A study of the vegetation of the South Burn valley, Waldridge Fell, County Durham

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"Commons often form islands of semi-natural vegetation in the midst of a sea of ploughed land. They have naturally become refuges for many rare or interesting plants or vegetation types ... and are thus of great interest ... and have been notified to Planning Authorities as Sites of Special Scientific Interest."

H.M. Govt. (1958),
cmmd. 462, para. 74

A STUDY OF THE VEGETATION OF THE SOUTH BURN VALLEY, WALDRIDGE FELL, COUNTY DURHAM

by

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ABSTRACT

The vegetation of the South Burn valley, Waldridge Fell, County Durham, was examined using an objective, quantitative phytosociological method. The vegetation units found to be present in the valley using this technique were then described and classified.

Certain parameters relating to the chemical and physical environment of each vegetation unit were measured and variations in these factors used to account for the distribution of the vegetation units within the valley.

The valley floor is broad and flat and situated below a series of spring lines. The majority of the area has a substrate composed of peat and the importance of water table height, ground water chemistry and tne degree of decomposition of this peat are emphasised as being the major environmental factors controlling the distribution of the main vegetation units of the valley floor.

In a small area of the valley floor, which has willow carr growing upon it, the substrate is composed of a mineral soil. Here the chemistry of the water supplying the area and the nature of the substrate are important environmental factors.

The valley sides are steep and composed of a sandy substrate and the dry nature and base-poor conditions of this habitat, seem to, in all probability, account for the type of vegetation found growing on these sites.

In a study of the population dynamics of the major tree species of the vegetation units, evidence was obtained showing that a change in tree species composition is taking place. Alder and Birch are the main dominants of the valley floor at present, but the evidence presented here suggests that these species are not regenerating and that ash is moving in to become the dominant tree of the valley floor. However, the small area of willow carr presently found in the valley will probably remain with such a species composition, but with a change in the predominant willow species. Further a small area of birch wood with a moss carpet ground layer appears to be losing its tree component and will probably change to a sphagnum bog. The tree composition of the valley sides also appears to be changing. On the fell side birch is being replaced by oak while, on the opposite side of the valley, sycamore is moving in to replace the birch. Reasons for these observed changes are given.

INTRODUCTION

Waldridge Fell is an area of common land of the lowland heath type occupying a cuesta of sandstone in the productive coal measures of County Durham. It lies some 3 kilometres south west of the centre of Chester-le-Street (see fig. 1) and has an areal extent of some 115 hectares. The north west side of the fell is bordered by the steeply incised valley of the Cong Burn. From here the valley sides rise steeply to the south east up to the highest point of the fell, the rim of a gently sloping plateau at a height of 129 m O.D. South east of this point the land drops gently for 1100 metres to the valley of the South Burn which provides the south east boundary of the site. The flat valley floor of the South Burn is at a height of approximately 75 metres O.D. while the top of the steep valley sides are some 15 metres above this.

The gently sloping land running south east from the ridge to the South Burn comprises the majority of the fell (see fig. 2). Most of this area has an irregular topography and is composed of heathland the characteristic vegetation being dominated by Calluna vulgaris although in places this gives way to Nardus grassland, with Pteridium aquilinum and, increasingly, with trees and shrubs now that grazing has been curtailed. Some of the low lying hollows in this area have a wetland type of vegetation. These communities are more fully described by Jeffries (1916) and Wheeler and Shaw (1976) (see fig. 3).

The South Burn follows a roughly south west to north east course en route for its confluence with the river Wear just south of Chester-le-Street. The stream has cut a steep sided, though shallow, valley through the sandstone. The valley floor is quite flat, relatively broad and rather wet being irrigated by a discontinuous line of springs. The valley sides are, however, quite steep, often up to 45^{o}, and this steepness combined with the sandy nature of the soil means that the valley sides are much dryer than the floor due to rapid run-off and seepage of water.

The South Burn provides an area of special interest as the damper floor and drier slopes support various types of woodland vegetation. The South Burn woods appear to provide a "refuge" for vegetation which elsewhere in County Durham is suppressed by "the improvements of man". In addition to this, environmental factors operating in the area of the wet valley floor cause the vegetation in that area to be surprisingly diverse and species rich. This latter point provides two of the main aims of this present study, namely: to identify and describe the main vegetation types present within the South Burn valley; and to determine the major environmental factors controlling the distribution and abundance of these vegetation types. A further aim was to study the population structure of the major tree species making up the different woodland types in an attempt to determine the status of the woodlands and to predict any future changes in the composition of the tree species making up the woodlands.

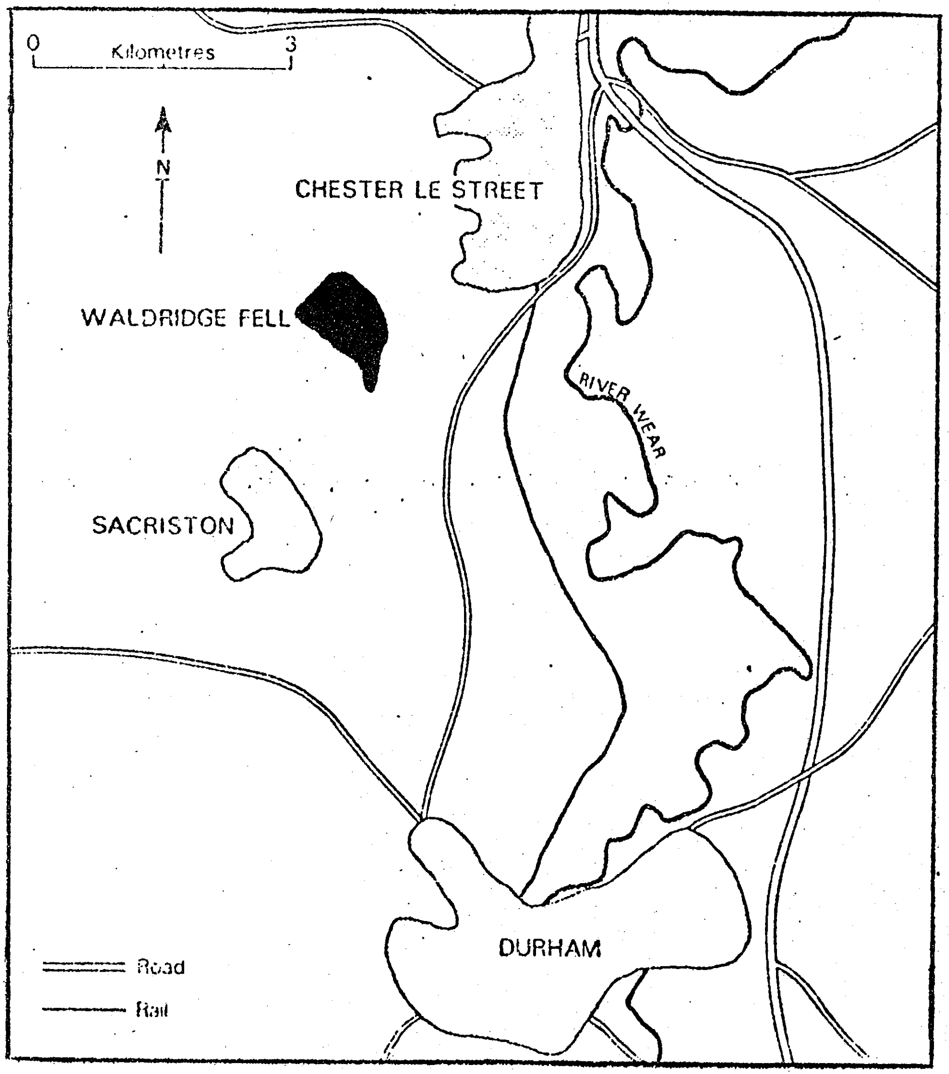


Figure 1 : Location of Waldridge Fell (after Ellison 1979)

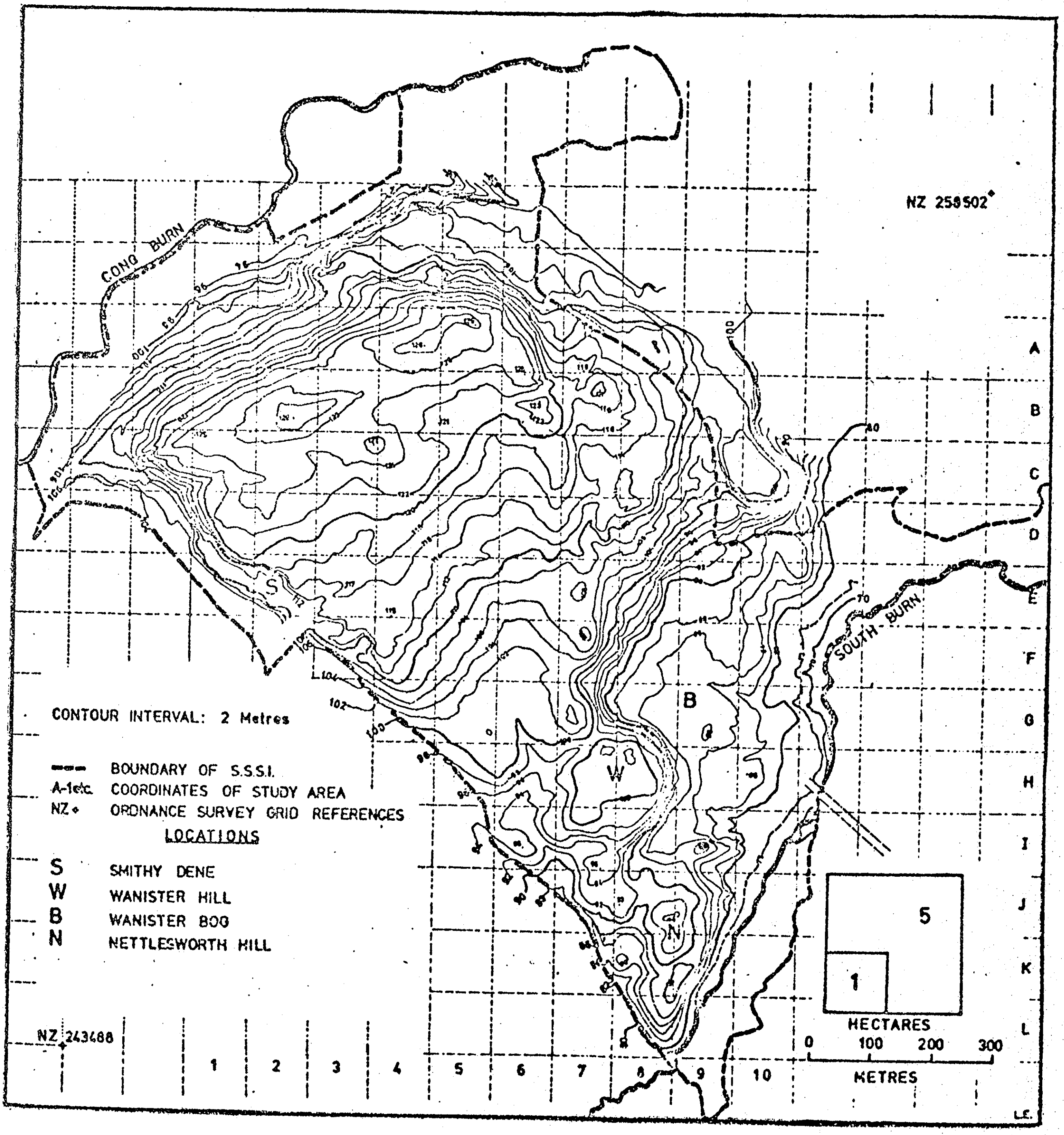


Figure 2 : Stereometric map of Waldridge Fell (after Ellison 1978)

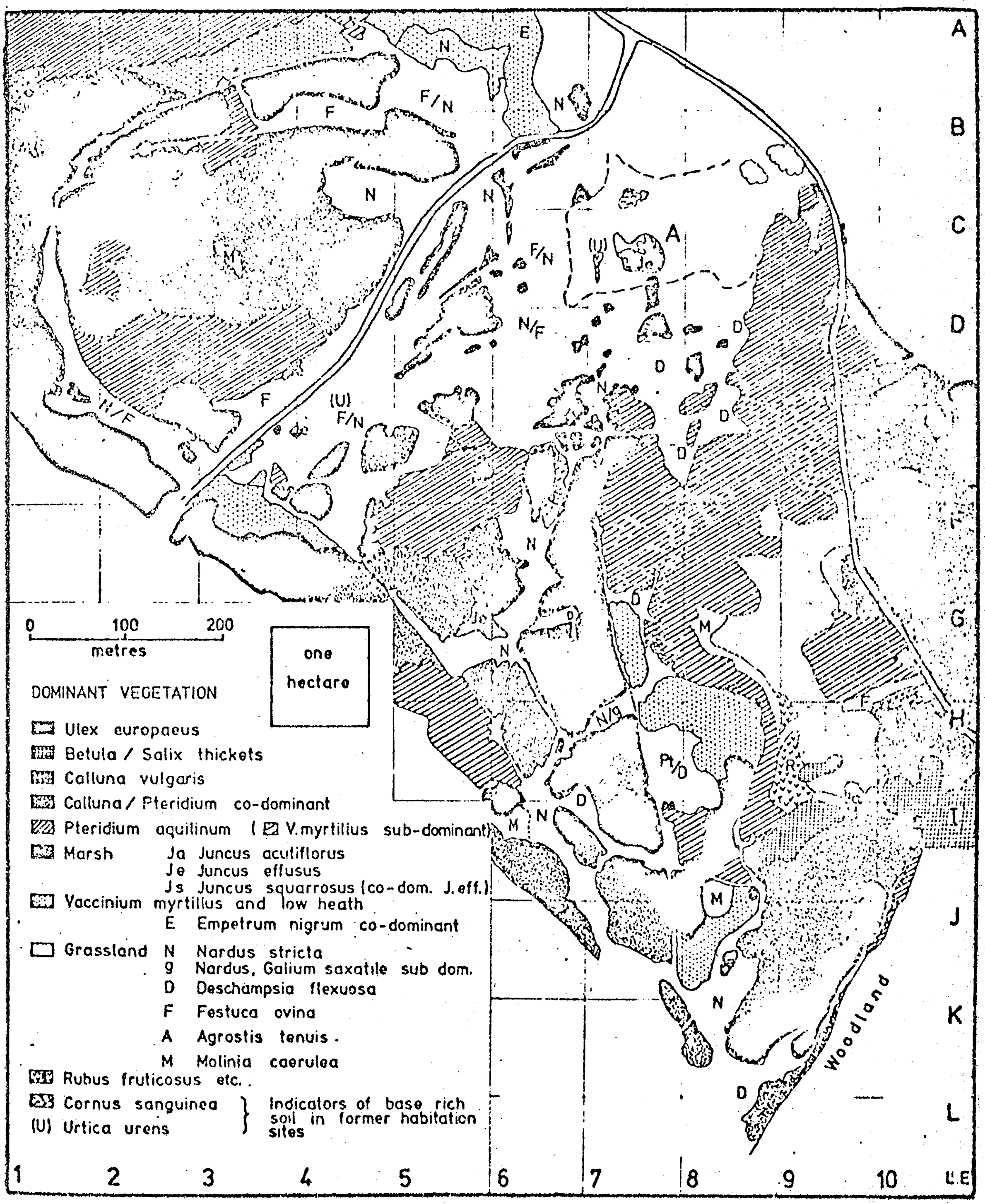


Figure 3 : The vegetation of Waldridge Fell in 1977 (after Ellison 1978)

CHAPTER 1

HISTORICAL BACKGROUND

The present area of Waldridge Fell is only a small remnant of the lowland heath that formerly extended over the low sandstone hills that form the dominant landform in the area between the river Wear and the river Derwent. In such lowland areas Tansley (1939), suggests that the long history of man's activities since mesolithic times must have prevented the development of forest, a fact also acknowledged by Gimmingham (1972), who states that lowland heaths are a prime example of Biotic Plagioclimax Vegetation; that is replacement vegetation stabilised by pasturing and other activities of man. However, it appears that the heath of Waldridge Fell was not created by forest clearance until the fourteenth century or even later. From evidence of preserved twigs at roughly corresponding layers in the peat of some surrounding sites, as well as at Waldridge itself, and also from pollen evidence, Tinsley (1975); Godfree (1975); Rainstock and Blackburn (1931); Kershaw (1967); and Ellison (1978) show that until about 1350 the area of Waldridge Fell was covered in woodland. This forest was then extensively cleared and further pollen records, as well as historical documents, show that from then until the present day there have been heath communities present upon the site. Such records also show that the steep valley sides of the South Burn have intermittently had woodland present upon them, woodland which Kershaw (1967) has shown to be very similar to that of today. The present woodland of the South Burn valley was established some 90 years ago (Jeffries 1916).

