the *Sphagnum magellanicum* and *Eriophorum angustifolium* complex.
3= the % of vegetation complexes associated with depths of acrotelm at 10 cm. This includes the transitional *Sphagnum magellanicum* complex.
4= the % of vegetation complexes associated with depths of acrotelm 0-5 cm. This includes the *Narthecium* complex and the drained area on Raheenmore.
5= the % of vegetation complexes associated with depths of acrotelm 0 cm. This includes the following community complexes Face-bank, *Trichophorum*, *Carex panicea*, *Rhynchospora alba*, *R. fusca*, and combinations.

A second illustration combines the first three categories as areas where the acrotelm is still functioning and the last two categories, where it can be said to be not functioning. Or, more simply, where vegetation complexes and their associated acrotelm characteristics are used to indicate the percentage of healthy and moribund areas of the bog remaining at Raheenmore, Clara West and Clara East in Fig. 8.5.

These exemplify the effect that surface drainage has had on Clara East, with over 70 % of that half of the bog lacking a functioning acrotelm. It also shows that both Clara West and Raheenmore, which were thought to be in relatively good condition, have less than half of their surface area covered by a functioning acrotelm.

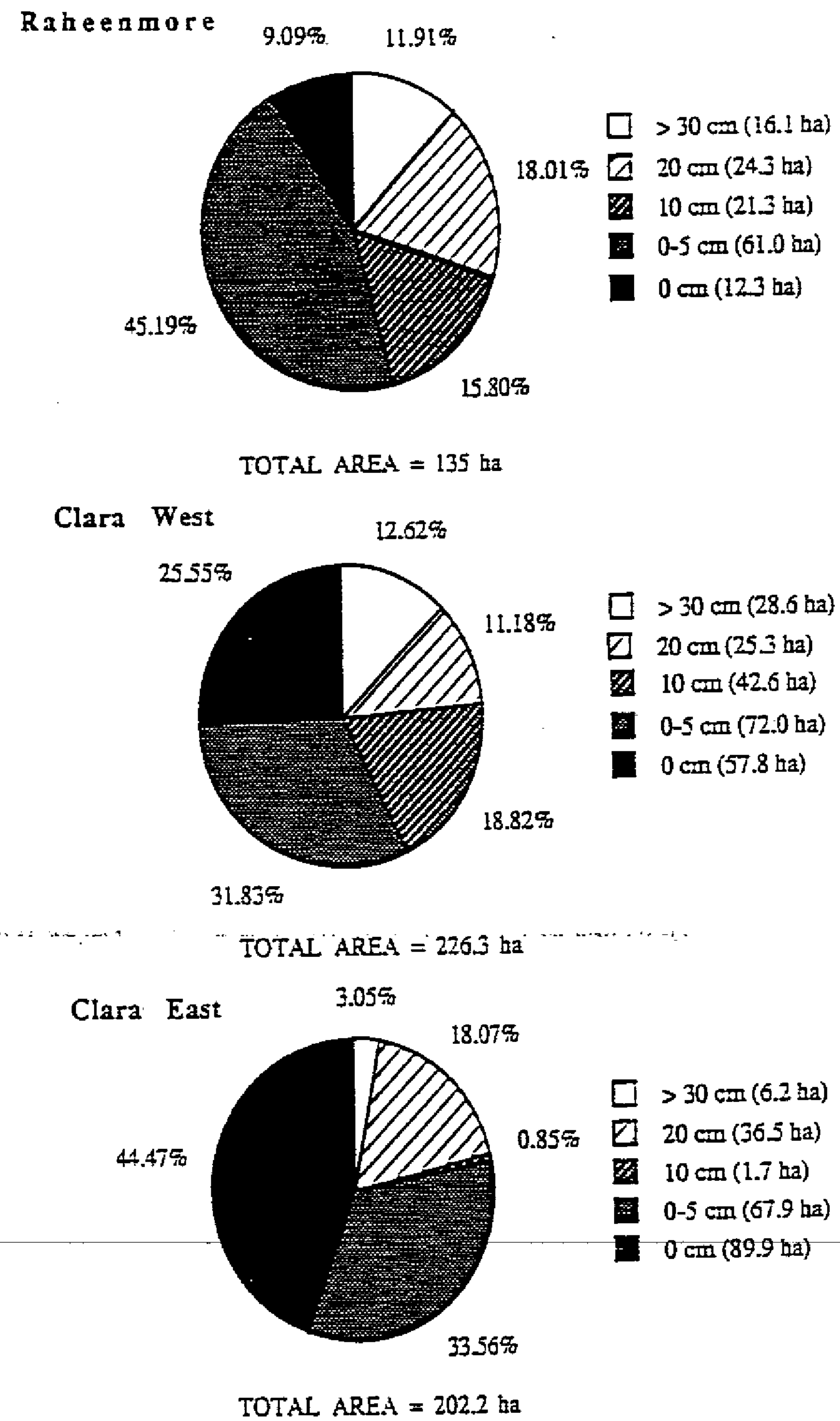


Fig. 8.4 Shows the percentage of vegetation cover on Raheenmore, Clara West and Clara East associated with particular acrotelm depths. The criterion used to distinguish depth classes was that the community complex was associated with that particular acrotelm depth > 70 % of the time.

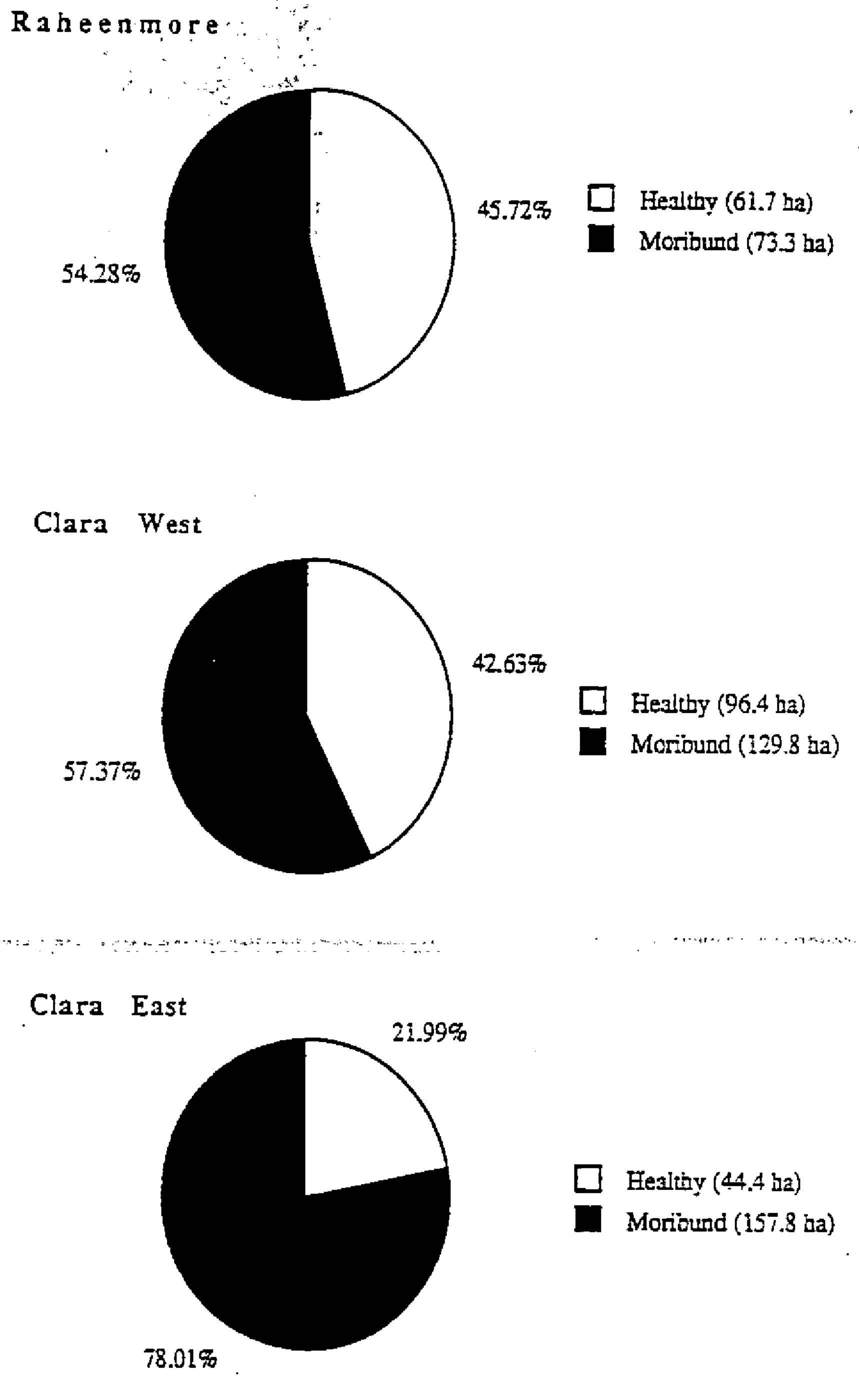


Fig. 8.5 Percentage of vegetation complexes on Raheenmore, Clara West and Clara East associated with moribund and healthy acrotelm classes. Healthy = 10 - > 30 cm deep and moribund = < 10 cm deep.

8.8 CONCLUSIONS.

The vegetation mapping carried out for this project highlights its applied nature. By linking vegetation patterns of the bogs with measured environmental parameters several functions are fulfilled. The necessary information for restoration procedures as regards the conditions required for different community complexes has been obtained. With the addition of the hydrological information gathered, it is possible to decide where dams must be inserted to ensure that the central complexes of the bog are conserved and to ensure that those complexes which are deteriorating due to drainage are protected. If water table levels are increased, the deterioration may be reversed. Fig. 8.6 illustrates the broad relationships between the main community complexes. It is possible from the environmental information obtained to predict probable community complex response to restoration measures.

In addition, a method has been devised whereby the hydrological condition of a raised bog may be relatively quickly appraised by a investigation of its vegetation cover using colour aerial photography. With the use of geographical information systems, this method may become even faster and more accurate in the future.

Frequent Pool Hummock/Hollow Complex
Conserved due to protection.

Scattered Pool Hummock/Hollow Complex
Should respond quickly to restoration.

Gradual drying out.

Transition Sphagnum magellanicum Complex
Eriophorum vaginatum Complex
Would respond well to restoration over time.

Narthecium Complex
Slow response to restoration.

Carex panicea Complex
Calluna Complex
Restoration very long term. Initial restoration procedures should take place inside these areas.

Trichophorum Complex
Facebank Complex
Restoration not practical.

Fig. 8.6 Suggested succession of vegetation complexes due to drainage effects and their possible response to restoration or protection measures.

CHAPTER 9: FINAL DISCUSSIONS. CONCLUSIONS AND RECOMMENDATIONS.

9.1 OVERVIEW.

Four main areas of vegetation have been identified as part of the raised bog system at Clara and Raheenmore. These are the high bog communities, the soak communities (Clara), the cut-away communities and the marginal (lagg) communities. They may be separated from each other on the basis of their species composition and their hydrological and hydrochemical regimes. The distribution of these community types has been mapped on a community level (Lough Roe), on a community complex level (soaks and high bog) and at an ecotope level (all).