Historical records also show that in the late eighteenth and early nineteenth centuries private acts of parliament inducing land improvements for agriculture, as well as a general rise in population levels, caused a drastic reduction in the area of heath around Waldridge Fell. The greatest threat to Waldridge Fell, however, came with the demands of car borne recreation-alists for informal leisure space in the 1960's and 1970's. This threat came about as new industries arrived in the area at about this time, especially at Sunderland, the Team Valley and along the Great North Road. The increased affluence caused by these industries created a public with a high number of car owning households, and hence high mobility, and also a demand for space to pursue outdoor recreational activities. Thus Waldridge Fell became an extremely popular area as it is the largest expanse of countryside with a natural appearance, over which people can walk, for some distance around. However, this usage created a pressure on the vegetation and caused increased damage to it. Thus, in an attempt to preserve the fell it was made into a countryside park in 1974. This made the management of the fell much easier and also provided funds for such work. At about the same time the importance of the South Burn valley, both as a refuge for species which are elsewhere lacking in County Durham and for educational purposes, was realised, and consequently the valley was designated a Site of Special Scientific Interest.

CHAPTER 2

PHYTOSOCIOLOGY

This study has the main aim of examining the relationship between the vegetation present in the South Burn Valley and the major environmental factors operating within that valley. In order to do this it was necessary to generate classes or groups of sample stands of vegetation which could be characterised in terms of the environmental variables measured. To achieve this it was necessary to adopt a system of classification of vegetation using phytosociological techniques.

Plants are usually found with some degree of spatial association with each other, whether of the same or different species. This association constitutes vegetation, and phytosociology is "the science of vegetation concerned with the social organizations of plants" (Wheeler 1975b). Therefore phytosociology in its widest sense encompasses the whole range of vegetational phenomena; i.e. structure, morphology, dynamics and inter-relationships with the associated environments. The nature of vegetation is defined by its component plant material, the basic unit of which is the species. Vegetation can thus be regarded as an interacting system of species-populations, the distribution of which is a function of both their availability (i.e. their ability to reach any particular site by dispersion mechanisms, this being related to geographical distribution) and ecological amplitude (i.e. ability to cope successfully with the environmental factors prevailing at a site).

Because of the effect of ecological amplitude, species - populations within a landscape tend to be restricted to certain sites. This imparts a pattern upon the vegetation which is expressed by the recurrence of particular combinations of species in association with one another. Hence, any plot of vegetation is differentiated into a patchwork of vegetational sites identifiable by their floristic composition. The presence of these vegetational sites has led to the concept of plant communities which is a fundamental concept of phytosociology.

Disagreement as to the precise meaning of the term "plant community" has caused controversy and confusion as the term has been used in two different ways. It has sometimes been used to refer to a particular portion of vegetation occupying real space; i.e. the "real" or "concrete" community (Westhoff 1951). Alternatively, the term has been used to denote some unit of vegetation which has been abstracted from samples of "real" vegetation i.e. the "abstract" community or community-type (Whittaker 1962), nodum (Poore 1956) or phytocoenon (Westhoff 1951). The latter meanings are phytosociological terms.

Various methods of phytosociological study are available for a descriptive survey aiming at detecting and describing different types of vegetation on the basis of the species of plants they contain. Accounts of some of these methods have been given by Whittaker (1962), Shimwell (1971) and in various articles in the "Handbook of Vegetation Sciences" (Whittaker 1973). Probably the most fully developed school of phytosociological research in Europe is that developed by Professor J. Braun-Blanquet (1921, 1928). There are two branches of this school known as the Braun-Blanquet School and the Zurich Montpellier (Z.M.) School. The methods of plant sociology developed by Braun-Blanquet have since expanded into a comprehensive system that has been applied throughout much of Europe and also in some non-European countries. Initially the system found little favour with British ecologists (see Tansley & Adamson 1926), however, with the recent re-awakening of interest in vegetation description it has been successfully adopted in Britain by many workers (Imney-Cook & Proctor (1966), Bridgewater (1970), Birks (1973) to name but a few). Details of the principles and practices of the school are given by Moore (1962), Whittaker (1962), Braun-Blanquet (1964), Shimwell (1971) etc.

In any descriptive phytosociological survey the following stages can be recognised.

(1) Selection of vegetation parameters to be used for the description.

(2) Sampling of the vegetation.

(3) Comparison of sample data.

(4) Extraction of vegetation units.

(5) Characterisation and synthesis of the units.

Sampling is one of the most important components of a phytosociological survey as the nature of the samples will determine the results of the survey. Sampling is also time consuming and so it should be efficient, accurate and commensurate with the aims of the project. The essential attributes to record in any sampling strategy are the species present as these are useful and clearly defined (with reference to current taxonomic opinion) recording units.

There are two ways of recording the floristic data; on a qualitative, binary (presence/absence) scale or using one of the quantitative scales available as a measure of abundance. Griey-Smith (1964) considers the comparison of samples using binary data alone to be crude, however, Williams & Dale (1962), Lambert & Dale (1964) and Orloci (1968) point out that in large scale work, or with heterogenous stands, qualitative data may be adequate or even preferable. However, with only a minimal increase in sampling time subjective estimates of the relative quantities of the species present can be added to binary data using one of the various cover-abundance scales available (see Kershaw 1964). Although these are imprescise and open to user bias, they provide a useful adjunct to help describe vegetation classes established upon binary data. The cover-abundance scale combines, in part, abundance (number) with coverage of the area. In the same way it is valuable to record the sociability i.e. a measure of the grouping of the species. The cover-abundance and sociability scales used in this survey are outlined below.

TABLE 2.1 : Domin Cover - Abundance Scale

Isolated, cover small	+
Scarce, cover small	1
Very scattered, cover small	2
Scattered, cover small	3
Abundant, cover about 5%	4
Abundant, cover 5-25%	5
Abundant, cover 25-33%	6
Abundant, cover 33-50%	7
Abundant, cover 50-75%	8
Abundant, cover 75%	9
Abundant, cover 100%	10

TABLE 2.2 : Braun-Blanquet Sociability Scale

Soc. 1	= Growing singly, isolated individuals
Soc. 2	= Grouped or tufted
Soc. 3	= In small patches throughout quadrat
Soc. 4	= Extensive patches joined throughout quadrat
Soc. 5	= In pure populations

There are two basic sampling regimes available for the collection of data, objective and subjective. In the latter case the operator selects the stand of vegetation to be sampled by observation in the field. This method has many disadvantages compared to the objective method where the samples are taken randomly or in the form of a systematic pattern. With objective sampling techniques there is a minimum of selective bias in the collection of the basic data. A further advantage is that this technique gives consistent and repeatable results to which statistics can be applied if this is required. Also this method does not assume that the whole area of vegetation to be sampled is differentiated into discernable stands, as subjective techniques do. There are, however, some disadvantages with objective sampling. For instance the sampling of rare vegetation types may be missed while the location of sampling points may sometimes be difficult in the field (Moore et al 1970) and the procedure can be more time consuming. However, Lambert (1972) recommends that this procedure should be applied wherever possible as the advantages usually outweigh the disadvantages.

Thus to obtain the raw data of a phytosociological survey (steps 1 and 2 above) several decisions need to be taken. The basic unit to record is normally quite straightforward namely, species present. This usually means all species present from trees down to mosses and even lichen sometimes. It needs to be decided whether mere presence/absence data will be collected or some form of quantitative data using one of the cover-abundance scales and sociability scale available. If quantitative data is to be taken the actual cover-abundance scale to be used also needs determining. Finally a decision on whether to use a subjective or objective sampling strategy must be made. The aim of the project i.e, the use to which the vegetation analysis is to be put and the treatment that the raw data is to receive all have a bearing upon the final choice of sampling strategy.

In the present study a quantitative estimate, using the Domin scale of cover abundance (see Table 2.1) and the Braun-Blanquet Sociability scale (Table 2.2), of the species present in each releve was recorded. The position of each releve was selected using random number tables after griding the site, the co-ordinates obtained from the random number tables referring to a particular 2 m^2 quadrat.

Having obtained the basic data a method to compare the stands and to detect and extract units of vegetation needs to be obtained. This is the process of classification which consists of two distinct processes:

(1) The creation of classes that are in some sense meaningful, and

(2) The allocation of individuals to these classes. Individuals assigned to any one class must be more similar, one to another (on the basis of some defined parameter of resemblence), than they are to individuals of other classes.

There are two basic types of class. Monothetic classes which are defined by a unique set of attributes i.e. all the members possess all the attributes used to define the class; and polythetic classes where no one single attribute is essential for group membership but individuals possessing the greatest number of shared attributes constitute the class. Classes may be formed by the sub-division of the set of individuals into a number of smaller sub-units (divisive approach) or by the fusion of the individuals themselves to form groupings (agglomerative approach). The first approach can be either monothetic or polythetic while the latter is purely polythetic. A "natural classification", set up using monothetic or polythetic and divisive or agglomerative approaches, is one where class members possess a large number of common characteristics so that within-class resemblance is maximised while between class resemblance is minimised (Gilmour 1964).

Problems arise in erecting a "natural classification" on the basis of floristic resemblances as there are no pre-existing categories to which the samples can be allocated. Instead the classes have to be generated de novo from the samples themselves, which creates additional problems in deciding which is the most meaningful grouping into classes and how many classes are required. Generally a polythetic approach is more likely to generate natural classes and is to be preferred to a monothetic approach.

To erect a classification of the vegetation of the South Burn in this study the following procedure was followed. (See Muller-Domnois & Ellenberg 1974.) The raw data was incorporated into a "raw table" where the columns represent n individuals (releves) and the rows P attributes (species) which define them. In this table the intersections contain information relating to the occurrence of each species in a given releve. This primary matrix can be classified in many ways. The first method to be developed, and the method used in this study, is by tabular re-arrangement. This is an empirical approach of re-ordering the positions of rows and columns to reveal blocks of correlated species records which can then be used to differentiate the sets of samples into discrete classes. This is a visual attempt to clarify the structure inherent in the raw table by the recognition of pattern. This involves the recognition of mutually exclusive sets of differential species followed by tabular re-arrangement, based upon these, through a series of steps as follows (Mueller-Dombois & Ellenberg 1974).

(1) Enter releve data into one table, the raw table.

(2) Count the number of times each species is present in the entire releve series and calculate the constancy value for each species (this can be expressed in absolute terms or, more usually, in percentage terms).

(3) As speces of very high and very low constancy are too common and too rare respectively to be used as differentiating species only those speces whose constancy value lying in an intermediate range (i.e. 10%-60%) are used. These species are re-written into a new table, the constancy table, from high to low constancy along with their releve data.

(4) These species in the constancy table are searched for mutually associated species which occur together in more than one releve. These are possible differentiating species. Also species which are mutually exclusive to the first group are sought as these are possibly another group of differentiating species. All species in the same category are underlined.

(5) These underlined species are extracted into a new partial table by moving the species of each group together.

(6) Now the releve order is changed by moving releve's

in which mutually associated species occur, together. This results in an ordinated partial table. Further refinement in releve and species order can be introduced by ordering the releves by number of differential species per group and ordering the differential species from broad to narrow amplitude and from high to low constancy within each differential species group.

(7) Finally all species are recorded into a completed differentiated table by first writing the differentiating species as found in steps 1-6 followed by the other species in order of constancy from high to low.

This process achieves a simultaneous classification of both samples and species. It is a polythetic technique which in a sense is agglomerative in that it is often necessary to initially specify those samples which are sufficiently similar to one another to be included in the same raw table. However, Moore et al 1970 describe the technique as a "polythetic subdivisive classification of releves followed by their linear ordination".

The end product of the sorting process is a differentiated table in which the contained vegetation units are displayed, together with their characterizing species. This technique uses the floristic data themselves to display the classifications and hence it readily shows: the degree of variation within a group; the distinctness of the boundaries; and one group's relationship to one another. Also the species data indicates the floristic composition of the groups and permits the extraction of floristic criteria by which the classes may be defined. There are some disadvantages with this method of classification. It is time consuming; the re-ordering of the matrix by re-writing is error prone; the process is sufficiently imprecise, and so somewhat subjective, for different workers to produce different groupings; and the upper limit of the number of samples that can be handled in any one analysis is low. However the technique is simple to apply, requires no modern technology for its application and produces a classification.

Having extracted vegetation units by the use of tabular re-arrangement it is then necessary to define them in terms of their floristic composition, in order that they may be suitably described. Within the Braun-Blanquet and Zurich-Monpellier Schools three types of species have been commended for this purpose: constant companions; differential species and character species. Together these form the "characteristic" species combination of a syntaxon.

Constant species occur in 81-100% of the samples of a given vegetation unit.

Differential species have pronounced affinities to certain vegetation units and can be used for differentiating between them.

Character species are a special case of differential species. They consist of those species of a narrow sociological amplitude which are more or less restricted to specific vegetation units. According to the degree of faithfullness of a particular species to a given syntaxon three categories of character species are recognized (Braun-Blanquet, 1964).

(1) Exclusive taxa: completely or almost completely restricted to one vegetation unit.

(2) Selective taxa: show a distinct preference for one vegetation unit but also occur with a low degree of presence in others.

(3) Preferential taxa: occur in several vegetation units but are optimally developed in one.

Only when data relating to all or most of the vegetation of a given area are available can faithfullness of a given species to a given community type be assessed. Character species are an important part of the Zurich-Montpellier methodology, although it seems likely that absolute character species are practically non-existent (Mueller-Dombois & Ellenberg 1974). Other possibilities for the floristic characterisation of vegetation units have been suggested. For example Westhoff & Den Held (1969) gave the concept of "character combination" in which a particular combination of species is regarded as being exclusive to a vegetation unit although none of the individual species need be. Both character species and character combinations are useful concepts in the floristic description of vegetation units.

Goodall (1953b) suggests that it is possible to apply numerical techniques as an aid to the extraction of character species. For this he suggests the use of an indicator value which distinguishes a species in a particular community from all other communities occurring in the area. This value can be obtained from the difference in frequency of the species under consideration in the vegetation unit under consideration and in the remaining area as a whole, after Yate's correction for continuity has been applied, viz:

$$I = \frac{(a-\frac{1}{2})(b+d)}{(b+\frac{1}{2})(a+c)} - 1$$

The values for a, b, c and d are obtained from a 2x2 contingency table thus:

	Community being considered	All other communities
species present	a	b
species absent	c	d

significance is tested using χ^2

This method was used in the present study to determine, objectively, species which could be used in the hierarchical classification of the vegetation units found.

The Zurich-Montpellier School uses such a hierarchical classification in which the Association is the basic unit; this is an abstract floristic unit defined by its characteristic species combination. Associations can be fused into higher units or sub-divided into lower ones with a suffix attached to the name of a unit to show its rank thus:

class	- etea
order	- etalia
alliance	- ion
association	- etum
sub-association	- etosum

Character speces are used to define units above the association while differential species are used to define sub-units below the association.

Summary of methods used in the present study

An objective, quantitative sampling procedure was used whereby releves for sampling were selected using random number tables, the species present in each releve were recorded and cover/abundance and sociability for each species noted. The data obtained was classified into discrete vegetation units using a tabular rearrangement technique and the vegetation units obtained were described and syntaxonomically classified using traditional Zurich-Montpellier techniques with the aid of certain statistical tests.

CHAPTER 3

THE VEGETATION

This chapter is concerned with the description of the vegetation groups found to be present in the South Burn valley using the phytosociological technique previously described. Table 8 shows these vegetation groups and species lists are given in Appendix 1.

The valley sides (group 1)

The woodland of the valley sides has a tree layer dominated by *Betula pubescens* which in places forms a dense canopy up to 15 metres in height, the trees forming dense stands while in other places the canopy is quite open. In addition to *B. pubescens*, *Sorbus aucuparia* and *Quercus petraea* are fairly common components of the tree layer and also in the sub-canopy layer. Shrubs are relatively rare with *Rubus fruticosus agg.* being the only one occurring with any constancy.

The herb layer is species poor and is mainly dominated by grasses (*Deschampsia flexuosa* and *Holcus mollis*) and bracken (*Pteridium aquilinum*) with occasional associated herb species the most important being, *Digitalis purpurea*, *Calluna vulgaris*, *Vaccinium myrtilis*, *Teucrium scorodonia*, *Stellaria holostea* and *Lonicera periclymenum*. A full species list for this group is shown in Appendix 1, table 1.

From the component species it appears that this vegetation type is in the phytosociological syntaxonomic class QUERCETEA ROBORI-PETRAEAE. The vegetation in this class is composed of species poor, poorly stratified deciduous oak-birch woodlands of the sub-atlantic and atlantic regions of Western Europe. These woodlands are dominated by species of Quercus and Betula. Due to the difficulty of specific identification of oak caused by the hybridization of Q. robori and Q. petraea either species can occur in this class. Within the Quercetea robori-patraeae there is one order (QUERCETALIA ROBORI-PETRAEAE) and one alliance (QUERCION ROBORI-PATRAEAE).

The character species which place group 1 into this syntaxonomic group are:-

Quercus petraea	Betula pubescens
Lonicera periclymenum	Pteridium aquilinum

and a group of species which, because of widespread woodland destruction, are common in heaths and upland areas but still characterise and differentiate Quercion woodland:-

Holcus mollis	Deschampsia flexuosa
Oxalis acetosella	Pleurozium schreberi
Calluna vulgaris	Vaccinium myrtilis

The woodland seems to fit into the OXILIDO-BETULETUM Association. This Association is virtually the same as Tansley's (1949) Highland birchwood complex. These birchwoods are still widely distributed although scantily developed mostly on valley sides. Although, because of widespread destruction these woodlands are not as common today as they were previously, a few rich areas still remain most notably along the River Spey.

The Association is characterised by the dominance of Betula pubescens; the relatively high constancy of Oxalis acetosella; and the preponderance of Holcus mollis in the herb layer. Sorbus aucuparia may be a component of the tree layer but apart from Quercus petraea few other tree species occur. An often noted feature of the ground layer of such woodlands is the uniformity of structure with a grass layer of Deschampsia flexuosa and occasionally Anthoxanthum odoratum in conjunction with Pteridium aquilinum dominating the most open parts, although many patches of ground exist with no vegetation present (note total ground cover of Table is 67.2%).

Two sub-associations of the Oxilido-betuletum are clearly discernable and of these this group seems to fit the VACCINIETOSUM sub-ass. most closrly. This sub-association is characterized by acid loving species most notably Vaccinium myrtilis and Calluna vulgaris, with Lonicera periclymenum, Pleurozium schreberi and Holcus mollis also being important.

Thus the hierarchical classification of the group 1 vegetation unit is as follows:

Class	: QUERCETEA ROBORI-PETRAEAE Br.Bl et R.Tx. 1943
Order	: QUERCETALIA ROBORI-PETRAEAE R.Tx. (1931) 1937 em 1955
Alliance	: QUERCION ROBORI-PETRAEAE (Malcuit 1929) Br.Bl. 1932
Association	: OXILIDO-BETULETUM
Sub-association	: VACCINIETOSUM

The Valley Floor

The valley floor possesses a mosaic of different woodland types, each type having a characteristic ground flora. Birch dominates the S.E. side of the stream although alder can sometimes be found fringing the stream. Further to the north on this side of the stream alder predominates with ash (Fraxinus excelsior) also being present. Towards the northern end of the valley, close to the road from Chester Moor to Waldridge, willow thicket predominates. On the fell side of the Burn alder is the main tree covering the bulk of the valley floor with ash and birch as occasional components. This differential distribution of tree species is reflected also in the associated species of the vegetation cover with differences in this cover within each woodland type also being evident. From the vegetation data given in table 8 it is evident that we are dealing here with a series of mire forest communities.

Terminology

It may be useful at this point to define some of the terms used in this study. A mire is an area of land possessing a nearly permanently waterlogged substratum (excluding bodies of open water) which are usually peat producing ecosystems. Fen is used *sensu* Du Rietz (1954) to refer to minerotrophic mires with the water table at or slightly above or below the surface of the substratum. A rich fen is rich in calciphytes. Fen carr refers to fen woodlands (Tansley 1911).

Alder carr

These are stands of mire forest vegetation developed within rich fen systems. The alder woodland of the South Burn valley can be defined as a fen carr composed of alder and willow (Alder carr (+ *Salix cinerea*) (Wheeler 1975b).

The best developed area of alder carr in the valley is on the fell side of the Burn where it forms a broad (up to 12 metres) belt between the stream and the base of the valley slopes. It is developed below a well marked spring and seepage line and forms an unbroken community for about two-thirds of the way along the valley from the S.W. end. The wet conditions become discontinuous towards the N.E. end and here a birch woodland of the group 1 type described above predominates on the drier portions. Alder carr is also present on the S.E. side of the stream but here it is fragmentarily developed being surrounded by a birch woodland (see below) and replaced at the N.E. end by willow thicket (see below).

Alnus glutinosa is the dominant tree but other species do occur especially Fraxinus excelsior and occasionally Sorbus aucuparia. These trees are well developed and form a high canopy, alder reaching 10 metres in height in places. This high canopy, in conjunction with limited shrub development permits easy penetration. There is a limited sub-canopy of mainly willows (Salix cinerea and occasionally Salix pentandra) with occasionally birch. Birch is also a rare component of the tree layer. Rubus fruticosus agg. is a regular, though not well developed, component of the shrub layer while Viburnum opulis and Rubus idaeus are also present in this layer. Several species of Lianas may occur in such forests but the only one noted here, and that not very abundantly or well developed, was Lonicera periiclymenum.

The herb layer of this alder carr is often tall and luxurient with Carex species being quite prominent.

For instance the hummocks of *Carex paniculata* are often quite prominent while the smooth-stalked sedge (*Carex laevigata*) can also be found in reasonable quantities. This latter is an interesting species as Graham et al (1972) give only one other record for its occurrence in County Durham. Various tall herb species are also present notably; *Filipendula ulmaria*, *Ranunculus repens*, *Crepis paludosa*, *Valeriana officianalis*, *Oenanth crocata* and *Eupatorium cannabinum*. These species together form a tall herb layer of about 1 metre in height with ferns, especially *Athyrium filix-femmina* and occasionally *Dryopteris filix-mas* and *Dryopteris dilatata*, also contributing to this layer. Smaller herb species are also present, notably; *Stachys sylvatica*, *Mentha aquatica*, *Caltha palustris* and *Cardamine pratensis*. There is a distinct pattern to this vegetation of the alder carr which is apprently related to wetness. This subject will be returned to in more detail below.

The extent of the bryophyte layer is variable with only isolated patches of mosses occurring, notably of *Acrocladium cuspidatum*. Elsewhere there is a richer development with *Brachythecium rutabulum*, some sphagna species and some mnoid species being important. The liver-wort *Pellia epiphylla* is also abundant in places but this also has a somewhat patchy distribution. In some alder carrs lichens can be found in abundance but their absence is striking in the South Burn. This is probably due to the relative youngness of this woodland.

Syntaxonomy

It should be noted that all of the syntaxonomic classifications proposed here are only tentative syggestions for the vegetation units found. The data on the vegetation, although adequate for the purposes of describing the vegetation units, is somewhat limited for the purpose of the classification of these units.

Various types of alder carr have been described for Britain (see for example Moss et al 1910; Pallis 1911; Ruskin 1911; Tansley 1939; Rose 1950 and Klötzli 1970) with four distinct types and several minor variants being recognised. Wheeler (1975a&b) believes that the alder carr of the present study is a very characteristic type with comparative examples in various parts of England and Wales.

Such an alder carr is typically found below springs and seepage lines along the floor of small shallow peat lined valleys cut into acidic, nutrient poor bedrock. Under the rheotrophic conditions which prevail in such places a mire forest develops which is dominated by Alnus glutinosa. The presence and dominance of this species means that such a woodland type is in the syntaxonomic class ALNETEA GLUTINOSAE and order ALNETALIA GLUTINOSAE, the only order in this class, Wheeler (1980). The only alliance is the ALNION GLUTINOSAE. This is also characterised by the presence of Alnus glutinosa and in addition Salix cinerea, S. pentandra, Carex paniculata and Cirsium palustre.

Klotzli (1970) in his survey of British alder woods placed them into two associations; the OSMUNDO-ALNETUM and the PELLIO-ALNETUM both of which are related to an association frequently described from the continent, the CARICI ELONGATAE-ALNETUM. Wheeler (1975b, 1980) suggests that the OSMUNDO-ALNETUM of Klotzli (1970) provides a useful phytocoenon into which lowland alderwoods of relatively nutrient rich habitats (into which category the Waldridge alder wood seems to fall) can be placed. This name is more or less equivalent to the Irido-Alnetum used by Bellamy (1970) to describe this woodland. The species which define this association and which are present in the Burn valley are Carex paniculata and Eupatorium cannabinum.

Wheeler (1975b) noted that the presence of Chrysosplenium oppositifolium, Oenanth crocata and Pellia epiphylla could be used to differentiate this version of alder carr from others occuring in lowland England and Wales. Thus he suggested placing this version in a sub-association, the CHRYSOSPLENIETOSUM and, although the abundance of C. oppositifolium noted by Wheeler was not noted in the present study, (but it still covered a relatively large percentage of the area, see table 2, Appendix 1), there is little evidence available at present to suggest an alteration of this classification as Oenanth crocata and Pellia epiphylla were still relatively abundant. Thus the full syntaxonomic classification of the alder carr of the South Burn valley is:-

Class : ALNETEA GLUTINOSAE Braun Blanquet & Tuscen 1943 em. Muller et Gors 1958
Order : ALNETALIA GLUTINOSAE Uleizer 1937 em. Muller et Gors 1958.
Alliance : ALNION GLUTINOSAE (Malcuit 1929) Meizer Drees 1936 em. Muller et Gors 1958.
Association : Osmundo-Alnetum Klotzli 1970
Sub-association : Chrysosplenietosum Wheeler 1975.

Wet and damp areas

The vegetation of the ground layer is by no means uniform throughout the whole of the alder carr. The dryer places, associated with the least active springs, are dominated by the enormous upstanding tussocks of Carex paniculata. The tops of these tussocks are sometimes crowned with a few specimens of Oxalis acetosella. Occasionally herbs are also found to be present in this community (see Appendix 1, table 3). This community is shown in table 8 as group 3.

Away from the dryest areas a less firm substratum supports a slightly different assemblage of plants (group 2, see Appendix 1, table 2). In addition to many of the species found in the dryer areas some species more characteristic of damp woodland than mire forest are present. These include Lysimachia nemorum, Mercurialis perennis, Valeriana officianalis, Stachys sylvestris, Caltha palustris and Oenanth crocata (see table 2). Such areas of relatively wet alder carr are characterised by the dominance of Filipendula ulmaria and Ranunculus repens in conjunction with a variety of other species. It is thus clear that the floor of the alder carr supports an interlocking mosaic of different microhabitats, primarily related to wetness of the substratum and each with a rather characteristic complement of plant species.

Willow carr

The willow carr area of the South Burn occurs on the S.E. side of the valley close to the Chester Moor to Waldridge road. It is a small area of primitively developed willow thicket where Alnus glutinosa is not an important tree but Salix cinerea and S. pentandra are the dominants, occasionally with Betula pubescens. The canopy is generally low, the trees only being about 5 metres in height, although it is generally quite open. Shrubs are absent below this but the open conditions allow the growth of a rich herbaceous flora somewhat similar to that of the alder carr described above with Filipendula ulmaria, Poa trivialis, Angelica nemoralis, Galium aparine, Stachys sylvatica, Stellaria holostea, Deschampsia cespitosa, Geranium robertanium, Arrhenatherum elatius, Crepis paludosa and Urtica dioica all being present; in addition several other species are present, notably Epilobium angustifolium and Heracleum spondilium. The moss layer is not well developed. See table 4 for a full species list.

Syntaxonomically this vegetation (group 4 of table 8) fits into the class FRANGULETEA, a class which includes many shrub communities of minerotrophic fens developed on peat or mineral ground with a high water table. It includes many successional phases of mire forests and Wheeler (1975b) postulates that the willow carr at Waldrige is a successional phase that developed from Carex diandra-lasiocarpa fen. It is not clear what community will follow this one in the seral development of the area although with drying out Betula pubescens will probably become more prominent. The general species composition of this group and the abundance of Salix cinerea clearly place it in this class.

Within this class there is only one order, the SALICETALIA AURITAE. The presence of Salix cinerea places this vegetation group within the SALICION CINEREAE alliance. This alliance is widespread in N. Europe both in lowland and montane localities (Wheeler 1980). There are several associations within this alliance but the presence of Salix pentandra, Salix cinerea, Betula pubescens and Crepis paludosa clearly place group 4 into the CREPIDO-SALICETUM PENTANDRAE. Thus the full syntaxonomic classification of the Willow carr of Waldridge is:-

Class	: FRANGULETEA Doing 1962 em. Westhoff 1968
Order	: SALICETALIA AURITAE Doing 1962 em. Westhoff 1968.
Alliance	: SALICION CINEREAE Muller et Gors 1958
Association	: Crepido-Salicetum pentandrae Wheeler 1975.

The valley floor birch woodlands

Certain areas of the valley floor on the S.E. side possess a mire forest community where Betula pubescens is the predominant tree with Alnus glutinosa and Fraxinus excelsior as only occasional components. The canopy of such woodland is rather open. On the basis of the floristic composition of the ground flora of this birch dominated woodland three distinct groups of communities can be recognised.

Group 5

The group 5 community (table 8) is situated on the

S.E. side towards the southern end of the valley. This is a rather characteristic vegetation type where Betula pubescens is the only tree present, forming a very open stand and canopy with the trees reaching approximately 8 metres in height. There is no sub-canopy or shrub layer present and the ground flora consists of an extensive bryophyte carpet composed chiefly of Sphagna species (mainly Sphagnum squarrosum and S. fimbriatum) and Polytrichum commune in conjunction with patches of Juncus effusus, Equisetum sylvaticum and several grasses (Deschampsia flexuosa, Holcus mollis, Molinia caerulea, and Agrostis canina). Herb and fern species are not well developed. A full species list of group 5 is shown in table 5.