The environmental characteristics (hydrological and hydrochemical) associated with the different areas have been identified and incorporated into desiccation and ecotope maps. Integration with the hydrological research on acrotelm depth was undertaken by assessing the relationship between vegetation complexes and acrotelm depth.

Three main trends in hydrological and hydrochemical characteristics between the communities of the high bog and between the high bog, soak, cut-away and lagg areas have been identified. These are:

1. Wet (waterlogged) ↔ Dry (aerated).
2. Na and Cl (ombrotrophy) ↔ Ca and HCO_3 (minerotrophy).
3. Low N and P ↔ Increased N and P.

With reference to Fig 1.3 (Chapter 1), it is now possible to draw up a scheme highlighting the most important hydrological factors determined by this work and their influence on, or correlation with, the distribution of present community types on the high bog, cut-away and marginal (lagg) areas (Fig. 9.1). It is therefore also possible to hypothesise on the vegetational changes that may occur if hydrological regimes are altered.

On the high bog the most important factors linked with plant community distribution are water table depth and fluctuation. The pool and lawn communities depend on a high water table throughout the year, while the hummock communities have relatively low water table levels. The hollow communities, which reach their maximum cover in the marginal and sub-marginal complexes, have relatively high water table fluctuations and thus slightly increased mineralisation. This is due to the effects of marginal drainage and peat cutting.

The soak communities, particularly those of Shanley's Lough, are influenced by lateral water movement, where the rate of supply of ions to plant roots is increased due to the focused flow of water through a sunken area. Lough Roe is influenced by dilute ground water (intermediate Ca content or ionic ratio). Water movement may also be important to the survival of Lough Roe.

The cut-away communities differ from the high bog communities, as the whole area experiences greater water table fluctuations and thus mineralisation rates are higher. This is again due to the effects of drainage and peat cutting. The cut-away communities on desiccated peat develop on areas where the water table is far below surface level.

Of those lagg (marginal) communities which are influenced by ground water, there is a range of types with varying influence of ground water, coupled with different mineralisation rates. Due to drainage the regional ground water table is relatively low and thus the conditions for true lagg communities are sub-optimal.

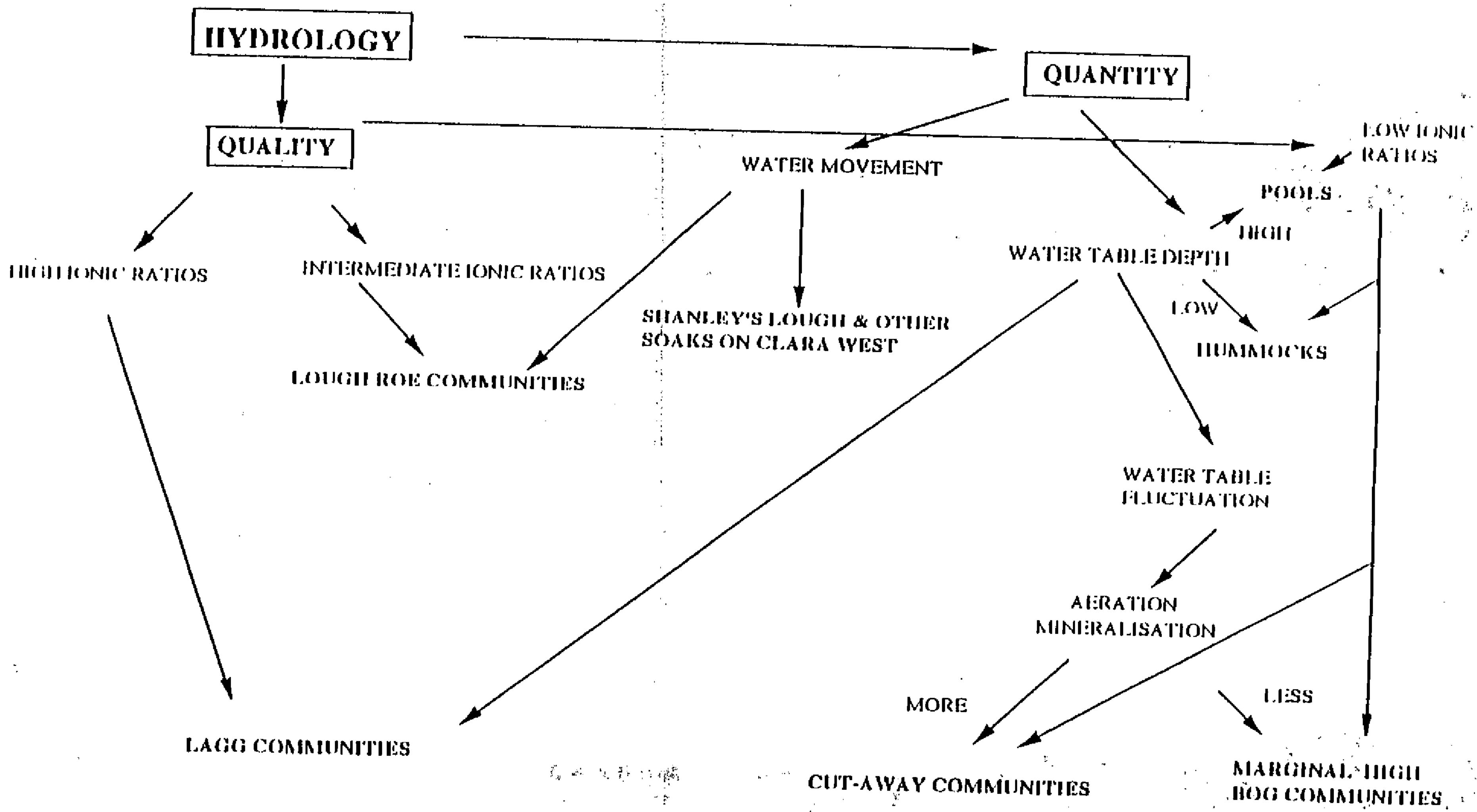


Fig. 9.1 The links between hydrology and hydrochemistry and their effect on the vegetation communities of Clara and Raheenmore raised bogs.

9.2 THE MAIN PROBLEMS FOR VEGETATION AND POSSIBLE SOLUTIONS.

Damage and degradation at both sites due to drainage and peat cutting has been quantified by the vegetation survey (see Chapter 8). The necessary information on community distribution and status is now available for the hydrologists and ecologists to formulate integrated management plans for both sites. The following is an examination of the main factors influencing vegetation succession at Clara and Raheenmore.

When peat is drained, certain structural changes take place as the removal of water allows subsidence to occur and aeration to increase, elevating mineralisation rates (Hobbs, 1986). If this process proceeds too far, re-wetting of the peat is not possible as the peat has become compacted and pore spaces are lost. This means that the water storage capacity of the peat is diminished. The effects of peat cutting are similar to that of drainage, with the addition of possible peat slumping and the formation of large cracks along the bog edge.

There are two main approaches open to those formulating management plans; to protect existing areas of intact vegetation or to attempt restoration of other degraded areas. The pursuit of either option does not necessarily exclude the other. The former is the option with minimum investment and involves the conservation of the wet central communities at both sites by preventing further drainage effects. This will involve the insertion of dams. The second option is to attempt to increase the area covered by the wet hummock/ hollow complexes by restoring areas which have become degraded due to the effects of drainage or peat cutting. The sub-marginal and transitional community types are included in this category. This would require much more extensive work and financial input. However, it is presumed that a non-disturbed system naturally would have a proportion of marginal communities in the area corresponding to the rand and, therefore, to increase the wet central core too much would be creating unnatural conditions. This second approach is to be preferred, as the existing areas are so restricted in size that their viability is questionable.

In all cases terrestrial re-generation is to be preferred, that is the amelioration of conditions for the extension of existing *Sphagnum* growth (raising phreatic water levels) rather than inundating large areas. This may result in further degradation of the ombrotrophic system due to possible eutrophication by birds.

The main problem at these two sites is that the marginal communities have extended due to disturbance. The main causes of site degradation and possible solutions are discussed below.

9.2.1 Surface Drainage.

9.2.1.1 Clara.

During the period 1983/84, approximately 150 km of drains of c. 0.5 m deep and 15 metres apart were inserted on the eastern side of Clara bog by Bord na Móna, in preparation for peat extraction. After the site was purchased by The Wildlife Service in 1984 these drains were blocked with peat dams. This work was carried out with little prior hydrological knowledge or knowledge of the requirements of the vegetation types. Although the blocking was successful in some areas, with significant colonisation by *Sphagnum cuspidatum*, in a number of areas no re-growth has occurred.

A survey was undertaken by McAfee (1993), to discover which factors were influencing colonisation of the drains by *Sphagnum cuspidatum*. He discovered that the most important factors associated with colonisation by *Sphagnum cuspidatum* were water table depth (a maximum and minimum optimum) and the intersection of the drain through a pool or hollow already colonised by *Sphagnum cuspidatum*, which could act as a focus point for growth into the drain. *Sphagnum cuspidatum* growth was found to be poor or non-existent close to the bog edges, owing to steeper gradients and thus lower water table levels. This work further illustrated that the most serious problem on Clara East is the general lowering of the phreatic water table due to surface drainage. This is favouring the spread of the disturbed community types as the site becomes heathified.

Effect on Vegetation.

These drains have had a serious effect on the vegetation complexes that occur on the eastern side of Clara bog. 70 % (approximately 147 ha) of the total area of Clara East supports vegetation complexes which are included in the category marginal to sub-marginal and thus it consists of mainly disturbed/ burnt plant communities, in addition to a significant amount of exposed bare peat, mainly spoil from the drains (Plate 25). Despite the drainage of this area, approximately 41.0 ha of central and sub-central vegetation cover remains on this side of the bog (see Chapter 8, Table 8.1). Although these areas are also affected by the drainage, they should be protected as they represent the vegetation cover of this side of the bog which corresponds closest to the central wet hummock hollow complexes. If restoration measures are taken here, these vegetation types should respond well.

Solution.
More effective blocking of the surface drains is required to promote infiltration of water and increase the phreatic water table level, with particular attention to marginal areas where blocking needs to be more frequent. This should also promote acrotelm development. The dams should be of semi-humified peat and of a sufficient size that the inevitable peat mineralisation which will occur will not result in breaching of the dams. They should be checked at regular intervals to ensure that they are still functioning correctly. This blocking should take place as soon as possible to prevent further deterioration of the site and to enhance suitable conditions for *Sphagnum* growth. As the drains on Clara East are quite shallow, blocking should still be effective in re-wetting the inter-drain areas. *Sphagnum* cover is still relatively high in many areas. These could form source areas for re-colonisation of disturbed situations.

Clara West appears to be least affected by surface drainage, although approximately 50% (124 ha) of the vegetation cover indicates site degradation.

9.2.1.2 Raheenmore.
Some of the surface drains on the east of Raheenmore (see vegetation map Appendix 8.1a) are at least 150 years old, as they are indicated on the Ordnance survey map of 1838, and the remainder are at least 83 years old, as they are shown on the Ordnance survey map of 1910. They are now mostly infilled with various *Sphagnum* species, including *Sphagnum cuspidatum* and *Sphagnum magellanicum*. Although their water carrying potential has been reduced, due to colonisation by Sphagna and other species, they still act as focus points for water flow.

Effect on Vegetation.
The vegetation of the immediate area which has been drained has been affected and can be mostly included in the *Narthecium* complex, with wetter areas around the drains supporting community types such as *Sphagnum magellanicum* lawns. It is possible that these drains are not the most important influence on the vegetation in this area, as the main effect may be the deep peripheral drain. However more effective blocking, using semi- humified peat dams (as described above), is advisable.

9.2.2 Deep Peripheral Drainage.

9.2.2.1 Raheenmore.
Raheenmore is surrounded almost completely by a very deep drain (up to 4 metres in places), which was dug as part of a drainage scheme in the area. Hydrological monitoring at the site over the last 5 years has shown that this drain is seriously affecting the hydrology of the bog; water loss is exceeding recharge, resulting in subsidence in the marginal areas.

Effect on Vegetation.
As the site is approximately ellipsoid, a zonation in vegetation types is readily apparent. The vegetation mapping of the site (Chapter 8) shows a central wet core of pools and hummocks, typical of a wet raised bog. This area experiences high water table levels throughout the year and thus appears to be have been buffered to a certain extent by the surrounding peat body. Outside this central core, communities which indicate marginal conditions increase rapidly. To the south of the site there is a broad *Sphagnum magellanicum* transition zone, which grades into the *Narthecium* complex with a high abundance of *Calluna* and then into the *Trichophorum* complex. To the north, the zone is narrower, consisting of the *Narthecium* and *Trichophorum* complexes. This marginal area is less extensive, as the present margins of the bog correspond closely to the original boundaries of the raised bog (Van Tatenhove and Van der Meer, 1990). Although the central area is still wet, aerial photographs from the 1950s show that the open pool communities were more extensive in the past. It appears that these open pools (probably *Sphagnum cuspidatum* pools) have been gradually infilled with *Sphagnum magellanicum* to form *S. magellanicum* pools or lawns. This is most probably due to the lowering of water table heights caused by the peripheral drainage.

In total, there are now only 35 ha which make up the central wet core of the site. This central area should be protected from further drying out. There are also two complexes which should respond relatively quickly to restoration measures. These are the transitional *Sphagnum magellanicum* and

Eriophorum vaginatum complexes which cover 26 ha of the 135.0 ha site. The vegetation of 74 ha of the site is therefore included in the categories marginal and sub-marginal. With restoration measures, this area could be reduced.

Solutions.

The only apparent solution to this gradual drying out of the whole bog is to reverse or minimise the hydrological gradients caused by the marginal drain. This could be achieved by the insertion of shallow semi-humified peat dams in the areas, identified by the hydrologists, where water losses are greatest. An increase in the height of phreatic water tables by approximately 5 cm should result in the spread of *Sphagnum cuspidatum* in the hollow communities. If dams were inserted there would be more control on water table fluctuation, thus decreasing mineralisation of N and P.

Ideally, in order to avoid large scale disturbance to the bog vegetation, highly humified peat (black peat) dams could be placed at the face-bank edge completely surrounding the site. These would have to be deep enough so that they were on a strongly humified peat base or else leakage would occur. This method has already been used in The Netherlands to conserve raised bog relicts (Schouwenaars, 1988). The peripheral drain should also be filled in, but this might raise considerable local opposition.

Shallow semi-humified peat dams should then be placed at various intervals up the slope from the face-bank. As drying out would be prevented, the bog surface should gradually swell as the peat pores are filled with water. As swelling of the bog surface would probably occur these dams should be gradually increased in height so that they would remain effective. This would decrease the slope towards the margins of the bog and conditions for *Sphagnum* growth would be improved. This would help the re-establishment of an acrotelm layer. Monitoring of the effectiveness of the dams should be carried out at regular intervals.

9.2.2.2 Clara.

Clara is also affected by deep boundary drains on its north-eastern and eastern edges. The northern drain was recently deepened on the eastern section, due to reclamation work in the adjacent farmland.

Effects On The Vegetation On Clara East.

The influence of the surface drains on the vegetation of Clara East is such that the effect of the marginal drainage is not so easily seen as on Raheenmore. However, it is certain that the consequences are substantial in relation to the vegetation, as the cover of disturbed community types increases towards the margins. The effect of the northern drain on the hydrology of the area was assessed by Blackwell (1992). He discovered that it was seriously affecting the local hydrology. If conditions more suitable for *Sphagnum* growth (that is higher water table levels) are to be created, the hydrological gradients in this area must be reversed. This could be achieved by blocking the deep northern drain and placing black peat dams at the face-bank edge as described above for Raheenmore. The deep drains along the edges of the road which bisects Clara Bog have also caused much hydrological change. It is estimated that their resulting increase in drainage rates has caused at least 5 metres subsidence of the bog surface on either side of the road (Bell, 1991; Samuels, 1992). The vegetation complexes close to the road reflect this hydrological damage, with a broad band of the *Carex panicea* and *Narthecium* complexes or marginal ecotope on either side of the road. The areas close to the road have been targeted for the insertion of dams, as the slope of the bog surface in this area is greatly increased.

Clara West.

Deep drainage channels on the northern boundary of Clara West are not as extensive as on Clara East, except for one section in the north-eastern corner. For most of the northern boundary, the bog vegetation grades into the esker vegetation (farmland or woodland). However the water movement is all downwards in this area, which indicates that water table levels are low and indeed the vegetation of this area supports this suggestion. A broad band of the *Carexpanicea* and *Narthecium* complexes is seen in this area.

9.2.3 Peat cutting.

Both bogs have been exploited for fuel in the past. While no peat cutting now occurs on Raheenmore, extensive peat cutting is still taking place on Clara. This is mostly confined to the southern and western edges, with only small private cutting on the northern boundary. The southern edge of Clara West is commercially exploited by machinery, whereas on the southern edge of Clara East most cutting is carried out by hand.

Peat exploitation in these areas has had a similar effect to marginal drainage because it also increases the drainage of peat water, causing subsidence and a lowering of the bog surface. Vegetation complexes in these areas once again reflect the hydrological changes that have occurred, with the widespread occurrence of the marginal complexes or marginal ecotope types. The immediate purchase of the areas which are still being cut is strongly recommended.

The main conclusion that may be drawn is that drainage and peat cutting have both increased homogeneity of the high bog vegetation cover of Clara and Raheenmore, with a trend towards heathification at both sites. This is mainly as the result of the lowering of phreatic water table levels and the increase in water table fluctuation.

9.3 RESTORATION OF LAGG COMMUNITIES.

In order to increase habitat diversity at both sites, the re-creation of areas of lagg vegetation is expedient. Both these systems have been extensively modified by anthropogenic activities. Therefore in order to restore these areas, proactive measures must be taken. It could be argued that large scale interference is not desirable in a natural system. However these lagg areas can only be termed semi-natural systems, having undergone many years of modification. Restoration would only involve re-creating conditions which naturally existed in the past.

The conditions associated with, and thus assumed to be required by, some lagg community types are now known for these two sites. The extension of these areas as well as the protection of communities should be possible through hydrological management. The most important action to be taken in this regard, would be that the lands adjoining these areas should be purchased or farmed under very strict guide-lines. The latter, despite compensation, might result in much local opposition. The more logical course of action, and probably the cheaper in the long term, would be to purchase the areas. The investments already made at these sites are large and protection of investment may require more financial input.

On Raheenmore the most suitable areas for lagg restoration are on the north-western edge and on the south-eastern boundary. The former area consists of patches of semi-lagg to lagg vegetation and the hydrochemical analyses indicate ground water influence. If drainage in this area was reduced and the regional ground water table height increased, it could form an area of vegetation which could be called a lagg. On the southern edge, ombrotrophic peat layers would have to be removed in order to increase the influence of ground water. Species such as *Carexdiandra* are already established in peat pits in this area and thus re-colonisation points exist in this situation.

The northern boundary of Clara East appears to provide the most suitable area for lagg restoration on Clara bog. Ground water influenced vegetation has been identified along this boundary. If the effect of the marginal drain was reduced these areas might become more extensive.

On the northern boundary of Clara West, hydrological investigations have only detected downward gradients in water movement. This is confirmed by the vegetation communities recorded in this area, as no plant communities indicating up welling ground water were identified. This area is not recommended for lagg restoration, as no areas of up-welling ground water appear to exist. However, it would be advisable to approach local farmers and investigate the possibility that these areas of farmland should be less intensively farmed. Much of the pasture is grown for silage and is thus heavily fertilised and run-off of chemical fertilisers may be affecting the adjoining bog vegetation. Ideally these esker grasslands could form a total unit, including raised bog and esker woodland, if they were allowed to revert back to the species rich grasslands typical of less intensively farmed sections of the esker. Although this is a remote possibility, the long term conservation of Clara bog depends on the protection of the surrounding areas and for complete ecosystem protection these sites should be included in conservation measures.

9.4 CONSERVATION OF THE SOAK SYSTEMS.

One of the primary aims of the Irish-Dutch project is to ensure the conservation of the soak systems on Clara. The soaks on the western section of the site may be affected by restoration procedures as drainage through the areas may be impeded. Care should be taken that dams are situated in places where they will cause the least impact on these soak systems. However if, as hypothesised in Chapter 7, these are disturbance induced features, they may have to be sacrificed to conserve hummock/pool areas.

Lough Roe is more problematic as its existence has still not been fully explained. However the blocking of the surface drains on Clara East should increase phreatic water table levels in the surrounding area. This may make conditions more suitable for aquatic communities. In addition, if the exit drain to the west of the Lough is unblocked so that water movement through the area is increased, the spread of ombrotrophic communities may be slowed.

9.5 RESTORATION MONITORING.

Monitoring at both sites will be necessary to evaluate restoration success. This may be carried out using either large-scale or small-scale methods.

Large-scale.

It is suggested that colour stereoscopic aerial photography should be used to monitor vegetation changes at both sites. Vegetation maps could easily be prepared using modern computer methods, such as The Geographical Information System, now available in The Parks and Wildlife Service. This should be carried out after two years and again after five years and at five year intervals over 20 years. Based on the results of those investigations, further restoration work could be carried out at these and other raised bog sites. This is now the fastest and least damaging method available to assess the vegetation and associated hydrology of a raised bog.

Small-scale.

In addition, more detailed work could be undertaken by investigating the vegetation changes within community complexes, after restoration procedures have been carried out. A number of 10 x 10 m plots could be set up in each of the major community complexes, such as the transitional *Sphagnum magellanicum* complex, *Narthecium complex*, *Carex panicea* complex and the hummock hollow complexes. The percentage cover of each community type should be estimated within each plot. They could be re-surveyed at the same time as the aerial photographs are taken. Hydrological monitoring of these plots would also be an advantage. Care should be taken that trampling at these permanent sites is kept to a minimum. This small -scale monitoring would check that the aerial photography is recording the vegetation changes with sufficient accuracy. Small-scale monitoring of the restoration of lagg areas would also be required.