It is difficult to fit this group into a hierarchical classification but it seems to resemble a system adopted by Westhoff and Den Held (1969) for the continent. If this is so then syntaxonomically this group seems to fit into the class BETULETO-PINETEA with Betula pubescens and Deschampsia flexuosa characterizing it, these species also placing it in the VACCINIO-PICETALIA order. The alliance which this group most closely resembles is the BETULION PUBESCENTIS (synonym SPHAGNO-BETULION PUBESCENTIS), with the dominance of Betula pubescens in the tree layer and Sphagna species in the ground layer determining this. Thus this group would appear to be in the association Betulum pubescentis.

The full suggested syntaxonomic classification for for group 5 is:-

Class	: BETULETO-PINETEA Kanpp 1942
Synonym	: VACCINIO-PICETEA Br.Bl. apud Br.Bl., Seiss et UL 1939
Order	: VACCINIO-PICETALIA Br.Bl. opud Br.Bl. Seiss et UL 1939
Alliance	: BETULION PUBESCENTIS Lohm et R.Tx. apud R.Tx. 1955 em. Scamoni et Passarge 1959
Synonym	: SPHAGNO-BETULIUM PUBESCENTIS Doing 1962
Association	: Betuletum pubescentis (Huech 1929) R.Tx. 1937 em R.Tx. 1955.

Group 6

This group is also found on the S.E. side of the valley but only patchily developed. It is also dominated by *Betula pubescens* in the tree layer with *Alnus glutinosa* and *Fraxinus excelsior* being occasional components. These last two species, together with *Sorbus aucuparia* are also present in the sub-canopy layer. The ground flora bears a striking resemblance to that of the alder carr of group 2 previously described except that in this group *Crepis paludosa* and *Mentha aquatica* are somewhat limited while *Oenanth crocata*, *Caltha palustris* and *Pellia epiphylla* are absent completely. The moss layer is also somewhat different with sphagna species being important in this group, although these are still patchily developed. A full species list for group 6 is given in table 6.

The presence of *Alnus glutinosa*, although it is not predominant, in addition to the general similarity of the ground flora suggests that this group fits into the same syntaxonomic hierarchical classification as groups 2 and 3. However, the absence of *Oenanth crocata* and *Pellia epiphylla* means that this group cannot be placed in the same sub-association as these groups, namely the Chrysosplenietosum, but it does clearly seem to be a member of the association Osmundo-Alnetum.

Perhaps the floristic data from group 6 suggest that an adaptation of Bodeux's (1955) classification of continental alderwoods be adopted in Britain once more data becomes available. In an attempt to define continental alder woods more vigorously through their floristic variation he determined two geographical association groups. Within one of these he recognised an association, the Carici elongatae-Alnetum which has clear affinities with the Osmundo-Alnetum. Within this association he recognised three sub-associations; a betuletosum sub-association of acid sites with Betula pubescens and sphagna species being important; a symphytetosum sub-association of richer sites with Symphytum officianalis and Eupatorium cannabinum being important; and a ranunculetosum repentis sub-association of intermediate sites where Ranunculus repens is important. It can be tentatively suggested that group 6 shows affinities to Bodeux's betuletosum and possibly that group 2 shows affinities with his ranunculetosum repentis. For the moment, however, the classification given for alder carr previously will suffice for group 6 until further work can be carried out to determine the extent of such types of alder wood in Britain and hence the need for any change in the classificatory system.

Birch Molinia woodland

This woodland, shown by group 7 of table 8, is also patchily present on the S.E. side of the Burn. It is again dominated by Betula pubescens with Alnus glutinosa and Fraxinus excelsior as occasional components. However, the ground flora is somewhat different to all other groups described above. In group 7 the ground flora consists of a fen grassland with Molinia caerulea predominating with only a limited occurrence of any other species. M. caerulea is present in this community as robust tussocks some 25-50 m. high with any associated species present occuring in the spaces between these tussocks. The moss layer of this group is fairly well developed considering that Molinia does not support a rich epiphytic moss flora and the accumulation of its litter provides unfavourable conditions for bryophyte growth. Species of Sphagna (especially Sphagnum squarrosum) are the main moss species present, these occuring in clear open spaces between the tussocks. The community of group 7 thus appears to consist of a fen grassland dominated by Molinia caerulea and forming a fragmented though distinct physigonomic category within the rich fen system of the South Burn valley.

Molinia caerulea has a wide sociological amplitude and thus is an important component of a variety of rich fen plant communities. Where this species predominates the substratum is usually relatively dry and the area generally possesses a fluctuating water table. Thus it appears that group 7 is a type of fen grassland community dominated by Molinia caerulea with birch as the major tree. Because of a lack of study of such communities in Britain, and the wide ecological amplitude of M. caerulea and hence the large number of different associations into which this species fits, there are problems in syntaxonomically describing the group 7 community of this study. Character species for any one alliance are missing and it would thus seem best to follow the precedent of continental phytosocialogists and place this community within the alliance MOLINION as Molinia caeralea is such an important species within this community. This dominance by M. caeralea with few, if any, truly associated species, suggests that group 7 should be placed in the Molinia society group suggested by Wheeler (1975b). Thus the suggested full hierarchical classification for this fen grassland community is:-

Class : MOLINIO-ARRHENATHERETEA Tuxen 1937
Order : MOLINIETALIA Koch 1926
Alliance : MOLINION CAERULEAE Koch 1926
Molinia society group Wheeler 1975

Thus there appears to be five woodland types within the South Burn valley each with a somewhat distinctive ground flora. Within certain woodland types there is a distinct mosaic of ground flora, apparently related to the degree of wetness of the substratum.

CHAPTER 4

THE ENVIRONMENTAL FACTORS

In this chapter the methods used in examining some of the environmental factors important in controlling the distributuion of the vegetation units found within the South Burn are described along with the results obtained using these methods. It was decided to examine certain physical and chemical properties of the substrate of each vegetation type and the data obtained for this are presented in tables 4.1 and 4.2. Appendix 2 gives an account of some of the additional methods used.

Organic Matter

On the basis of organic matter content two general soil types are recognised; mineral soils, which possess less than 30% organic matter, and organic soils, which possess more than 30% organic matter. Both of these soil types are present in the valley, with the majority of the valley floor being composed of peat. In both types of soil, organic matter plays an important role in determining certain physical and chemical properties and so it was felt necessary to determine the exact amount of organic material present in each soil.

The usual method employed for this is based upon loss on ignition. In this process a weighed quantity of soil is oven dried at 105^{O}C overnight, reweighed and then ignited in a muffle furnace at 375^{O}C for 16 hours. This temperature and duration was found by Keeling (1962) and Ball (1964) to minimise weight losses from other sources

Table 4.1 : The measured parameters of the seven soils of the vegetation groups of the South Burn Valley

Group	1	2	3	4	5	6	7
pH	3.905 ±0.069	5.799 ±0.117	5.125 ±0.207	5.325 ±0.201	5.090 ±0.182	5.390 ±0.282	4.26 ±0.17
HCO_3^- (mgL^{-1})	0	0.12418 ±0.06840	0.22755 ±0.04370	0.1439 ±0.0402	0.0832 ±0.0287	0.1672 ±0.1317	0
% organic matter content	19.5495 ±2.1354	67.4480 ±2.3447	79.4380 ±2.1127	13.5350 ±0.1439	80.635 ±2.153	78.3110 ±4.8424	76.7490 ±3.0696
Bulk Density	-	0.1069 ±1.923×10^{-3}	0.14705 ±4.108×10^{-3}	-	0.08923 ±2.746×10^{-3}	0.19659 ±4.018×10^{-3}	0.15506 ±2.262×10^{-3}
Field Capacity	55.0610 ±3.3126	148.8030 ±20.5717	164.3440 ±14.0401	76.213 ±5.175	171.585 ±17.470	117.6660 ±11.2334	125.0180 ±6.5288

such as the loss of CO_2 from carbonates; loss of elemental carbon; and loss of structural water from clay minerals. Thus to get an accurate result it was used here.

Organic matter in mineral soils

Table 4.1 shows that groups 1 and 4 possess less than 30% organic matter content and so are classed as mineral soils. In such soils organic matter is important in providing structure as it forms aggregated mineral material with considerable pore space providing aeration and access to organisms. It also helps to bind clay particles to form a network of such particles and macromolecules, the clay-humus complex, which is an important component of the cation exchange capacity of a soil. Generally the higher the cation exchange capacity of a soil, the more exchangeable bases it can adsorb and so the higher the base status of the soil. Thus organic matter in mineral soil affects that soil both chemically and physically.

Organic Soils

Table 4.1 shows that groups 2, 3, 5, 6 and 7 (the soils which make up the majority of the valley floor) are organic in nature. High rainfall, accompanied by topogenic water accumulation through poor surface drainage, may permit the development of waterlogged conditions and of organic soils. When the plants growing in such areas die they are covered by water which shuts out the air, slows oxidation and so acts as a partial preservative allowing the build up of organic soils. Some decay of this organic material does occur thus causing the formation of humic colloids. The type of organic soils formed is determined in part by the nature of the original plant materials and in part by the amount of decomposition of these materials which has occured.

From an examination of the organic soils of the valley floor it appears there are two types present. Group 5 is a fibrous peat of the order Histosol sub-order Fibrist of the comprehensive soil classification system (Farnham and Finny 1966). It is little decomposed and composed mainly of mosses with some rushes and grasses. The remaining organic soils, groups 2, 3, 6 and 7, have dense stands of trees and a dense ground flora growing upon them. These soils are composed of a more decomposed, homogeneous, woody peat which is somewhat granular in nature due to the presence of undecomposed woody material. This peat is in the sub-order Hemist of the soil classification system.

The differences in amount of decomposition between these two types of organic soils are probably due in part to the nature of the organic material which makes up the soil. The degree of waterlogging may also play a part with the higher water table in group 5 limiting decomposition. Also the low pH values found in this group may reduce decomposition by its inhibatory effect on microorganism activity.

The physical properties of organic soils

As the substrate of the floor of the South Burn valley is composed of peat it was deemed necessary to investigate the physical properties of this peat in an attempt to determine the environmental factors controlled by these physical properties which in turn affect the vegetation. It is probable that the hydrologic features of these organic soils are the most important physical properties affecting the vegetation in these areas, these features being water retention, water yield coefficient and hydraulic conductivity. All of these factors can be easily estimated by determination of the bulk density of the soils.

Both water retention and water yield coefficient are characteristics of the water storage of peat. Organic soils develop under conditions of excess water and are saturated or nearly saturated most of the time and thus are able to store large amounts of water, as they are porous. But at conditions other than saturation these water storage characteristics are extremely important as they determine the quantity of water involved in a given water table fluctuation within the peat profile.

It has been shown by Boelter (1968) that saturated water content and porosity decreases gradually with increasing decomposition, although both are high for all peat materials. However, at conditions less than saturation the results of Boelter's experiment show that pore size distribution is more significant than total porosity. Undecomposed peats contain many large easily drained pores while more decomposed peats possess finer pores which are less easily drained. Thus the water retention of decomposed peats is greater than that of undecomposed peats under conditions of less than saturation.

Water yield coefficient (also known as storage coefficient, coefficient of drainage or coefficient of groundwater level) is a measure of the quantity of water removed from the profile when the water table is lowered. This quantity includes both water removed from the saturated zone and also the capillary fringe above it. This measure is also related to the pore size distribution. With any change in water table elevation in less decomposed peats more water is involved than the same change in more decomposed peats. This is due to the fact that the larger pores of the less decomposed peats contain more water and relinquish it more easily than the smaller pores of highly decomposed peats.

Hydraulic conductivity is a measure of the rate of water movement through the peat profile and it has important hydrologic implications since it influences the run-off characteristics of organic soils. Again differences in pore size distribution affect the physical character of the peat in terms of its hydraulic conductivity (Boelter 1965). With larger pores, as in undecomposed peats, hydraulic conductivity is rapid while with increasing decomposition, and so, smaller pores, hydraulic conductivity decreases.

Thus the physical properties of peats are dependent to a large degree on porosity and pore size distribution. In organic soils both of these factors are primarily controlled by the degree of decomposition of the organic material for with increasing decomposition the size of the organic particles decreases with the result that smaller pores and more dry matter per unit volume occurs.

Degree of decomposition is thus a key property of organic soils. However, it is not clearly defined and is difficult to quantify as it is a relative measure usually obtained by quantifying one of the physical or chemical properties which change with increasing decomposition. On this basis Kaila (1956) suggests that volume weight (bulk density) can be used as a basis for estimating the degree of decomposition.

Bulk density is equal to the mass of dry material per unit bulk volume. It must be calculated on the basis of wet bulk volume to represent field conditions as when peat material is dried its volume is reduced considerably. For this reason the volume must be calculated on the basis of field conditions as changes in volume of peat occurs rapidly due to changes in moisture content. Bulk density is measured in the following way. Cores are taken in the field using a cylinder of known volume. These samples should not be allowed to dry out and if storage before analysis is necessary this should be done at 5°C to prevent any biochemical activity. The samples are then dried at 105°C for 16 hours and bulk density calculated from

$$\frac{\text{Oven dry weight}}{\text{Wet (fresh) volume of sample}}$$

Bulk density gives a measure of decomposition in that undecomposed peat have a lower bulk density than decomposed peats. Curvilinear regression analyses by Boelter (1968) showed that with increasing bulk density: water retention increases; water yield coefficient decreases; and hydraulic conductivity decreases.

From the data given on bulk density in table 4.1

and the discussion presented above it can be seen that the physical properties of the organic soils of the South Burn valley, as dictated by bulk density and related to degree of decomposition, do vary. All the bulk density values obtained for these soils are significantly different from one another ($p < 0.05$). On the basis of these values certain of the physical properties of these soils can be deduced.

Group 5 possesses the lowest bulk density value and hence less decomposition has occured in these soils than in any of the other organic soils. Thus the pores of this soil will ne large and the water storage capacity high (note field capacity value of table 4.1). Water retention will be low in these soils, however, due to easy and rapid drainage of these large pores with a fall in the water table. This means that water yield coefficient will be high. Hydraulic conductivity will be high in these soils as water is able to pass through these large pores easily and rapidly.

With the increase in bulk density shown by the other groups an increase in decomposition of the organic matter is shown. This results in a decrease in total porosity with group 6 having the lowest total porosity, the smallest pores and the greatest amount of organic colloid present. Consequently the values of water storage, water retention, water yield coefficient and hydraulic conductivity will also vary such that water storage, water yield coefficient and hydraulic conductivity will decrease to reach a minimum in group 6 while water retention will increase to reach a maximum in this group.

What effect do these variations in physical properties have? High water storage capacity produces a wet and potentially unstable substrate under saturated conditions while lower values indicate a more stable substrate. The variation in water retention are also indicative of this, with high values showing a substrate less liable to rapid and substantial variations in its water regime. Thus the supply of water, and minerals, to a plant is more constant in soils with a high water retention value than those with a lower value, stable soils also possessing a low water yield coefficient.

Low water retention values are indicative of high rates of hydraulic conductivity and these two factors combined show that the passage of water through the substrate is rapid. This means that the soil may be subject to flushing of exchangeable bases, and also toxic substances, and so a decrease in percentage base saturation (see later). On the other hand supplies of fresh bases may be rapidly brought into this soil although the overall effect will probably be to reduce the supply of bases to plants,as rapidly changing groundwater within the substrate will result in an overall decrease in the equilibrium concentration of these bases within the soil solution.