Expected responses to restoration would be the spread of *Sphagnum* dominated communities, such as *Sphagnum magellanicum* lawns, and a decrease in the number of *Narthecium* hollows. The transitional *Sphagnum magellanicum* complex, the *Narthecium* complex, the *Sphagnum magellanicum* and *Eriophorum angustifolium* complex and the *Carex panicea* complex are the sections which would be expected to respond most significantly to restoration. None of these complexes are devoid of *Sphagnum* cover and thus if the hydrological conditions were improved (higher water table levels) the cover of the various *Sphagnum* species should increase.

9.6 SITE ACCESS.

As some of the main reasons cited for conservation of these sites is their tourism and educational potential (Chapter 1), site access must be controlled if damage is to be kept at a minimum. Already there are signs of damage at both sites due to visitor access and continuous monitoring effects. On Raheenmore, the hydrological transect which was inserted over five years ago is now apparent on aerial photography, as the trampling effect has increased the occurrence of *Rhynchospora alba* in the immediate area of the transect. On Clara the effects of five open days over the last three years, associated with the Clara festival, have resulted in much trampling between the road and Shanley's Lough. The risk of fire is also increased with visitor access.

The amenity potential of Clara is probably greater than that of Raheenmore, due to its proximity to the town of Clara. The construction of walkways onto the bog is the main method available to minimise the effects of visitor access. Some research into the most suitable method of construction was undertaken (O'Neill, 1992). This involved the insertion of hand driven timber piles. If Clara is subject to much more uncontrolled visitor access (the present situation) irreparable damage may result. The construction of suitable walkways as soon as possible is advisable, in order to protect the site from further damage. The positioning of these walkways is significant, as controlling where maximum visitor pressure occurs is important. Visitors should be directed away from the areas of highest scientific interest . These walkways would also be useful for any further scientific investigations that may be undertaken, but their use should be closely monitored. If undue adverse effects were noted, the wooden structure could be readily removed.

Walkway access to Raheenmore is not required, as this site is rarely visited by the public. However some guide-lines should be drawn up for visitors, such as educational parties.

9.7 MAIN MANAGEMENT OBJECTIVES.

1. To decrease the effect of marginal and peripheral drainage by the insertion of various types of dam, depending on the hydrological research. This should increase phreatic water table levels in the sub-marginal and sub-central complexes, while protecting the central complexes.

2. To thus increase the cover of the vegetation complexes which indicate 'healthy' raised bog conditions.
   On Raheenmore it is estimated that the central wet core could be approximately doubled in size, from 35 ha to 62 ha, to include the transitional *Sphagnum magellanicum* and *Eriophorum vaginatum* complexes. The cover of *Narthecium* (38.0 ha) and *Narthecium/ Calluna* (22 ha) complexes could be decreased by the spread of the transitional *Sphagnum magellanicum* complex. The cover of the face-bank and *Trichophorum* complexes are likely to remain more or less the same.
   On Clara East it is estimated that the sub-central complex of 24 ha could become a central complex, giving a total wet core complex of approximately 42 ha. The aim should be to decrease the cover of degraded complexes by 50 %, that is, by at least 50 ha. These should then form a sub-central complex. Due to the elongated nature of the southern section of the site, the amount of marginal communities will always be higher than those at either Raheenmore or on Clara West.
   On Clara West the central complexes of hummocks and pools cover 17 ha. The transitional *Sphagnum magellanicum* complex, covering approximately 43.0 ha, should show an increase in the number of *Sphagnum* pools, following insertion of dams, and could then be included in the central complex types. In addition to the *Eriophorum vaginatum* complex this could increase the central complexes by 52 ha, to approximately 70 ha or 33 % of the total vegetation cover.
   The final aim is therefore to increase the central communities on Raheenmore and Clara West to a third of the total vegetation cover. On Clara East a more realistic estimate would be that central community types could form 20 % of the vegetation cover, with more sub-central complexes.
   If these aims were achieved over the next ten to twenty years and methods perfected these areas could be increased again.

3. To halt any further peat cutting on Clara bog by immediate purchase of the areas still being exploited.

4. To attempt to conserve the soak systems, using some trial methods such as unblocking the drain leading from Lough Roe.

5. To re-create areas of lagg vegetation, by the protection of existing areas and the creation of other suitable areas by either: raising the regional ground water level, so that the influence of base rich water is greater or by removing layers of ombrotrophic peat, so that the fen peat is exposed and the roots of colonising plants are in contact with ground water.

9.8 IN CONCLUSION.

Before the findings of this project, in particular the vegetation mapping of both sites, the extent of the damage to these two raised bog sites had not been realised. This research has shown that although a number of Midland raised bog sites are protected from further drainage or peat cutting, they will not be protected from further degradation until damming procedures have been carried out. Moreover this work has highlighted the urgency with which restoration or preventative measures should be carried out.

At Clara and Raheenmore there is now sufficient information available about the hydrology, hydrogeology and the links between hydrology, hydrochemistry and vegetation for effective conservation and restoration work to be done. They can thus act as trial areas for the insertion of different dam types and various methods of lagg restoration. The effects of these restoration methods may be monitored as the base line conditions are known. This will allow the application of the most successful methods to other sites in Ireland and elsewhere.

However it is important to remember that restoration or re-generation is not a replacement for what remains. The success of restoration measures should not be taken as a solution to the problems of peat exploitation, as restoration can never be a substitute for 5,000-7,000 years of raised bog development.

Despite the problems that both bogs are experiencing and the enormity of site protection that is required, these sites are still relatively intact compared to raised bog sites in other parts of Europe. We still possess a large percentage of the remaining oceanic raised bogs and thus these measures must be taken to ensure that the raised bog habitat is conserved.

Praeger (1937) wrote "Offaly ....is the most bog-covered part of the Central Plain, no less than one-fifth of its area covered by this strange vegetable blanket. ....There is not much of special interest....". Attitudes have changed.

REFERENCES.

Aerts, R. (1989).
Plant Strategies and Nutrient Cycling in Heathland Ecosystems. Ph. D. Thesis. pp 13.

Aerts, R. and Berendse, F. (1989).
Above-ground nutrient turnover and net primary production of an evergreen and a deciduous species in a heathland ecosystem. Journal of Ecology. **7** 7: 343-356.

Ahmad-Shah, A. and Rieley, J. O. (1989).
Influence of tree canopy on the quantity of water and amount of chemical elements reaching the peat surface of a basin mire in the Midlands of England. Journal of Ecology. **7** 7: 357-370.

Allen, S. E., Carlisle, A., White, E. J. and Evans, C. C. (1968).
The plant nutrient content of rainwater. Journal of Ecology. **5** 6: 497-504.

Allen, S. E., Grimshaw, H. M., Parkinson, J. A. and Quarmby, C. (1974).
Chemical Analysis of Ecological Materials. Blackwell, Oxford.

An Foras Forbartha. (1981).
Areas of Scientific Interest in Ireland. National Heritage Inventory. An Foras Forbartha, Dublin.

Armstrong, W. and Boatman, D. J. (1967).
Some field observations relating the growth of bog plants to conditions of soil aeration. Journal of Ecology. **5** 5: 101-110.

Armstrong, W. (1985).
Waterlogged soils. In: J. R. Etherington. Environment and plant ecology. (2ed.). John Wiley and Sons, Chichester. pp 290-330.

Bell, J. (1991).
A study of the hydrological effects of a bog road, Clara Bog, Co. Offaly. MSc. Thesis. Department of Civil Engineering, Imperial College, London.

Bell, J. N. and Tallis, J. H. (1973).
The responses of *Empetrum nigrum* L. to different mire water regimes, with special reference to Wynbury Moss, Cheshire and Featherbed Moss, Derbyshire. Journal of Ecology. **6** 2: 75-95.

Bell, P. R. (1959).
The ability of *Sphagnum* to absorb cations preferentially from dilute solutions resembling natural waters. Journal of Ecology. **4** 7: 351-355.

Bellamy, D.J. and Bellamy, R. (1966).
A ecological approach to the classification of the lowland mires of Ireland. Proceedings of The Royal Irish Academy B. **6** 5: 237-251.

Bellamy, D. J. (1968).
An ecological approach to the classification of the lowland mires of Europe. Proceedings of the 3rd International Peat Congress. pp 74-79.

Bellamy, D. (1986).
The Wild Boglands. Country House, Dublin, Ireland.

Blackwell, I. (1992).
A hydrological study of the lagg zone of Clara Bog, Co. Offaly, Ireland. MSc. Thesis, Imperial College, University of London.

Bloetjes, O. A. J. and van der Meer, J. J. M. (1992).
A preliminary stratigraphical description of peat development on Clara Bog. Fysisch Geografisch en Bodemkundig Laboratorium, Universiteit van Amsterdam.

Boatman, D. J., Hulme, P. D. and Tomlinson, R. W. (1975)
Monthly determinations of the concentrations of Sodium, Potassium, Magnesium and Calcium in the rain and in pools in the Silver Flowe National Nature Reserve. Journal of Ecology. 63: 903-912.

Boelter, D. H. (1970).
Important physical properties of peat materials. Proceedings of the 3rd International Peat Congress, Quebec. 150-154.

van den Boogaard, M. J. G. (1993).
Regional hydrogeology of Clara Bog: An Irish Raised Bog. Department of Water Resources. Group Hydrogeology. Wageningen Agricultural University, The Netherlands.

ter Braak, C. J. F. (1988).
CANOCO-A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal components analysis and redundancy analysis (version 2.1). Agricultural Mathematics group, Wageningen, The Netherlands.

ter Braak, C. J. F. and Prentice, I. C. (1988).
A Theory of Gradient Analysis. Advances in Ecological Research. V. 18. Academic Press Inc. Ltd. London.

ter Braak, C. J. F. (1990).
Update notes on CANOCO (Version 3.10). Agricultural Mathematics group, Wageningen, The Netherlands.

Chapman, S.B. (1965).
The ecology of Coom Rig Moss, Northhumberland, III. Some water relations of the bog system. Journal of Ecology. 53: 371-384.

Clapham, A. R., Tutin, T. G. and Moore, D. M. (1989).
Flora of The British Isles. (3rd ed.). Cambridge University Press, Cambridge.

Clymo, R. S. (1963).
Ion exchange in *Sphagnum* and its relation to bog ecology. Annals of Botany. 27: 310-324.

Clymo, R.S (1970).
~~The growth of *Sphagnum*: methods of measurement. Journal of Ecology. 58: 13-49.~~

Clymo, R. S. and Hayward, P. M. (1982).
The ecology of *Sphagnum*. In: A. J. E. Smith (ed.). Bryophyte Ecology. Chapman and Hall, London. pp 30-78.

Comeau, P. L. and Bellamy, D. J. (1986).
An ecological interpretation of the chemistry of mire waters from selected sites in Eastern Canada. Canadian Journal of Botany. 64: 2576-2581.

Connolly, A. (1992).
A report on the palaeoecoloogy of Lough Roe, Clara Bog, Co. Offaly. School of Botany, University of Dublin, Trinity College.

Coulson, J. C. and Butterfield, J. (1985).
The invertebrate communities of peat and upland grasslands in the North of England and some conservation implications. Biological Conservation. 34: 197-225.

Cross, J. R. (1989).
Peatlands: wastelands or heritage. Wildlife Service of Ireland.