Thus higher values of bulk density imply a stable substratum which has a relatively constant water regime and mineral supply with high levels of organic colloid, while a low bulk density value for an organic soil shows an unstable substrate which possesses a high water content but which, with any fluctuation in groundwater level, is prone to rapid fluctuations in its water content. Thus the water supply to plants may be variable and, combined with this, so may the mineral supply, this last factor being added to by rapid flushing due to high hydraulic conductivity values and also by a low cation exchange capacity due to low levels of organic colloid content.

Waterlogging

Waterlogging has a major effect on soil properties in that it affects the oxidation-reduction (redox) potential of a soil. The movement of gases through any soil is by diffusion. The movement of gas through water by diffusion is much slower than through air and so, under waterlogged conditions, the oxygen supply to a soil is reduced. When this happens a proportion of the soil microorganism make use of electron acceptors other than oxygen for their respiratory oxidation which results in the conversion of a number of chemical compounds into a state of chemical reduction and which is reflected by a lowering of the redox potential, a physiochemical property of the soil (Pearsall 1938). Thus waterlogging plays an important role in determining the chemical properties of organic soils.

Chemical properties of the organic soils affected by waterlogging

Under waterlogged conditions anaerobosis causes the inhibition of nitrifying bacteria and the stimulation of denitrifying bacteria. Thus in groups 2, 5 and 6 where the water table is close to the surface (see table 4.2) there will probably be less free nitrate than in groups

Table 4.2 : Water table height and water chemistry of the organic soils of the South Burn Valley floor

Group	2	3	5	6	7
Water table height (see note 1) (cm from surface)	5	12	4	7	see note 2
pH	6.295 ±0.809	5.9750 ±0.2124	5.843 ±0.313	6.420 ±0.119	5.535 ±0.164
Ca (mgL^{-1})	36.270 ±1.999	20.580 ±1.479	20.45 ±1.43	41.70 ±7.45	14.63 ±1.16
Mg (mgL^{-1})	7.82 ±0.88	4.780 ±0.361	5.375 ±0.603	8.04 ±*1.61	5.133 ±0.933
Na (mgL^{-1})	11.310 ±0.529	12.950 ±0.918	13.763 ±1.089	16.140 ±0.165	14.20 ±1.97
K (mgL^{-1})	1.510 ±0.146	2.020 ±0.211	5.150 ±0.799	1.960 ±0.412	3.000 ±0.681
Mn (mgL^{-1})	0.390 ±0.261	0.120 ±0.044	0.569 ±0.218	0.106 ±0.039	0.357 ±0.078
Fe (mgL^{-1})	0.175 ±0.107	0.027 ±0.018	1.634 ±0.732	0	5.08 ±1.73

1. The value for water table height can only be taken as a rough estimate as only one reading was obtained for each group by merely digging a pit and measuring the depth from the substratum surface to the water level in the hole once equilibrium was established.
2. No value for water table height was obtained for group 7 as the water table could not be reached using the method described above. Thus this soil, at the time of sampling, was not waterlogged.

3 and 7 where oxidising conditions exist close to the surface. The supply of phosphorous is also affected by waterlogging. Under oxidising conditions phosphorous is often unavailable to the plants as it is held insoluble by iron. However, with waterlogging the iron is reduced from a ferric to a ferrous state which does not hold phosphorous and hence the latter is made available in solution. Thus in group 7, and possibly group 3, phosphorous may be limited in supply while in the groups possessing a high water table (groups 2, 5 and 6) it is probably available and in good supply.

Sulphate is abundant in soils undergoing decomposition due to its release from organic matter. However, under waterlogged conditions sulphate is reduced to sulphide which is highly toxic to plants. But as Connell and Patrick (1968) point out ferric iron is reduced to ferrous iron at higher redox potentials than that of sulphate reduction. Ferrous iron precipitates sulphate and so in soils with adequate supplies of iron present (groups 5 and 7) sulphide toxicity will not be a problem. Due to the large amounts of iron in group 7, even under strong reducing conditions sulphide will not be abundant. In the other groups (2, 3 and 6) under sustained water-logged conditions sulphide toxicity may become a problem. In the present study nitrate, phosphate and sulphate were not measured due to lack of time.

The levels of sodium obtained here shown in table 4.2, show that this element is fairly constant in its abundance throughout all the organic soils of the valley. Sodium is an easily dissolved ion which is rapidly leached from mineral soils of low cation exchange capacity. These levels of sodium suggest that leaching does occur within the soils of the valley side assuming that the water percolating through these soils provide the groundwater for all of the organic soils of the valley floor.

Calcium and magnesium are also probably supplied by such leaching. The levels of calcium are higher than those of magnesium but both are abundant in all groups. On the basis of the concentration of these bases three groupings of the organic soils can be recognised. Groups 2 and 6 have significantly higher calcium concentrations than groups 3 and 5 ($p < 0.05$) and all groups have significantly higher concentration than group 7 ($p < 0.05$). These differences are related to groundwater height and degree of decomposition. High amounts of humus present means high amounts of these bases held on the exchange complexes of the soil. With a high groundwater level more of these exchange surfaces are able to supply the bases to the soil solution thus creating a higher equilibrium concentration within that solution. Thus groups 3 and 5 have little humus present (see bulk density values table 4.1) and in addition group 3 possesses a lower water table. The groundwater is also a supplier of bases and so the low groundwater of group 7 will account for low concentration of calcium and magnesium here.

Soil pH

The pH of a soil gives an indication of certain chemical properties of a soil and so is a useful parameter to measure. The presence of hydrogen and aluminium ions on the exchange complex of a soil, and the existance of an equilibrium solution of hydrogen ions in the interstitial waters, constitutes soil acidity. This is defined by the conventional physical and chemical concept of hydrogen ion activity, expressed as pH, this being defined as the negative logarithm of hydrogen ion activity, where activity is understood to mean effective concentration (Etherington 1975).

Measurement of soil pH is usually achieved by employing an electrometrical method using a glass electrode (the calomel half cell). Such pH measurements indicate the mean pH of the liquid surrounding the soil particles. This pH reading is, however, somewhat susceptable to dilution effects and so, for consistency of readings, a standardised soil: water ratio is used (the ratio used here was 1:2). After adjusting the water content of a soil in such a way some time for pH equilibration must be allowed as slow processes, such as cation exchange, are involved.

The results obtained are shown in table 4.1. These results show that all the soils in the area are acidic in nature ranging from 3.9 on the valley sides to 5.7 in certain areas of the valley floor.

<u>The mineral soils</u>

The valley sides, which possess the Vacinetosum sub. ass. (group 1) vegetation growing upon them, have a mean pH value of 3.9. These areas are often steep and possess a sandy textured soil. As Brady (1974) has pointed out soil properties have a definite effect on nutrient losses via leaching, with sandy soils generally permitting greater losses than clay soils, not only because of the lower rates of percolation in the fine textured soils but also because of the greater nutrient adsorbing power of such soils. When leaching occurs exchangeable bases are preferentially lost leaving hydrogen ions on the colloidal complex and in the soil solution. Thus leaching causes a lowering of the percentage base saturation, that is the amount of the exchange complex of a soil occupied by exchangeable bases. This causes a lowering in the base status of such soils which is reflected in a low pH value.

Because of the sandy texture of these soils they probably possess very little inorganic colloidal material. This lack of clay content in the surface layers may be due, in part, to the process of lessivage (re -location of the clay minerals within the profile). Also, as seen from table 4.1, the organic matter content of these soils is low. The processes of soil metabolism, which cause the breakdown of organic material, vary in their rates with pH such that under acidic conditions they are relatively slow. Thus the organic matter present in this soil is not well decomposed and is of a "mor" type. This reduced metabolic breakdown, combined with a lack of calcium (due to loss by leaching) limits the rate of organic matter decomposition and means that there will be little humus present in these soils and also that the rate of mineral re-cycling is limited.

Thus there is little colloidal material in these soils which indicates a low cation exchange capacity.

In addition to this the slow rates of organic matter breakdown, causing limited mineral re-cycling, and the heavy losses caused by leaching mean that the base status of these soils is low. The acid conditions also have an effect on the fertility of these soils. Reduced metabolic activity, caused by these acid conditions, means that nitrification will not be rapid and so there will be a lack of free nitrate. Also release of phosphorous from organic matter by micro-organisms will be limited, thus possibly causing a deficiency in this element.

The other mineral soil present in the South Burn is on the valley floor in the area of the willow carr (group 4). The pH of this soil is significantly higher ($P < 0.001$) than that of the soil of the valley sides, having a mean of 5.325. This soil contains less organic matter than those of the valley sides ($P < 0.05$) and so higher organic colloid content does not account for this higher pH value. However, this soil may contain a higher proportion of clay minerals and if this is so then exchangeable bases will be held more tightly in the soil causing less leaching and a higher percentage base saturation. A clue to this higher percentage base saturation is given by the presence of bicarbonate ions in this soil (see table 4.1). The presence of this ion is indicative of the presence of calcium, in relatively large amounts, upon the colloidal complex of the soil. The bases present in this soil are probably derived mainly from the groundwater which reaches the soil after percolating through, and leaching bases ffom, the soils of the valley side.

Although this soil may contain a higher proportion of clay colloid than the soil of the valley sides, it still probably has a sandy texture. There are three reasons for this postulation. Firstly, the parent rock material of the area is sandstone. Secondly, any soil particles washed from the valley sides will predominantly be in the sand size class. Thirdly, the pH of this soil is still acidic which suggests low amounts of colloidal material in this soil.

Thus the mineral soil of group 4 appears to have a relatively high percentage base saturation brought about by a good supply of bases via the groundwater reaching the area. It also possibly has a relatively high clay mineral content, the majority of which will be derived from run-off from the valley sides (although the greater part of material which reaches the group 4 site from this source will be sandy in texture). Thus there is possibly a higher cation exchange capacity in these soils which, combined with an adequate supply of bases, gives this soil a relatively high base status compared with the soils of the valley sides. It should be noted that, even though this soil is found on the valley floor it does not appear to undergo waterlogging for any sustained period. However, the situation of these sites on the valley floor mean that it will be somewhat more moist, due to the presence of groundwater mainly, than the soils of the valley sides.

<u>The organic soils</u>

The organic soils of the valley floor all have a higher pH value than the mineral soils of the valley sides.

The fact that the areas are subject to periodic, though often long-term, waterlogging provides one explanation for this. Etherington (1975) points out that most anaerobic soils tend to stabilize in the pH range 5.0-7.0 and Greene (1963) suggests that the conversion of inert ferric sesquioxides to more basic ferric hydroxide accounts for the rise in pH of acid soils under waterlogged conditions. However, this is only one possible explanation for the higher pH values of these soils.

All of these soils exist below spring and seepage lines. As the water emerging from these springs has been in contact with mineral soil for some time then it is probable it contains a high proportion of exchangeable bases leached from these mineral soils. The data of table 4.2 shows that these soils do have a groundwater with relatively high, but variable, amounts of certain exchangeable bases present in them. Thus these soils appear to have high percentage base saturation values.

The presence of organic material will lead to large amounts of organic colloid being present in these soils compared to most mineral soils. However, this is dependent upon the amount of decomposition which has occured, a factor controlled by water table height primarily. Organic colloids possess high cation exchange capacities and so are able to adsorb exchangeable bases, which are supplied by the groundwater in this case, in relatively large quantities. Thus the base status of these soils is generally high.

Under waterlogged conditions the vertical movement of water, and hence dissolved bases, is somewhat restricted which means there is generally very little leaching in these soils. Thus there is a high base status and a high percentage base saturation in these soils which, added to the influences of waterlogging, accounts for their observed pH values. However, there are variations in pH between these soils which will reflect variations in base status and other environmental conditions.

The soils of group 2 have a higher pH ($p < 0.05$) than those of group 3 for example. The higher water table in group 2 will cause reducing conditions to prevail nearer the surface than in group 3. This in itself may account for some of the observed difference but it also means that exchangeable bases in the groundwater will be available to the organic colloids of the surface layers of group 2. Thus there will be a higher percentage base saturation in this group. Thus group 2 appears to have a higher base status than group 3, a fact borne out by the data of table 4.2. This larger supply of bases seems to compensate for the lack of organic colloid present in group 2 (inferred from the bulk density value of table 4.1) to cause a higher pH.

The differences in these factors of degree of waterlogging, supply of exchangeable bases and degree of decomposition also account for the variations in pH of groups 5, 6 and 7.

Group 7 is an interesting case in that it has a significantly lower pH than all other organic soils in the area ($p < 0.01$). This group is dominated by the presence of Molinia caerulea growing in large tussocks. To grow successfully, as here, this plant requires a regularly fluctuating water table (Gore and Urquart 1966), these fluctuations occuring over some distance. As the water table moves down it will carry dissolved exchangeable bases with it and so, through this leaching, there will be a lowering of the percentage base saturation, and base status, of these soils. This, combined with the drying out of the soil, cause a reduction in pH.

Thus waterlogging appears to exert a major influence on the pH of the organic soils both directly, by its effect on the redox potential of the soil, and indirectly, through its effect on the supply of exchangeable bases to the cation exchange complexes of the surface layers of these soils. The amount of organic colloid present in the soil, i.e. the degree of decomposition, also has some effect. Because of these factors a knowledge of the pH of the soils gives an indication of their base status.

CHAPTER 5

POPULATION DYNAMICS

In this chapter a discussion of the population dynamics of the major tree species of the vegetation units of the South Burn are considered in an attempt to discover the successional stability of these units.

The populations of species which make up a stand of vegetation are not static. During a period of time new individuals will become established while old ones die. If for any one species the rate of addition exceeds mortality over an appreciable time period then its population density will increase, and vice versa. Many variables affect this balance. Some of these are intrinsic, such as seed production, life span etc. while others are extrinsic relating to the multitude of external environmental factors which affect a particular species growth, reproduction and survival. Thus it can be seen that the population dynamics of plant species are somewhat complex in both nature and control.

In many types of vegetation each stand contains a substantial record of its dynamic status. To "consult" this record the properties of the various age groups present must be determined and interpreted autecologically. To achieve this in tree species two basic methods have been proposed.

A fairly precise method is to count the xylem layers on increment boreings which terminate at the morphological centre of the stem and which were taken at the level of the original germinating surface (see Tucker, 1979). However, this method is somewhat laborious and subject to some error since xylem layers are frequently not formed at the rate of one per year (Daubenmire, 1968).

The second method, which is applicable to trees and shrubs with active cambia as above, uses stem diameter at breast height as a reasonably reliable indicator of relative age. With this technique the circumference of the tree at breast height is measured and this measurement converted to diameter. These diameters are then divided into classes and the number of trees in each class plotted on a histogram as in Fig. 5.1. This is a useful simple and informative technique providing that the diameter classes are not divided too finely or interpreted too closely and that no assumption that the same size range in different species indicates the same age is made. Although age in years is only roughly proportional to diameter, a graded series of sizes, as obtained using this technique, has approximately the same successional significance as a graded series of ages.

Figures 5.1 to 5.7 show the results obtained using the method discussed above of population dynamics analysis. What conclusions can be drawn from these results about the successional stability of each vegetation unit?

The Oxilido Betuletum woodland of the valley sides

The data from these areas are shown in figures 5.1 and 5.2. Betula pubescens is the major component of the woodland on both sides of the valley. However, as can be seen from these two figures regeneration of this species is

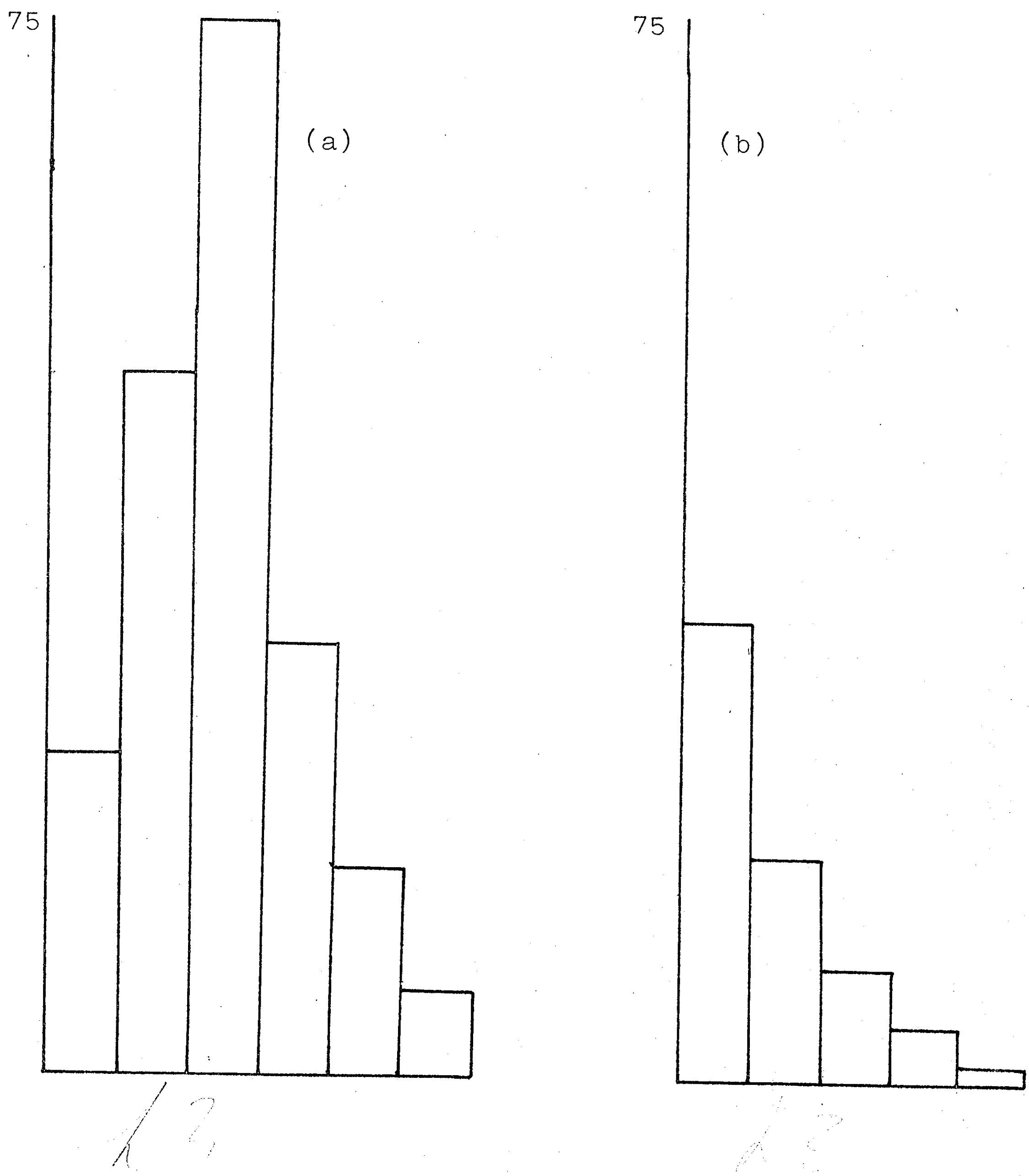


Figure 5.1 : Population structure of (a) Betula pubescens and (b) Quercus petraea in the woodland of the N.W. valley side (group 1).

extremely low. This drop in regeneration appears to have occurred at approximately the same time on both sides of the valley, corresponding to size class 3, and so it appears that a change in some environmental factor, or factors, affecting regeneration occurred at this time and is persisting at present, for, although plenty of trees of seed bearing age are present, regeneration is still low.

Betula pubescens is a pioneer woodland species possessing all the characteristics of such a species such as high seed production, light easily dispersed seeds, rapid growth rate and relatively short life span. Such species require relatively high light intensities for germination of their seeds and so the rapid growth of birch creating a dense canopy tends to shut out the light and so limit regeneration.

Species with slower migration rates, due to larger less easily dispersed seeds, are generally able to tolerate low light intensities for their germination. Thus on the N.W. side of the South Burn valley Quercus petraea has relatively recently "arrived on the scene", as can be seen from the low number of oak trees generally, and the small proportion of old trees present. Oak is growing and regenerating under the birch canopy. With no change in the prevailing environmental conditions it can be postulated that birch, through a lack of regeneration and the dying of trees already present, will be replaced by oak as the major canopy species of the N.W. side of the valley.

The S.E. side of the valley has Acer pseudoplatanus present in the tree layer. There is a noticeable reduction

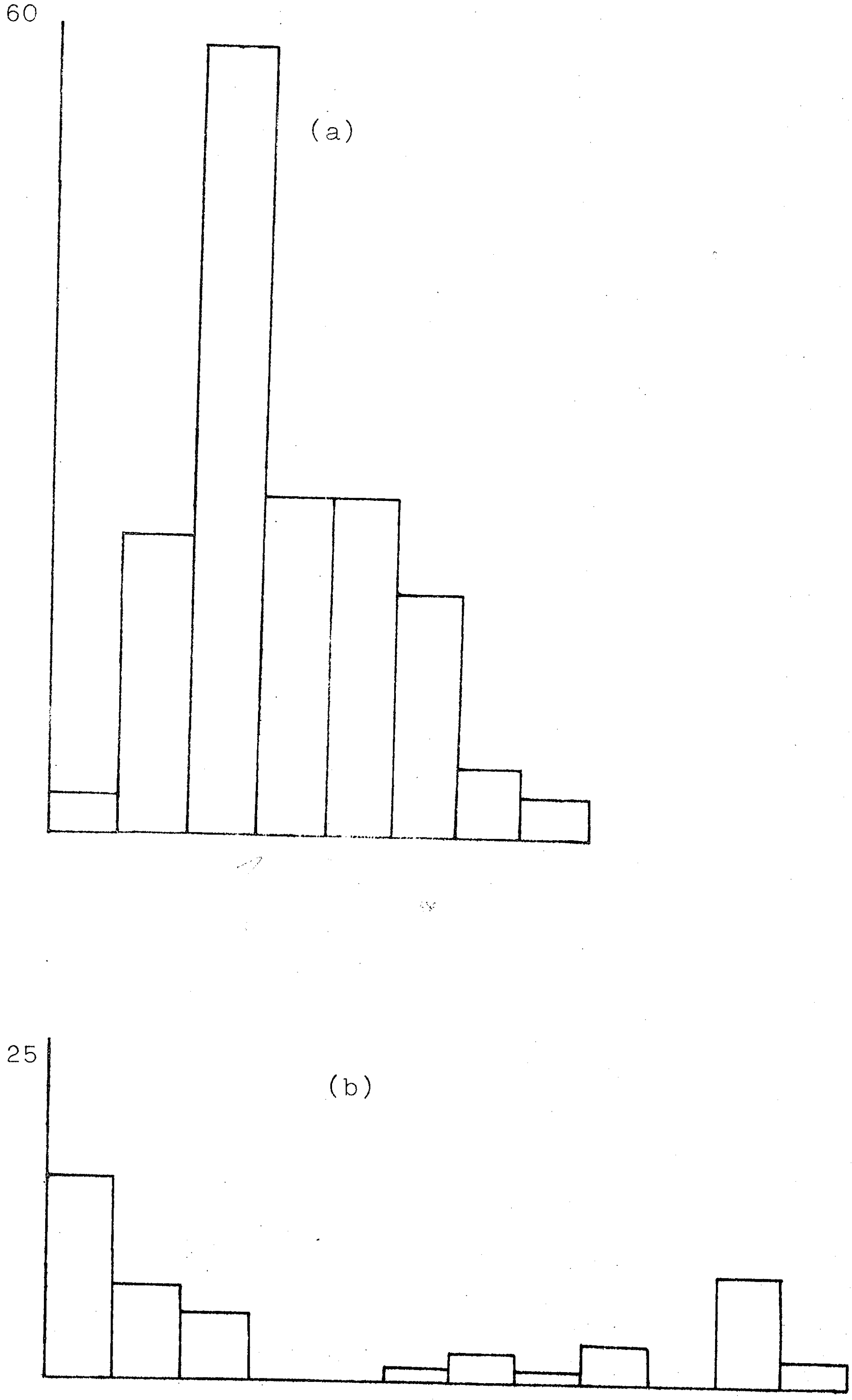


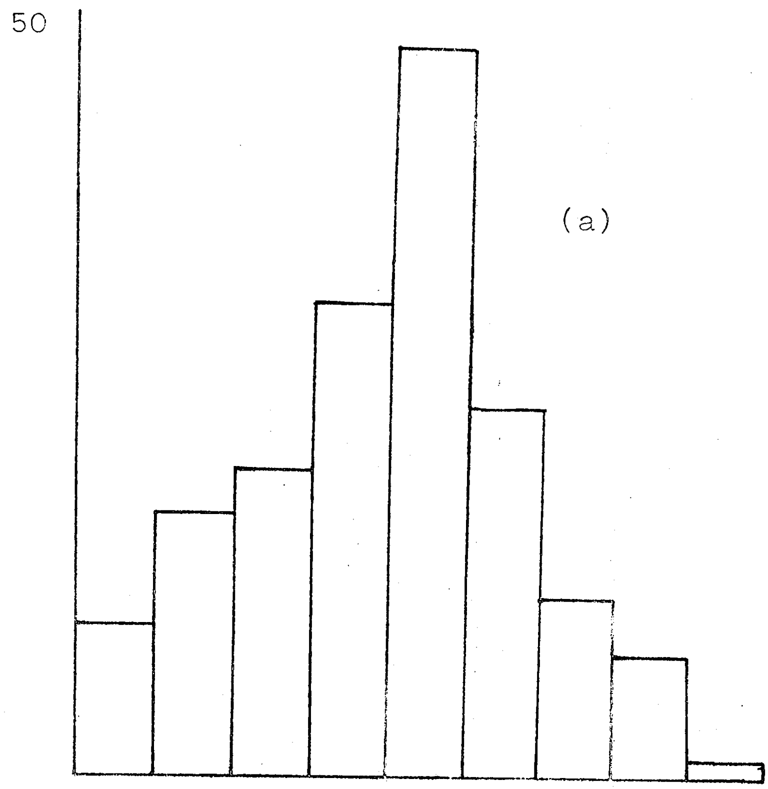
Figure 5.2 : Population structure of (a) Betula pubescens and (b) Acer pseudoplatanus in the woodland of the S.E. valley side (Group 1).

in the presence of oak on this side of the valley, possibly due to unfavourable microclimatic conditions on the north facing slope of a relatively poor habitat for this species. Sycamore is also a pioneer species, as can be seen from the fact that old trees of this species, which presumably arrived early in the development of the present woodland about 90 years ago, are present. However, the lack of sycamore trees of middle age is also noticeable and this may be due to the closing of the canopy by the dominant birch thus preventing germination of sycamore during this period. With the reduction in birch regeneration, and the dying of trees already present, the canopy probably opened up and, due to the relative longevity of sycamore, there were still trees of seed bearing age and capability present to exploit this favourable change in environmental condition. Hence the increase in young sycamore trees shown in Fig. 5.2.

Thus the woodland of the valley sides appears to be changing in its composition. It is postulated that birch will become less important as old trees die and are not replaced. In its place on the N.W. side of the valley oak, and on the S.E. side sycamore, at least in the short term, will become the major constituents of the woodland.

The alder carr and birch woodlands of the valley floor

The data for these sites are presented in Figures 5.3 and 5.4. At present Alnus glutinosa is the dominant in most of these woodlands, although Betula pubescens is important in some areas, especially the birch - molinia woodland. Consdering firstly the alder dominated woodland;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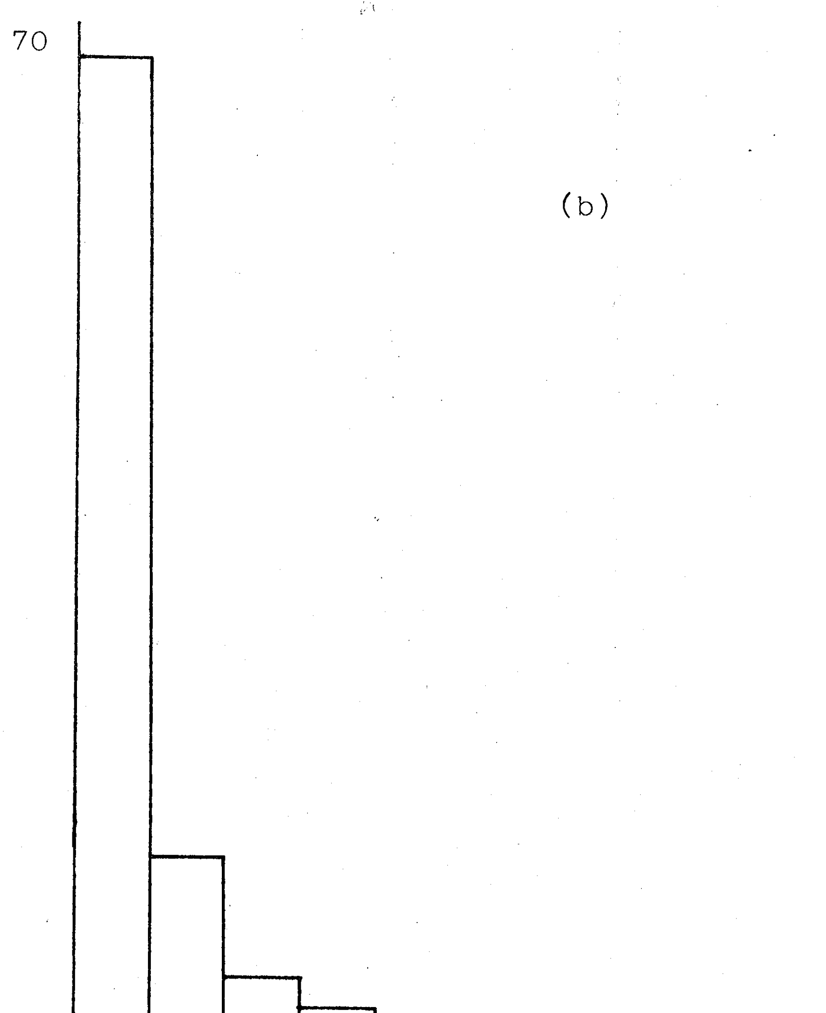
(a)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(b)