A4

Cross, J. R. (1990).
The Raised Bogs of Ireland: their ecology, status and conservation. Report to the Minister of State at the Department of Finance. Stationery Office, Dublin.

van der Cruijsen, Grent, A. and van Wolfswinkel, R. (1993).
Acrotelm mapping on Clara Bog. Department of Water Resources. Group Hydrogeology. Wageningen Agricultural University, The Netherlands.

Daniels, R. E. (1975).
Observations on the performance of *Narthecium ossifragum* (L.) Huds. and *Phragmites australis* Trin. Journal of Ecology. **6 3**: 965-978.

Daniels, R. E. (1989).
Adaptation and Variation in bog mosses. Plants Today. **2**: 139-144.

Dierssen, K. (1982).
Die Wichtigsten Pflanzengesellschaften der Moore NW Europas. Geneve: Conservatoire et Jardin Botaniques.

van Dijk, J. and Young, R. (1984).
Effects of Human influence on the edge vegetation of Irish Midland raised bogs. Unpublished Internal Report of the Hugo de Vries Laboratory, University of Amsterdam.

Douglas, C., Garvey, L., Kelly, L. and O'Sullivan, A. (1989).
Survey to locate blanket bogs of scientific interest in Mayo. Part II. Internal Report to The Wildlife Service, Office of Public Works.

Douglas, C. and Grogan, H. (1985).
Survey to locate Raised bogs of Scientific interest in Co. Galway (East) and Roscommon. (Part 2). Internal Report to The Forest and Wildlife Service.

Douglas, C. and Mooney, E. (1984).
Survey to locate Raised bogs of Scientific interest in Co. Galway (East) and Roscommon. Internal Report to The Forest and Wildlife Service.

Doyle, G. J. (1982).
Narrative of the excursion of The International Society for Vegetation Science to Ireland, 21-31 July 1980. In: J. White, (ed.). Studies on Irish Vegetation. Journal of Life Sciences, Royal Dublin Society. **3**: 43-64.

Doyle, G. J. and Foss, P. J. (1986).
Vaccinium oxycoccus L. growing in the blanket bog area of North-West Mayo (H27). Irish Naturalists Journal. **2 2**: 101-104.

Doyle, T. (1990).
A Study of Decomposition in Mongan Bog. A Raised Bog in Co. Offaly. Unpublished Ph.D. Thesis, Trinity College Dublin.

Eber, W. (1982).
The ecology of bogs and bog plants. Journal of the Life Sciences. Royal Dublin Society. **3**: 243-254.

Flynn, R. M. (1990).
Clara Bog: A Hydrological Study. MSc. Thesis, University of Birmingham.

Flynn, R. (1993).
The hydrogeology of Clara Bog and the surrounding area. A report to The National Parks and Wildlife Service, Office of Public Works, Dublin.

Fowler, J. and Cohen, L. (1992).
Practical statistics for field biology. pp 83-89. John Wiley and Sons, Chichester.

Given, P.H. and Dickenson, C.H. (1975).
Biochemistry and microbiology of peats. In E.A. Paul and D. Mc Laren (eds.) Soil Biochemistry 3. Deker, New York. pp 123-212.

Godwin, H. and Conway, V. H. (1939).
The Ecology of a Raised Bog near Tregaron, Cardiganshire. Journal of Ecology. 27: 313-363.

Goodwillie, R. (1980).
European Peatlands. Nature and Environment Series No. 19. Council of Europe, Strasbourg.

Gore, A. J. P. (1983).
Introduction. In: A. J. P. Gore. (ed.). Ecosystems of the World. 4A Mires: Swamp, Bog, Fen and Moor. Elsevier Scientific Publishing Company, Amsterdam.

Gorham, E. (1956).
The ionic composition of some bog and fen waters in the English Lake District. Journal of Ecology. 44: 142-152.

Gorham, E., Eisenreich, S. J., Ford, J. and Santelmann, M. V. (1985).
The chemistry of bog waters. In: W. Stumm (ed.). Chemical processes in lakes. pp 339-363. John Wiley, New York.

Green, B.H. and Pearson, M.C. (1968).
The ecology of Wynbury Moss, Cheshire I: The present vegetation and some physical, chemical and historical factors controlling its nature and distribution. Journal of Ecology. 56: 245-267.

Greenberg, A. E., Connors, J. J. and Jenkins, D. (eds.) (1980).
Standard methods for the examination of water and waste water. Washington D.C. American Public Health Association.

Greenwood, D. J. (1961).
The effect of oxygen concentration on the decomposition of organic materials in soil. Plant and Soil. 14: 360-376.

Grootjans, A. P. and ten Klooster, W. (1985).
Changes of groundwater regimes in wet meadows. In A. P. Grootjans. Changes of groundwater regimes in wet meadows. Rijksuniversiteit te Groningen. pp 59-73.

Hammond, R.F., v.d. Krogt, G. and Osinga, T. (1990).
Vegetation and water tables on two raised bog remnants in County Kildare. In: G.J. Doyle (ed.). Ecology and Conservation of Irish Peatlands. Royal Irish Academy, Dublin. pp 121-134.

Hayati, A. A. and Proctor, M. C. F. (1990).
Plant distribution in relation to mineral nutrient availability and uptake on a wet-heath site in South West England. Journal of Ecology. 78: 134-151.

Heath, G. H. and Luckwill, L. C. (1938).
The rooting system of heath plants. Journal of Ecology. 26: 331-352.

Herries Davies, G. L. and Stephens, N. (1978).
The Geomorphology of The British Isles. Ireland. Metheun and Co. Ltd.

Hill, M.O. (1979).
TWINSPAN- A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Cornell University Ithaca, New York.

Hobbs, N. B. (1986).
Mire morphology and the properties and behaviour of some British and foreign peats. Quarterly Journal of Engineering Geology. 19: 7-80.

196

Howard, J. A. (1970).
Aerial Photoecology. Faber and Faber, London.

van 't Hullenaar , J. W. and ten Kate, J. R. (1991).
Hydrology of Clara and Raheenmore Bogs: Evapotranspiration, Storage co-efficients, lateral flow in the acrotelm, catchment definition and test of the piezometer method for hydraulic conductivity. Wageningen Agricultural University, The Netherlands.

Hussey, V. (1992).
Levelling on Clara Bog. A report to The Parks and Wildlife Service, Office of Public Works.

Hutchinson, C. D. (1989).
Birds in Ireland. Irish Wildbird Conservancy. Poyser, England.

Ingram, H. A. P. (1967).
Problems of hydrology and plant distribution in mires. Journal of Ecology. 5 5: 711-724.

Ingram, H. A. P. (1983).
Hydrology. In: A.J.P. Gore (ed.). Ecosystems of the world 4A Mires: Swamp, Bog, Fen and Moor. General Studies. Elsevier Scientific Publishing Co., Amsterdam. pp 67-150.

Ingram, H. A. P. and Bragg, O. M. (1984).
The diplotelmic mire: some hydrological consequences reviewed. In: Proceedings of the 7th International Peat Congress, Dublin I. pp 220-234.

Ivanov, K. E. (1981).
Water Movement in Mirelands. Academic Press, London.

Jeffrey, D. W. (1970).
A note on the use of ignition loss as a means for the approximate estimation of soil bulk density. Journal of Ecology. 5 8: 297-299.

Jeffrey, D. W. (1987).
Soil-plant Relationships: an ecological approach. Croom Helm, London.

Jefferies, T. A. (1915).
Ecology of Purple Heath Grass (*Molinia caerulea*). Journal of Ecology. 9 3: 93-109.

Jermy, A. C., Chater, A. O. and David, R. W. (1982).
Sedges of the British Isles. (2 ed.). BSBI Handbook No. 1.

Johnson, L. C., Damman, A. W. H. and Malmer, N. (1990).
Sphagnum macrostructure as an indicator of decay and compaction in peat cores from an ombrotrophic South Swedish peat-bog. Journal of Ecology. 7 8: 663-647.

Jones, H. E. and Etherington, J. R. (1970).
Comparative studies of plant growth and distribution in relation to waterlogging I: The survival of *Erica cinerea* L. and *Erica tetralix* L. and its apparent relationship to iron and manganese uptake in waterlogged soils. Journal of Ecology. 5 8: 487-496.

Jongman, R.H.G., ter Braak, C.J.F. and van Tongeren, O.F.R. (eds.) (1987).
Data analysis in Community and Landscape ecology. Pudoc, Wageningen.

Kemmers, R. H. (1986).
Calcium as hydrochemical characteristic for ecological states. Technical Bulletin of The Institute for Land and Water management. No. 47. P. O. Box 35, 6700 AA Wageningen, The Netherlands.

Key, R. (1989).
Peat cutting and the Invertebrate fauna of lowland peatland, with particular reference to the Humberhead Levels Mires of Thorne and Hatfield Moors. In: W. Fogt and R. Meade (eds.) Cutover Lowland Raised Mire. Proceedings of a conference held on the 4th and 5th of October, 1988 at Doncaster. Nature Conservancy Council. pp 32-37.

Kopecky, K. and Hegny, S. (1974).
A new approach to the classification of anthropogenic plant communities. Vegetatio. **29**: 17-20.

Küchler, A. W. (1967).
Vegetation Mapping. The Ronald Press Company, New York.

Lawton, J.H. (1990) (ed.).
Red Grouse populations and moorland management. Ecological Issues No. 2. British Ecological Society, London.

Leach, S.J. and Corbett, P. McM (1987).
A preliminary survey of Raised Bogs in Northern Ireland. Glasra. **10**: 57-73.

Lindsay, R A, Everingham, F., Faden-Lilja, Y., Mayer, P., Nicholls, R., Reid, E., Rowell, T. A. and Ross, S. (In press).
Raised Bogs in Great Britain. The National Peatland Resource Inventory. Scottish Natural Heritage, 2/5 Anderson Place, Edinburgh.

Loach, K. (1968).
Seasonal growth and nutrient uptake in a Molinietum. Journal of Ecology. **56**: 433-444.

Mackereth, F. J. H., Heron, J. and Talling, J. F. (1978).
Water Analysis: Some revised methods for limnologists. Fresh Water Biological Association Scientific publication.No. 36.

Madden, B. (1987).
The Birds of Mongan Bog, Co. Offaly. Irish Birds. **3**: 441-448.

Madden, B. and Doyle, G. J. (1990).
Primary Production on Mongan Bog. In: G. J. Doyle (ed.). Ecology and Conservation of Irish Peatlands. R.I.A. pp 147-161.

Malmer, N. (1986).
Vegetation gradients in relation to environmental conditions in northwestern European mires. Canadian Journal of Botany. **64**: 375-383.

McAfee, D. A.(1993).
A preliminary investigation into some of the factors that affect the colonisation potential of *Sphagnum cuspidatum*, with particular reference to the drainage channels on Clara Bog, Co. Offaly. Unpublished B.A. (Mod.) Thesis, School of Botany, Trinity College, Dublin.

Miles, J. (1976).
The growth of *Narthecium ossifragum* in some Southern English Mires. Journal of Ecology. **64**: 849-858.

Mitchell, G.F. (1981).
The Littletonian Warm Stage-Post 10,00 BP. In: C. H. Holland (ed.). A Geology of Ireland. Scottish Academic Press, Edinburgh.