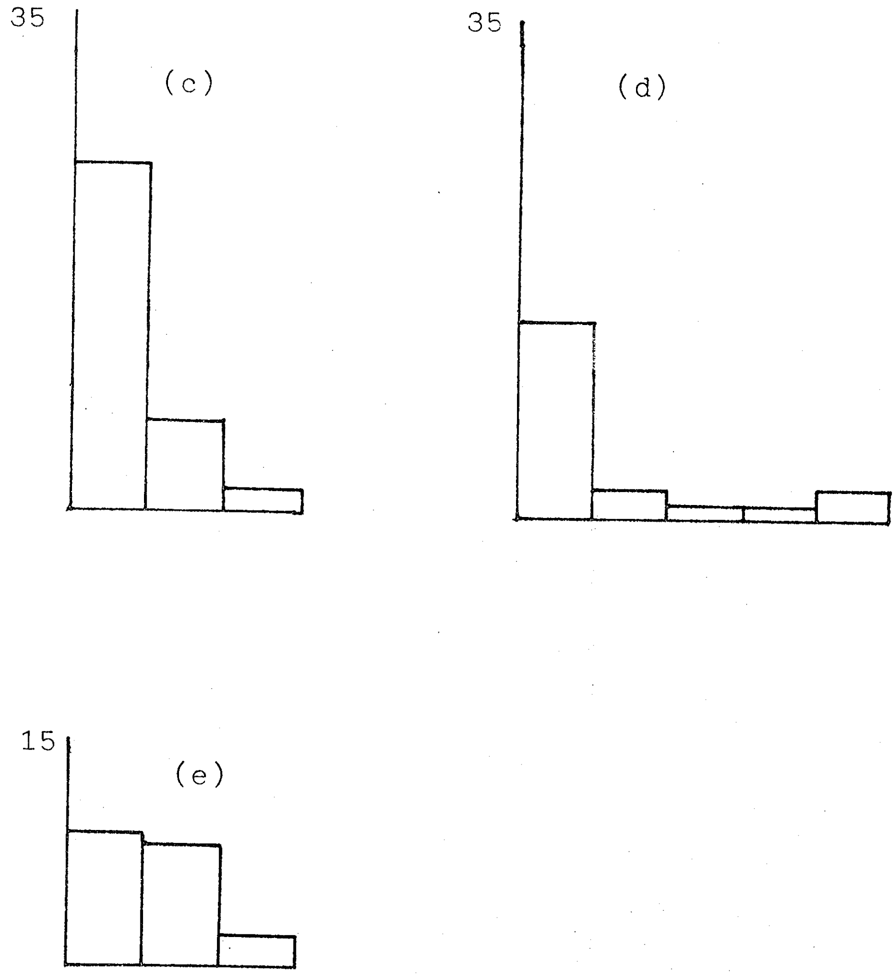

Figure 5.3 : Population structure of (a) *Alnus glutinosa*; (b) *Fraxinus excelsior*; (c) *Sorbus aucuparia*; (d) *Salix cinerea* and (e) *S. pentandra* of the alder carr (groups 2 and 3) of the valley floor.

from Fig. 5.3 it can be seen that alder is not regenerating. This species is also very sensitive to shading with respect to the germination of its seed. Such shading coming both from the trees of the community and the often dense ground flora. Also for adequate seedling growth the species requires relatively high light intensities (McVean 1953). These factors combine to make internal regeneration of the woodland extremely rare. Regeneration is also impeded by a high water table at or close to the surface, although this does not stop it completely, and indeed seedlings will only establish on a soil where the capillary fringe of the water table comes close to the surface during about 20-30 days between April and June. Any regeneration that does occur tends to be peripheral to the main stands of the tree and, indeed, this was noted in the present study with the majority of seedlings being present in open areas outside the main stands of the alder carr. Therefore the main reason for the lack of regeneration of Alnus glutinosa noted here is shading by the parent trees, and the ground flora, which inhibits both germination and seedling growth. The high water table also contributes to this lack of regeneration in a minor way.

As can be seen from Fig. 5.3 Fraxinus excelsior is an important tree in this community. It is regenerating well, showing a classic reverse J distribution (Leek 1965). In situations such as this, i.e. areas with high soil fertility and moisture, ash is a frequent component of the woodland along with alder. Ash is common in waterlogged habitats as its seedlings only need a small depth of nonsaturated soil for germination and growth. Although in such conditions the growth of the trees is poor, it is still possible (Wardle 1961). Seed germination is possible under shade but seedling growth is intolerant of shade, especially the dense shade cast by vernal field layers such as that of Mercurialis perennis. Ash is a prolific seed producer and so seedlings are able to establish themselves wherever the field and tree layers show a decrease in density. This was noted in the South Burn where clumps of ash saplings were found in relatively open conditions. Once germinated seedlings living under shade are able to persist for many years, then once gaps appear, due to the death of a nearby tree, these seedlings begin to grow. This will account for many of the clumps of ash saplings noted above; but it should be noted that the density of such clumps will eventually be decreased by intra-specific competition, mainly due to shading.

Thus in the alder carr, alder, although at present the dominant tree, is not regenerating very well due probably to shading inhibiting germination. Thus eventually this tree will become much more limited in its distribution, its place being taken by ash. Ash shows prolific regeneration in the area especially where gaps in the canopy have appeared due to the death of a tree, such gaps allowing the continued growth of "dormant" seedlings. Thus it is probable that the alder carr will change to a woodland where ash predominates. However, as can be seen from Fig. 5.3 Sorbus aucuparia, Salix cinerea and S. pentandra are also surviving, and regenerating, in this woodland at present.

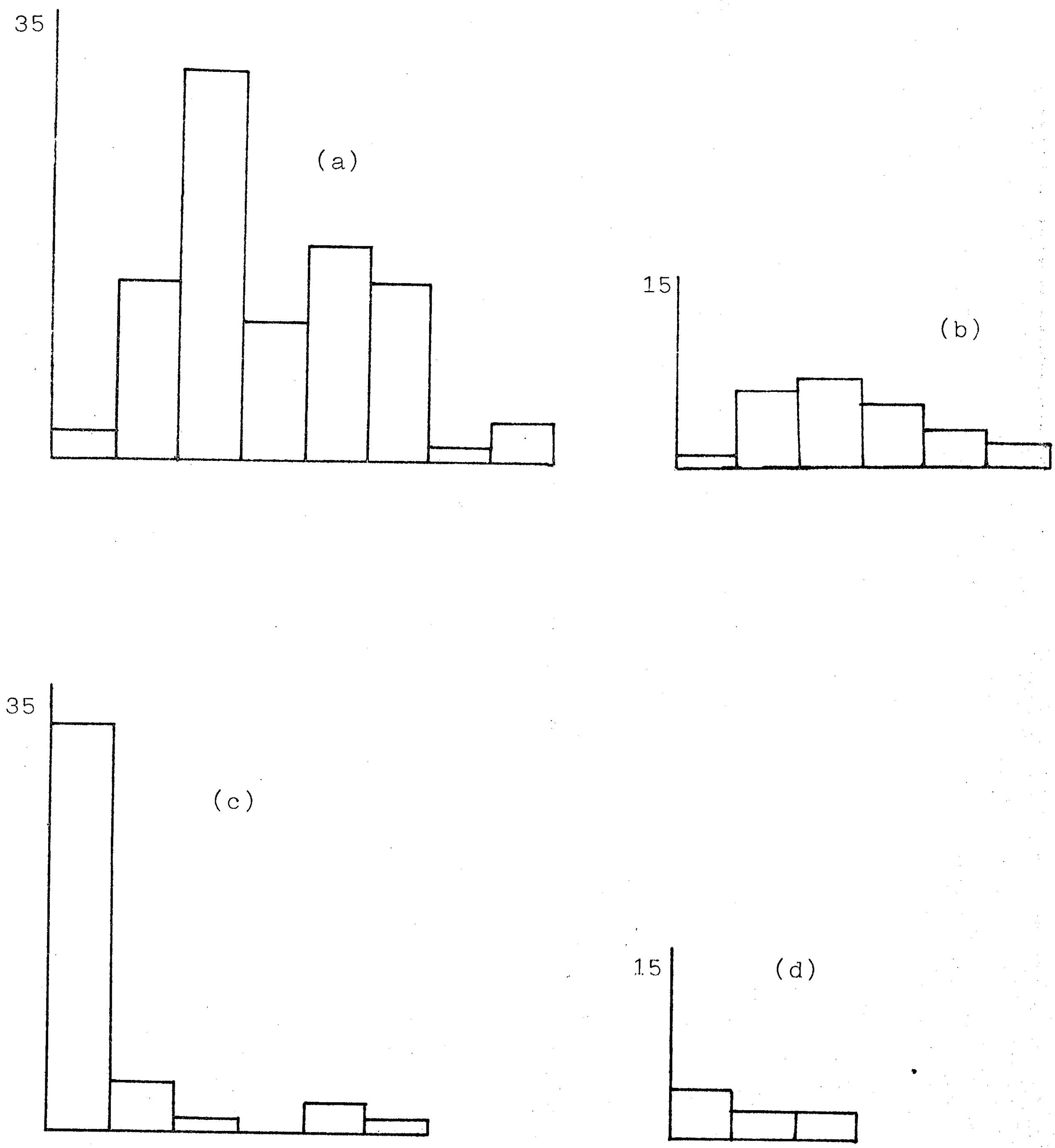

Figure 5.4 : Population structure of (a) *Betula pubescens*; (b) *Alnus glutinosa*; (c) *Fraxinus excelsior* and (d) *Salix pentandra* of the birch mire forest and birch-*Molinia* woodland (groups 6 and 7) of the valley floor.

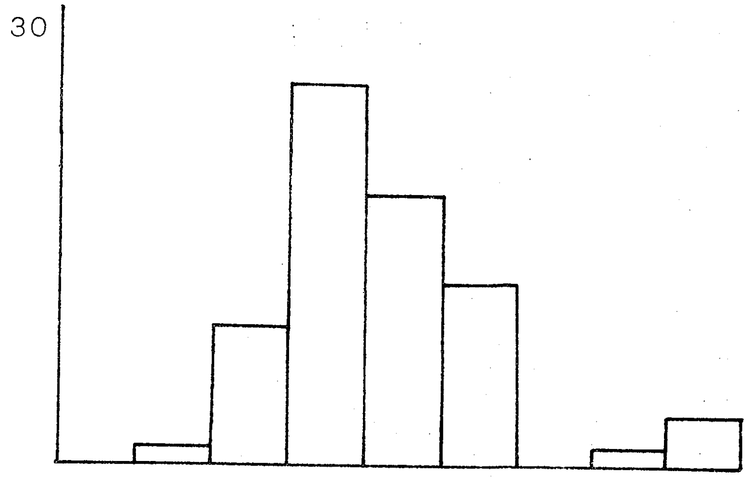

Figure 5.5 : Population structure of Betula pubescens in the birch-sphagnum woodland (group 5) of the valley floor.

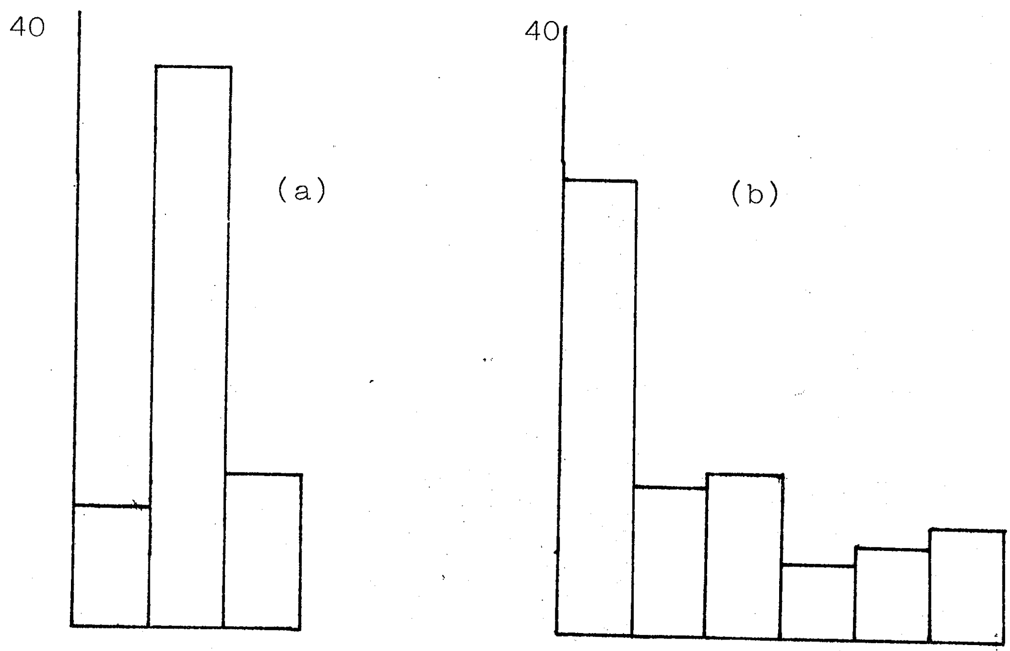

Figure 5.6 : Population structure of (a) Salix cinerea and (b) Salix pentandra in the willow carr woodland (group 4) of the valley floor.

Thus this ash dominated woodland will probably also contain rowan and willow, the latter mainly as at present, i.e. as sub-canopy components within it.

Shading is also the major reason for the lack of regeneration of birch in the areas of the mire forest where it is at present an important component. Fig. 5.4 shows that both birch and alder are not regenerating while ash and the bay-willow are, ash especially prolifically. This is due to the same factors as discussed above and will apparently cause the same result, namely the development of a foest dominated by ash, with occasional other components, and where birch and alder are not important.

The birch - sphagnum woodland

The data for this woodland are presented in Fig. 5.5. Betula pubescens is the only tree present in this community and, as can be seen from Fig. 5.5, it forms a relatively even-aged stand where no regeneration is occuring. The canopy of this woodland is open and the ground layer, although complete is not tall, being compared mainly of mosses. Thus shading is not an important factor in the lack of regeneration of birch in this woodland. It is probable that the high water table, which is probably high for long periods, is the major inhibatory factor to germination of the birch seeds. This may also be the reason for the lack of any ash seedlings or saplings in the community for, as we have seen, ash requires some, though not much, unsaturated soil for germination and seedling growth. The reasons for the lack of alder are more difficult to ascertain although as we have seen previously, this soil (group 5), is possibly unstable due to the high water content and lack of humus and this may account, to some extent, for the lack of alder.

Thus this community will alter most dramatically of all the communities of the South Burn valley. Birch will eventually disappear from the community and it will not be replaced by any other tree species for, although species which could enter the area are present, (ash, alder and willow), on the evidence presently available none of these species are capable of growing under the prevailing environmental conditions of the area. Thus, without a change in environmental condition within this area, namely a sustained drop in water table level, it appears that this community will change from that of a woodland to a "bog" community.

The Willow Carr

Fig. 5.6 shows the data obtained for this community. Two willow species at present dominate this community, *Salix cinerea* and *S. pentandra*. From the data of Fig. 5.6 it can clearly be seen that *S. cinerea* is not regenerating at all well while *S. pentandra* is thriving. If this trend continues it is apparent that *S. cinerea* will be lost from this vegetation type and *S. pentandra* will become the dominant species present.

The reasons for this lack of regeneration of *S. cinerea* are not clear. It can obviously germinate and grow well in wet shady conditions as it is found as a sub-canopy component of the alder carr, often in association with *S. pentandra*.

CHAPTER 6

DISCUSSION

In Chapter 4 it was shown that the environmental factors within the different vegetation units of the valley do vary. In this chapter a consideration of the way in which these variations control the distribution of the vegetation units will be made. In addition to this a discussion on the successional changes looked at in Chapter 5 will also be made.

The control of the distribution of the vegetation units

A fundamental reason for the presence of a different type of vegetation on the valley sides compared with the valley floor is the nature of the topography and substratum of these different sites. The valley sides are often steep and possess a sandy substrate. These factors combine to produce a relatively dry environment with rapid infiltration and percolation rates and also fast run-off on the occasions when the infiltration capacity of the soil is exceeded.

Rapid movement of relatively large amounts of water through the soil causes high rates of leaching and so loss of exchangeable bases, which causes these soils to have a low percentage base saturation, and hence a low pH. These soils also possess a low cation exchange capacity due to a lack of colloidal material. The low amounts of organic colloid present in the soil is caused by low rates of organic matter breakdown, brought about by the acid conditions reducing the metabolic activity of microorganisms.