Mitchell, F. (1990). Revised edition.
Shell Guide to Reading the Irish Landscape. Country House, Dublin.

178

Moore, J. J. (1955).
Distribution of *Scheuchzeria palustris* on a raised bog in Co. Offaly. Irish Naturalists Journal. 11: 1-7.

Moore, J. J. (1968).
A classification of the Bogs and wet Heaths of Northern Europe (Oxycocco-sphagnetea Br. Bl. et Tuxen, 1943). In: R. Tuxen (ed.). Pflanzensoziologische Systematix. Bericht Uber Das Internationale Symposium in Stolzenau/Weser, 1964. pp 306-320.

Moore, P. D. and Bellamy, D. J. (1976).
Peatlands. Elek Science, London.

Mueller-Dombois, D. and Ellenberg, H. (1974).
Aims and methods in vegetation ecology. Wiley and sons, New York.

Newbould, P. J. and Gorham, E. (1956).
Acidity and specific conductivity measurements in some plant communities of the Newforest Valley bogs. Journal of Ecology. 44: 118-128.

Newbould, P. J. (1989).
Historical and International Perspective. In: C. Mollan (ed.). The Utilisation of Irish Midland Peatlands. The Proceedings of a workshop held in the R.D.S. from September 21th to 24th, 1988. Royal Dublin Society. pp 15-25.

O'Connell, C. (1991).
Bogs in the Classroom-A Peatland Resource Pack for Teachers. Irish Peatland Conservation Council, Dublin.

O'Connell, C. (1992) (ed.).
Peatland Education Pack. Irish Peatland Conservation Council, Dublin.

O'Connell, M. (1981).
The Phytosociology and Ecology of Scragh Bog, Co. WestMeath. New Phytologist. 87: 139-187.

O'Neill, B. J. (1992).
The design of a walkway for Clara Bog, Co. Offaly. BAI Thesis, Trinity College, Dublin.

Osvald, H. (1949).
Notes on the vegetation of British and Irish Mosses. Acta Phytogeographic Suecica. 26: 1-62.

Overman, H., Sinnige, N. and Veerkamp, P. (1989).
Vegetation mapping of the margins of three raised bogs in Central Ireland. University of Amsterdam.

Praeger, R. Ll. (1937).
The Way That I Went. Hodges,Figgis., Dublin.

Proctor, M. C. F. (1974).
The vegetation of Malham Tarn. Field Studies. 4: 1-38.

Proctor, M. C. F. (1992).
Regional and local variation in the chemical composition of mire waters in Britain and Ireland. Journal of Ecology. 80: 719-736.

Reynolds, J. D. (1985).
Some vertebrates of Lough Roe, Co. Offaly: A rare and endangered habitat. Bulletin of The Irish Biogeographical Society. 9: 41-45

Rivsdijk, K. F. and van der Meer, J. J. M. (1990).
Lacustrine deposits in the areas of Clara and Raheenmore bogs. Facies development and relations to surrounding deposits. Fysisch Geografisch en Bodemkundig Laboratorium, Universiteit van Amsterdam.

Rodwell, J.S. (ed.) (1991).
British Plant Communities, Volume 2: Mires and Heaths. Cambridge University Press.

Rohan, P.K. (1986).
The climate of Ireland. Stationery Office, Dublin.

Rutter, A. J. (1955).
The composition of wet heath in relation to the water table. Journal of Ecology. **43**: 507-543.

Ryan, J. B. and Cross, J. R. (1984).
The conservation of peatlands in Ireland. Proceedings of the 7th International Peat Congress. Dublin, Ireland I. pp 388-405.

Rycroft, D. W., Williams, D. J. A. and Ingram, H. A. P. (1975).
The transmission of water through peat I: Review. Journal of Ecology. **63**: 535-556.

Samuels, H. (1992).
Drainage and subsidence in a Raised Bog. MSc. Thesis, Imperial College, University of London.

Scheffers, M. C. and van der Meer, J. J. M. (1993).
An additional study in the Quaternary geology of Clara bog, Co. Offaly. Fysisch Geografisch en Bodemkundig Laboratorium, Universiteit van Amsterdam.

Schouten, M. G.-C. (1984).
Some aspects of the ecogeographical gradient in the Irish Ombrotrophic bogs. Proceedings of the 7th International Peat Congress, Dublin. pp 1-20.

Schouten, M.G.C. (1990).
Problems of scale in the phytosociology of Irish bogs. In: Doyle, G.J. (ed.). Ecology and Conservation of Irish Peatlands. pp 91-107.
Royal Irish Academy.

Schouwenaars, J. M. (1988).
The impact of water management upon ground water fluctuations in a disturbed bog relict. Agricultural Water Management. **14**: 439-449.

Sjörs, H. (1950).
On the relation between vegetation and electrolytes in North Swedish mire waters. Oikos **2**: 241-256.

Small, E. (1972).
Ecological significance of four critical elements in plants of raised *Sphagnum* peat bogs. Ecology. **53**: 498-503.

Smilauer, P. (1990).
Canodraw 2.1: A computer program to read the solution files of CANOCO. Kozelkova 1419, Praha 4-Chodov, 149 00 Czechoslovakia.

Smith, A. J. E. (1980).
The Moss Flora of Britain and Ireland. Cambridge University Press, Cambridge.

Sparling, J. H. (1966).
Studies on the relationship between water movement and water chemistry in mires. Canadian Journal of Botany. **44**: 747-758.

Speight, M. and Madden, B. (1987).
Insects of Peatlands. In: C. O' Connell (ed.). The I.P.C.C. guide to Irish Peatlands. Fodhla Printing Co. Ltd., Dublin.

Spieksma, J. F. M. (1993).
Hydrology of Clara and Raheenmore Bog: Permeability of Raheeenmore Bog and Subsidence study of Clara Bog West. Department of Water Resources. Group Hydrogeology. Wageningen Agricultural University, The Netherlands.

Stary, T. and Jirásek, V. (1978).
A concise guide in Colour: Herbs. Hamlyn, London.

Stoneman, R., Barber, K. and Maddy, D. (1993).
Present and past ecology of *Sphagnum imbricatum* and its significance in raised peat - climate modelling. Journal of the Quaternary Research Association. **7**: 14-22.

Streefkerk, J. G. and Casparie, W. A. (1989).
The hydrology of Bog Ecosystems. Staatsbosbeheer, The Netherlands.

Stuyfzand, P. J. (1990).
Chemproc 3.0.: A water Classification computer program.

Summerfield, R. J. (1974).
The reliability of mire water chemical analysis as an index of plant nutrient availability. Plant and Soil. **40**: 97-106.

Sutcliffe, J. F. and Baker, D. A. (1974).
Plants and Mineral Salts. Studies in Biology No. 48. Edward Arnold, London.

van Tatenhove, F. and van der Meer, J. (1990).
The Quaternary geology of Clara and Raheenmore, Co. Offaly, Ireland. Preliminary mapping of superficial deposits. Fysisch Geografisch en Bodemkundig Laboratorium, Universiteit van Amsterdam.

Tomlinson, R. W. (1984).
Mapping Peatland Vegetation from readily available air photographs: A field test from Northern Ireland. Irish Geography. **17**: 65-83.

van Tongeren, O. (1991).
CEDIT: Cell editor, CANOCO editor, Cornell editor preliminary manual. Limnological Institute, Nieuwersluis, The Netherlands.

Vegbase 3.0 (1990).
Relationeel Database Management Systeem voor opslag en manipulatie van vetetatieopnamegegevens. Rijksuniversiteit Groningen Lab V. Plantenoecologie Postbus 14 9750AA, Haren. The Netherlands.

Veldkamp, N. M. and Westein, R. (1993).
Hydrology of Raheenmore Bog. A water balance study. Wageningen Agricultural University, The Netherlands.

Verhoeven, J. J. A. (1992).
Fens and bogs in The Netherlands: Vegetation, History, Nutrient dynamics and Conservation. Kluwer Academic Publications, Dordrecht.

Watson, E. V. (1981).
British Mosses and Liverworts. Cambridge University Press, Cambridge.

Webb, D.A. (1977).
An Irish Flora. Dundalgan Press (W. Tempest) LTD. Dundalk.

Webster, J. R. (1962).
The composition of wet heath in relation to aeration of the ground water and soil. II: Response of *Molinia caerulea* to controlled conditions of soil aeration and water movement. Journal of Ecology. **50**: 639-650.

Westhoff, V. and den Held, A. J. (1969).
Planten-Gemeenschappen in Nederland. BV WJ Thieme and Cie, Zutphen.

White, J. and Doyle, G.J. (1982).
The Vegetation of Ireland: A catalogue raisonne. Journal of Life Sciences, RDS 3: 289-368.

Whittaker, R. H. (1973).
Ordination and Classification of Communities. Junk, The Hague.

Whittaker, R. H., Levin, S. A. and Root, R. B. (1973).
Niche, habitat and ecotope. American Naturalist. **107**: 321-338.

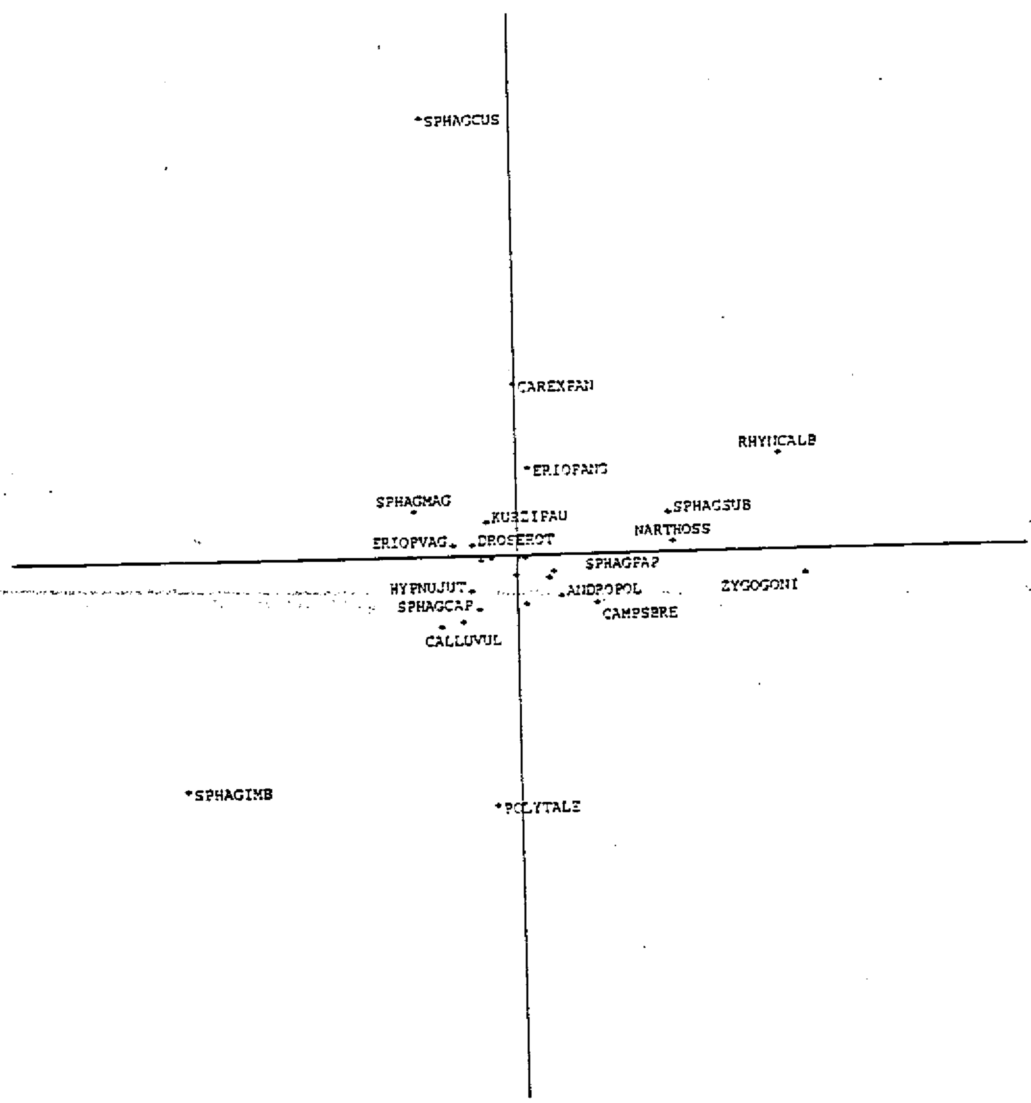
Whittow, J. B. (1974).
Geology and Scenery in Ireland. Penguin Books, England.

van Wirdum, G. (1980).
Eenvoudige beschrijving van de waterkwaliteitsverandering gedurende de hydrologische kringloop ten behoeve van de natuurbescherming. In: J. C. Hooghart (ed.). Waterkwaliteit in grondwaterstromingsstelsels. Rapporten en Nota's No. 5. Committe for Hydrological Research. TNO, The Hague, The Netherlands. pp 118-143.

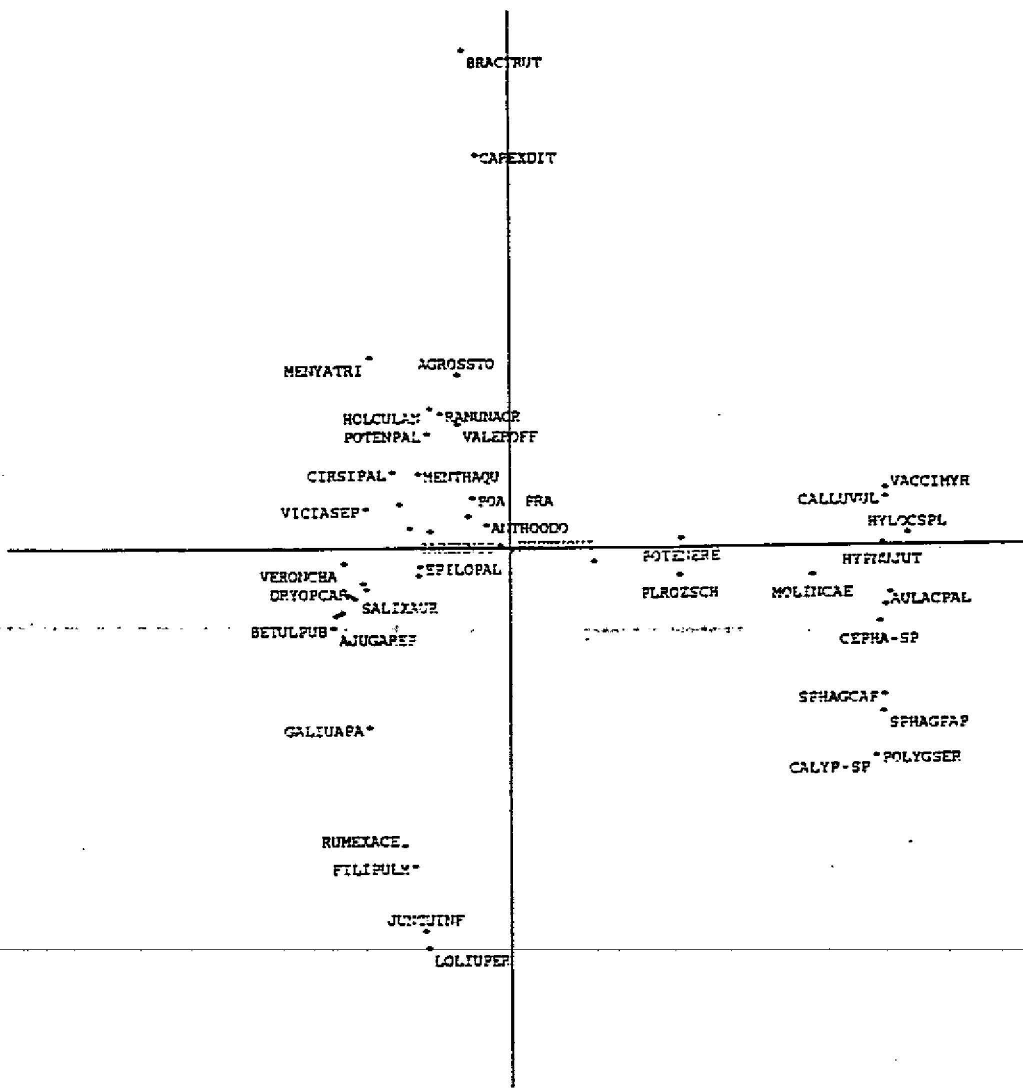
Wymer, E. (1987).
Student investigations of a peatland ecosystem. In: C. O'Connell (ed.). The IPCC guide to Irish Peatlands. Irish Peatland Conservation Council, Dublin. pp 64-67.

182

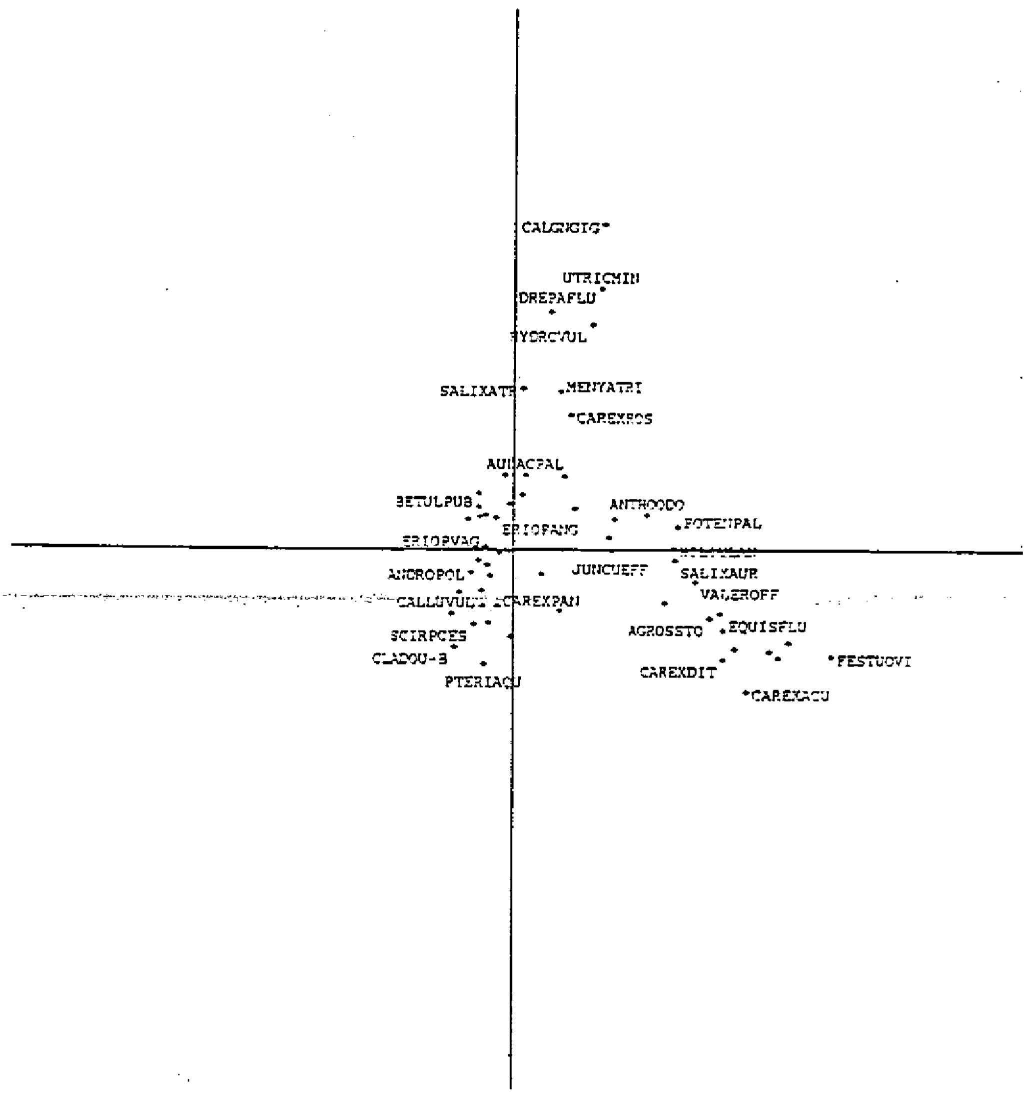
APPENDIX 5 (b): CCA SPECIES PLOT OF THE BOG DATA 1991-1992.



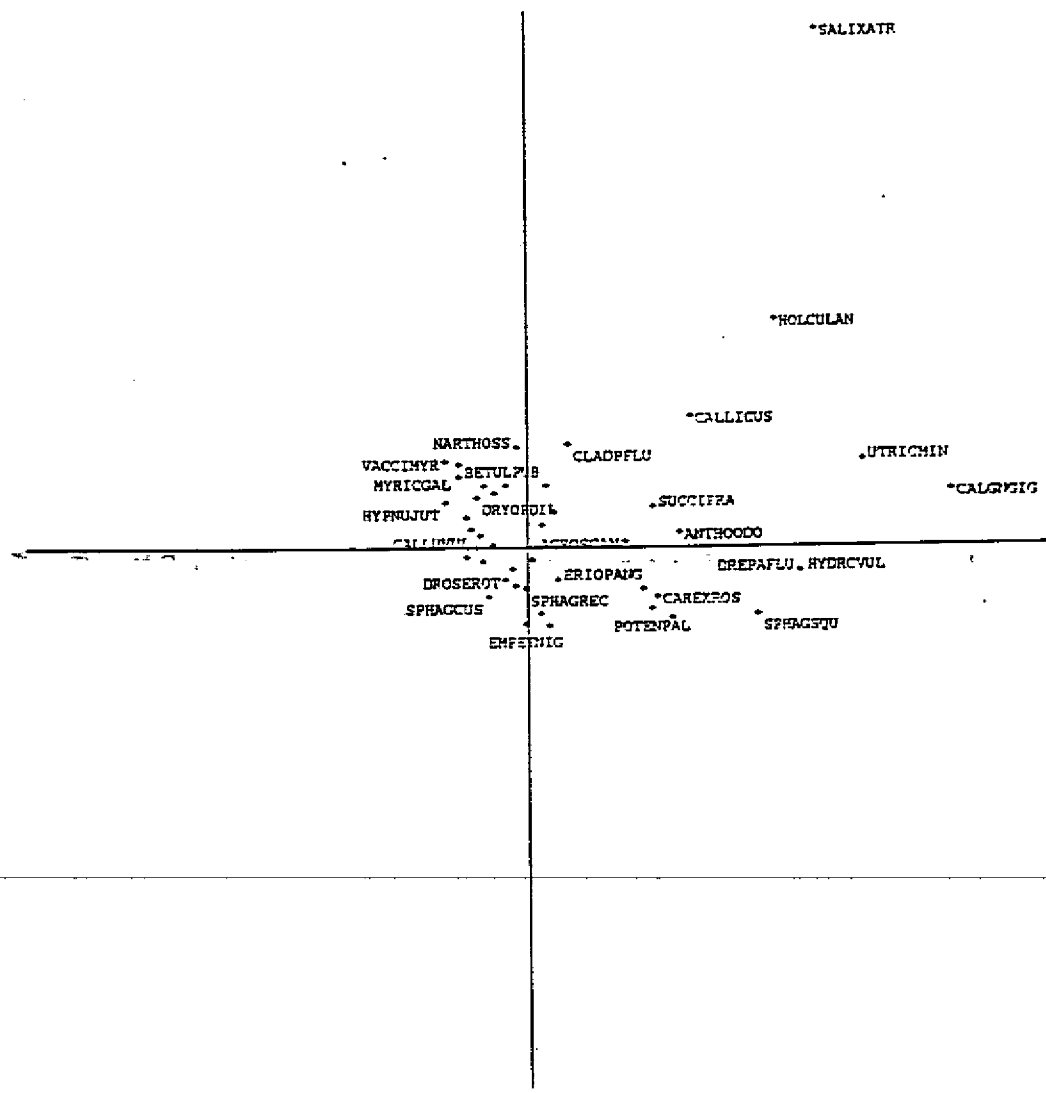
APPENDIX 5.: (d): CCA SPECIES PLOT OF THE BOG AND MARGINAL DATA 1991-1992.



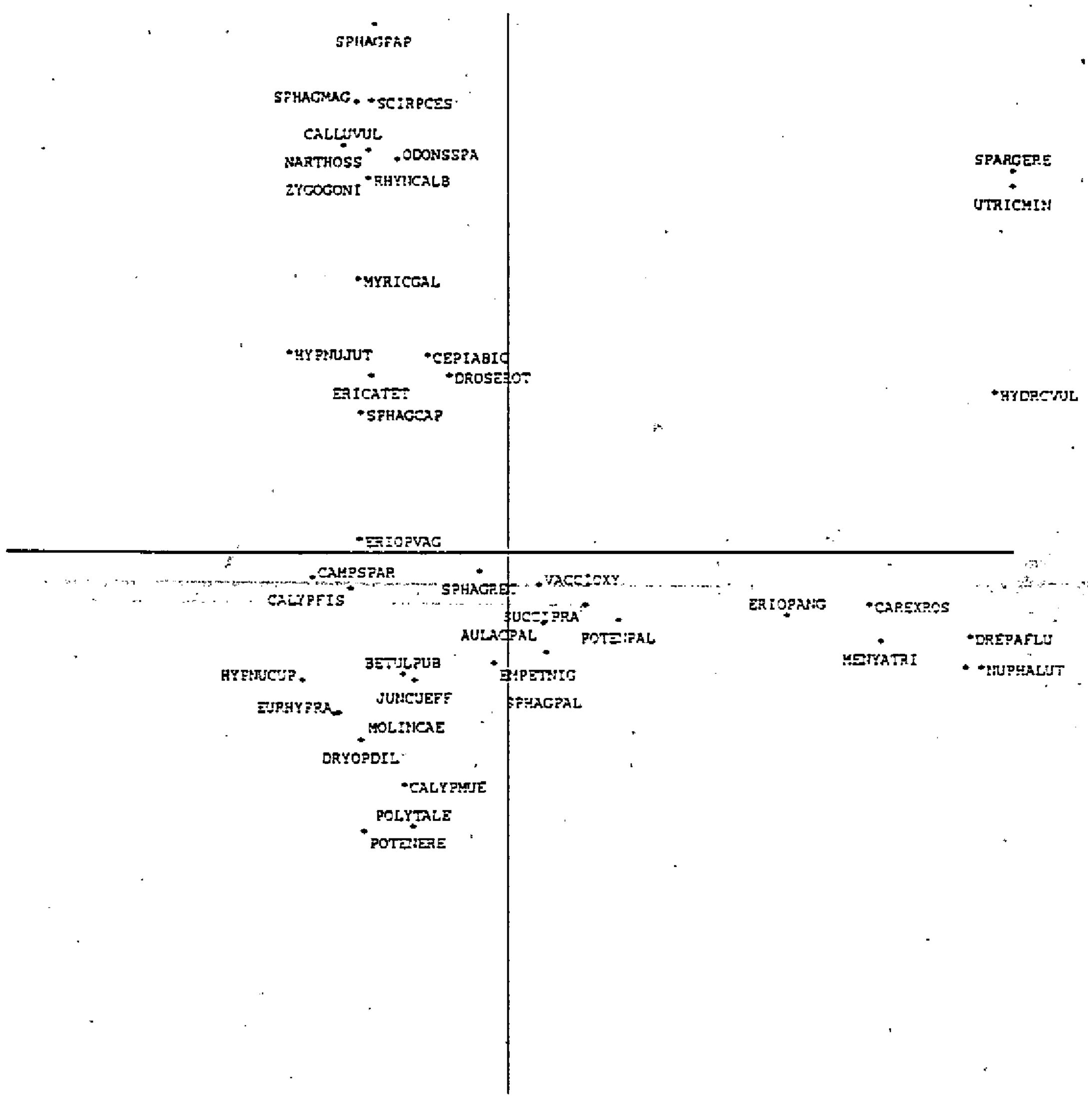
APPENDIX 6.1 (b): CCA SPECIES PLOT OF THE BOG. MARGINAL (Oct. 1990) AND THE SOAK (Oct. 1991) DATA.



APPENDIX 7.2 (a): CCA SPECIES PLOT OF THE SOAK DATA (Aug. AND Oct. 1991).



APPENDIX 7.2 (b): CCA SPECIES PLOT OF THE SOAK DATA (1991-1992).



Appendix 8.1d VEGETATION MAP KEY.

Code	Design	Complex Zone	Communitiy Types
1		Face bank Complex.	4G, 3A, 3E, 3D, 4A, 4B, 1.
2		*Trichophorum* Complex.	3E, 3A, 3D, 4A, 1.
3		*Carex panicea*/burnt Complex.	3D, 1, 3A, 3E, 4B, 3Bb.
3a		*Narthecium & Carex panicea*/ burnt Complex.	3A, 1, 3D, 4B, 3E, 4A.
3b	D D	*Dactylorhiza maculata*/ *Carex panicea* Complex.	1, 3A, 3D, 3E,4B, 4A, 3Bb.
4	R R R	*Rhynchospora alba* Complex	1, 3Bb, 4A, 3Ba.
5		*Rhynchospora fusca* Complex.	1, 2B, 3Bb, 4A, 3D, 4B.
5a		*Rhynchospora fusca*/ *Carex panicea* Complex.	1, 2B,3D, 3Bb, 4A, 4B.
6		*Narthecium* Complex.	3A, 1, 3D, 3E, 4A, 4B.
6a		*Narthecium* / *Calluna* Complex.	3A, 3D, 4A, 4B, 3E, 1.
7		*Calluna* Complex.	3D, 3E, 4A, 4B, 3A.
7a	E E	*Calluna*/ *Eriophorum angustifolium* Complex.	3D, 3E, 4A, 4B, 3A, 1.
8		*Sphagnum imbricatum* Complex.	4D, 4A, 4F, 3Bb, 3Ba, 2A, 1.
9		*Eriophorum vaginatum* Complex.	4A, 4B, 3D.
10		Transition *Sphagnum magellanicum* Complex.	3Bb, 3A, 3Ba, 4A, 4E.
11		Hummock/hollow orientated pool Complex.	3Ba, 3Bb, 2B, 4B, 3C, 3A, 4A. 4E. 4F. 3A.
12	S S	*S. magellanicum*/ *E. angustifolium* Complex.	4B, 3D, 3A, 3Ba, 3Bb, 2A, 7. 11. 8C.
13		*Calliergon cuspidatum* Complex.	10, 3Bb, 3Ba, 3A, 4A, 4E, 4D. 3E. 3D. 3C. 1. 2A.
14		Hummock/hollow Frequent pool Complex.	3Ba, 2B, 3Bb, 4B, 3C, 4A, 3A., 4E. 4F.
15		Hummock/hollow Scattered pool Complex.	3Ba, 3Bb, 2B, 4B, 3C, 3A, 4A. 4E. 4F. 3A.
16		Enriched *Sphagnum magellanicum* Complex.	3Bc, 3Ba, 3Bb, 4A, 3C, 8C, 4E. 4F.
17		Enriched *S. magellanicum* /*S. cuspidatum* Complex.	3Bc, 2A, 3Ba, 3Bb, 4A, 3C. 8C. 4E. 4F.
18	M M	*Myrica gale* Complex.	3A, 3F, 2A, 3Bb, 3Ba.
19	M M M	*Myrica gale* and *S. magellanicum* Complex.	3F, 2A, 3Bb, 3Ba.
20	Mo Mo	*Molinia caerulea* Complex.	14B, 14A, 12Ab.

Appendix 8.1d cont. VEGETATION MAP KEY.

21	Mo M Mo	*Molinia* and*Myrica* Complex.	14A, 14B, 12Aa, 3F, 3Bc.
22		*Betula pubescens* scrub /*Molinia* Complex.	12Ab, 12Aa, 3Bc, 9A.
23	▲ ▲ ▲ ▲ ▲	*Betula pubescens* woodland Complex.	12Bb, 12Ab,3Bc, 9A.
24	X	*Betula pubescens* & *Juncus effusus* woodland Complex.	12Ba.
25	J J	*Juncus effusus* Complex.	
26	T	*Typha latifolia* Complex.	
27	♦ ♦	Enriched w. soak Complex.	12Ab, 12Aa, 11, 4I, 8C, 12Bb, 12Ac, 14B, 10, 4F.
28		Less enriched W. soak Complex.	12Ab, 12Aa, 11, 4I, 8C, 12Ac, 14B, 10, 4F.
29	+ +	*Sphagnum recurvum* & *S. cuspidatum* lawn Complex.	8Aa, 8Ab, 9A, 9B, 7, 2A.
30		*Sphagnum recurvum*/ *E. vaginatum* Complex.	8Aa, 7.
31	2 2	Central Lough Roe Complex.	5A, 5B, 5C, 6, 7, 5, 8Aa, 8Ab, 8B, 8C.
32		Marginal Lough Roe Complex.	12Ab, 11, 3Bc.
33	+ + + + + + + +	*Cladonia portentosa* an important element.	
34	Pt	*Pteridium aquilinum* present.	