The lack of inorganic colloid can be inferred from the sandy nature of the soil.

Thus the soils of the valley sides have a low cation exchange capacity and, because of leaching losses, a low percentage base saturation. These base-poor, dry, acidic conditions maintain a vegetation (group 1) completely different from that of the valley floor.

Figure 6.1 shows the abiotic factors measured in this project plotted in relation to the vegetation units found. The factors shown in this diagram appear to be, on visual inspection of the data, the ones most important in controlling the distribution of the vegetation within the valley. These factors are, or are related to, the degree of decomposition, waterlogging and the base status of the soils. These are all factors which are important properties of the organic soils of the valley floor. Group 4, the willow carr, is a special case being a mineral soil of the valley floor where unusual conditions prevail. The factors affecting this group will be considered later. At present let us consider the environmental factors which appear to be important in controlling the distribution of the vegetation on the organic soils of the valley floor. The floor of the South Burn valley is situated below a series of spring and seepage lines. This positioning has two important effects. Firstly, it produces an area which is permanently wet and often waterlogged and secondly this wetness impedes microorganism breakdown of the organic material and so produces a substrate which is organic in nature. These two factors of waterlogging and type of

GROUP 1

Org. matter	19.549	
pH	3.905	Base status, low

GROUP 2

Org. matter	67.4480	
Bulk density	0.1069	Decomposition, low
Water table	5	Waterlogging, medium
pH	5.7990	
Ca	36.2700	Base status, high
Mg	7.8200	

GROUP 3

Org. matter	79.43800	
Bulk density	0.14705	Decomposition, medium
Water table	12	Waterlogging, low
pH	5.125	
Ca	20.580	Base status, medium
Mg	4.780	

GROUP 4

Org. matter	13.535	
pH	5.325	Base status, high

GROUP 5

Org. matter	80.63500	
Bulk density	0.08923	Decomposition, low
Water table	4	Waterlogging, high
pH	5.090	
Ca	20.450	Base status, medium
Mg	5.375	

GROUP 6

Org. matter	78.31100	
Bulk density	0.19659	Decomposition, high
Water table	7	Waterlogging, high
pH	5.39	
Ca	41.70	Base status, high
Mg	8.04	

Figure 6.1: The environmental factors of each group which appear important in controlling the distribution of the vegetational units.

GROUP 7

Org. matter	76.74900	
Bulk density	0.1556	Decomposition, medium
Water table	–	Water table, fluctuating
pH	4.260	
Ca	14.630	Base status, low
Mg	5.133	

substrate are extremely important in determining the distribution of the different vegetation units.

Waterlogging plays a major role in determining the chemical environment of a particular organic soil, through its control of the oxidation-reduction potential. Under different redox potentials different elements become available and also change the form in which they are in, which affects both solubility, and hence availability to the plants, and also toxicity.

The organic nature of the majority of the soils and the valley floor is important in that it affects both the chemical and physical properties of such soils. Organic colloids, produced on breakdown of organic matter, have a high cation exchange cpacity and so are able to hold a large number of exchangeable cations, especially calcium, leached from the valley sides.

Organic soils also have their physical properties controlled, to a large extent, by the organic matter in them. The most important physical properties within an organic soil are related to the water held within, and moving through, the soil. The more water held within an crganic soil the more physically unstable it is; with rapid movement of water the equilibrium concentration of bases within the soil is lowered; also distance from the source of the groundwater seems to affect the base status of the soils . The physical and chemical properties which are controlled by organic matter are related to the degree of decomposition.

Degree of decomposition, waterlogging and the base status of the soils appear to be the major environmental factors operating in the soils of the valley floor which affect the distribution of the vegetation units. Fig. 6.1 shows that there are variations in the values of bulk density, water table height and base status between each group which appear to be related to the distribution of the vegetation units. So how do these factors vary between the different vegetation units and what other variation in environmental factors do they cause?

The alder carr (groups 2 and 3) are found growing on a woody peat substrate. Earlier it was shown that group 2 was present on wetter areas of the valley floor while group 3 is found in conjunction with less active springs on dryer areas. Less decomposition has occured in group 2, compared with group 3, presumably due to the higher water table and wetter conditions reducing organic matter breakdown. Thus the physical properties of the substrate of group 2 are such that the soils have a relatively high water capacity, water yield coefficient and hydraulic conductivity. Thus group 2 is a physically unstable substrate liable to large and rapid fluctuations in water status with any change in water table height.

Chemically the soils are quite base rich (see Fig. 6.1 to compare pH, calcium and magnesium values from this group with other groups). The rapid rate of water movement through the soils, and the proximity of this group to the source of the base charged groundwater, means that a plentiful and continuous supply of bases is available to these soils. The high water table levels mean that these bases are available to the plants close to the surface, which is important as little of these bases will be held in the soil due to the lack of organic colloid present.

The difference in the height of the water table between groups 2 and 3 may account for the lower base concentration in group 3 (see Fig. 6.1). Groundwater is the only source of such bases to the soil and so if it is not present in the phreatic zone then there will be fewer bases available in the soil solution. Those bases that are available are probably derived mainly from the exchange complex of the soil which is well developed in this group. This may to some extent help to account for the lower base levels in group 3 as the high cation exchange capacity will tend to remove bases from the groundwater by adsorption thus reducing their concentration in the soil solution. The fact that these sites are situated some way away from the main groundwater source, i.e. the springs, and that they have low hydraulic conductivity values may also produce a lower base concentration in the soils of group 3. Water reaching these soils has passed through other soils (chiefly those of group 2) which may have removed bases from the groundwater; while the movement of water through the soils of group 3 is relatively slow, which will reduce the supply of bases to the soil.

Other chemical properties of the soils will also vary due to the differences in waterlogging in these two groups. Thus due to the saturated conditions being closer to the surface in group 2 it is probable there is less free nitrate in this group than in group 3, this lower level being caused by higher rates of denitrification, brought about by waterlogging, in group 2. The levels of phosphorous in the wetter areas of group 2 will probably also be lower due to reduced rates of mineralization by micro-organisms, again caused by waterlogging. However, what phosphorous is present is probably available to the plants as it is not precipitated or occluded by oxidised ion as some will be in group 3. In both groups sulphate will probably be present although the more intense reducing conditions of group 2 will probably mean that there is more sulphide in the surface layer of this group. This, however, will probably not reach toxic levels due to the presence of reduced iron which will precipitate out much of the sulphide. However, the determination of the exact levels of nitrate, phosphate, sulphate and sulphide, and the variation between these soils, must await further work as these nutrients were not measured here, as the aim was only to determine the major factors affecting the distribution of the vegetation.

Thus differences in the degree of wetness and the proximity of waterlogged conditions to the soil surface are major causes of the differences in the chemical environments of the wet and damp alder carr areas. Plants growing in the wet areas (group 2) must be adapted to low levels of nitrate and phosphorous although the habitat is generally quite base rich. The physical properties of these soils are such that the soil of the wet alder carr is somewhat more unstable than the dryer areas and are also more liable to rapid fluctuations in water content than the damp areas with any fluctuation in water table height.

The species growing in the dryer alder carr areas (group 3) live in a less base rich habitat but are probably still able to obtain sufficient bases for adequate growth. Free nitrate is probably more abundant in these soils although phosphorous may be limited in its availability. Thus there are physical and chemical differences in the environments of groups 2 and 3 which are primarily related to the height of the water table and which may to some extent account for the differences in vegetation noted.

Group 6 is similar, but not identical, in its species composition to group 2. Fig. 6.1 shows that the base status of both soils, as shown by the calcium and magnesium concentrations and also by a similar pH, are somewhat similar and also that the water table height is much the same. However, the organic matter contents, and the degree of decomposition of that organic matter, do vary. Thus the physical properties of the two soils are somewhat different with group 6 having a lower water holding capacity, and so being more stable, than group 2.

Because the depth of the phreatic fringe zone is quite shallow then, as in group 2, reducing conditions will prevail close to the surface. Therefore, free nitrate may again be limited although nitrogen may be available to the plants in the form of ammonia produced by organic matter decomposition. Ammonia may also be a nitrogen source in group 2 but, due to the high hydraulic condctivity rates in this group, this ammonia may be easily lost from the soil. However, water movement in group 6 will be lower than in group 2 due tc lower hydraulic conductivity values, which means that less of this nitrogen source will be lost from this soil over a given space of time. Also as in group 2, sulphide will be produced; but in group 6 there is a complete lack of iron which will mean that the sulphide levels may be relatively high in this group. These high sulphide levels may be toxic to certain plant species and this may account for their absence from the vegetation of this group.

Group 7, like groups 2, 3 and 6, has a substrate composed of a woody peat. As can be seen from Fig. 6.1 this group has a relatively low base status. This group is dominated by Molinia caerulea in the ground layer, a species which grows optimally under conditions of a fluctuating water table (Gore and Uequart 1966). The fact that this soil has low base levels may be due to the fact that it is situated some way away from the spring line and hence any water reaching it will have a low concentration of bases present in it due to adsorption by other soils. Also with a fluctuating water table any bases dissolved in the groundwater will be lost from the substrate as the water table is lowered. Thus there is a kind of leaching occuring in this area which may account for the low percentage base saturation, and hence the low pH and base status, of these soils.

Fig. 6.1 also shows that these soils have undergone a high degree of decomposition. Thus there will be slow movement of groundwater through them which will tend to further reduce the supply of bases to the soil. However, the soils will be quite stable and not liable to rapid changes in water content even though it appears that the water table fluctuates in this area.

Thus the vegetation of group 7 is growing on a relatively base poor soil where phosphate is probably limited due to precipitation by iron brought into solution by the acidic conditions and where free nitrate may also be somewhat limited due to these acid conditions inhibiting the activity of nitrifying bacteria. In addition to this the plants must also be adapted to periodic waterlogging followed by periods of much lower water content.

Group 5 is found growing on a substrate of fibrous peat composed mainly of mosses. Figure 6.1 shows that the base concentration in this group is similar to that of group 3. However, group 5 has a much lower organic colloid content due to a lack of decomposition caused by the high groundwater level (see Fig. 6.1). Therefore the majority of bases present in the groundwater are not adsorbed in the soil complex and so are liable to be lost from the area through water movement. Such movement is rapid due to the high hydraulic conductivity values that this soil possesses; this will tend to cause both rapid flushing of bases and rapid renewal in the area. However, as the site is situated some way from the source of the groundwater then the base concentration will remain low.

The lack of decomposition in these soils means that they are unstable, both physically, due to the high water table, and chemically, as the low water retention capacity of the soil means that any drop in water table will cause a rapid draining of the soil and the loss of the only real source of bases to the plants. The primary causes of these environmental conditions in this area are, again, the groundwater height and chemistry. These factors combine to produce a habitat where mosses thrive. These mosses are not easily decomposed and this is a further contributary factor to the prevailing environmental conditions.

Group 4 is also found on the valley floor but this vegetation is growing on a mineral soil. This soil is obviously wetter than the soil of the valley sides but still has a sandy texture although more clay minerals may be present. From the pH value of this soil it appears that it has quite a high percentage base saturation and is probably quite base rich. These conditions would suit the growth of alder in this area but it is lacking possibly, according to Jeffreys (1916), due to its removal by man. This allowed willow to establish itself which has tended to shade out alder.

The presence of a few individuals of species normally found on disturbed sites may be caused by the topography of this area of the valley. The lowest point of an arable field which is adjacent to the valley is in this region and hence run-off, carrying agricultural chemicals, will reach the site of group 4 and so enrich it. Thus group 4 is found on a base rich, relatively moist mineral soil.

Thus there are differences in the physical and chemical environments between the habitats of the different vegetation units. Within the area of the valley floor base status, waterlogging and degree of decomposition of the organic matter appear to be the major factors controlling both the physical and chemical environments of these soils. Thus it can be inferred that these are the most important factors which play a part in controlling the distribution of the vegetation units.

There is a clear distinction between the vegetation found on the valley sides and that on the valley floor. The habitat of the valley sides is that of a dry mineral soil of a sandy texture with a low amount of bases present. The other mineral soil of the area (the willow carr of group 4) has a much higher availability of water as it is situated on the valley floor and so is supplied by ground-water. This also supplies bases leached from the soils of the valley sides (and also from some local agricultural run-off) which means that this is quite a nutrient rich habitat.

There are variations in the environmental factors of the organic soils of the valley floor. Groups 2 and 6 are both base rich and both possess a high water table, these similarities being emphasised by the similar species composition of the two areas. The differences that occur in species composition are possibly due to higher soil stability and higher sulphide levels in group 6.

Group 3 is less nutrient rich than these groups and possesses a soil stability somewhere between the values for groups 2 and 6. Group 5 has a similar nutrient status to group 3 but this group has less stable physical properties. Group 7 has a very low base status, brought about chiefly by a fluctuating water table. However, this group possesses quite a stable substrate.

Thus the variations in the composition of the vegetation units found growing on the organic soils of the valley floor can be explained by variations in base status and physical stability of the substrate. In turn these environmental parameters are controlled mainly by water table height and degree of decomposition.

Changes in species composition indicated by population dynamics study

As shown in Chapter 5 the tree species of the area are in a state of change with the predominant trees of the present showing signs (mainly lack of regeneration) of disappearance from the area. Thus on the valley floor alder and birch will eventually disappear from the area as no new trees grow to take the place of old dying ones. Ash will take the place of these species over much of the valley floor, and indeed this process is beginning already. Thus, assuming that the environmental conditions within the valley remain unaltered the majority of the site will go to an ash woodland. The only change in environmental factors which seems probable is a general and sustained lowering of the water table. However, this would probably only have the effect of enhancing the rate of change and producing a better developed ash woodland.

There are two areas of the valley floor which, on present evidence, appear not to be changing to an ash woodland. These are group 5, the birch woodland with moss ground layer, and group 4, the willow carr area. Present evidence suggests that group 5 will eventually lose its tree cover as no regeneration of any species is occuring in this zone. The major cause of this appears to be the groundwater height being so close to the surface. Thus, again with no change in environmental conditions, it appears that the area of group 5 will become a sphagnum bog surrounded by ash woodland.

Within group 4, the willow carr, it appears that there will be very little change in the type of woodland. Evidence presented here shows that willow is maintaining its predominance in the area. However, there may be a change in dominant species with Salix cinerea, the present dominant, being replaced by S. pentandra.

On the valley sides birch, the present dominant, is slowly being replaced as trees die and are not replaced by regeneration. On the fell side of the valley, on the south east facing slopes, oak is the predominant replacement tree while on the north west facing slope of the opposite side oak is not important and sycamore is the major tree moving in.

The study on population dynamics was only carried out on the major tree species of each vegetation unit. It is much more difficult and imprecise to carry out a similar analysis on the ground flora of the present woodland and to make predictions concerning any future change in species composition. Therefore, no attempt will be made here to suggest what the ground flora of the replacement woodland will be like.

Thus the woodlands of the South Burn valley are in a state of change which, with no interference by man or drastic change in environmental condition, will eventually cause the development of ash woodland over large areas of the valley floor. Small sections of this valley floor will, however, possess a different vegetation with a small section maintaining a willow carr and another area being composed of a sphagnum bog. The valley sides will also change their woodland type with the fell side supporting an oak forest while the opposite side will be dominated by sycamore.

APPENDIX 1

The following tables give the species lists for the seven groups of vegetation found in the South Burn valley. Figures for percent constancy, percent average cover and indicator value are also given.

Percent constancy

This is a value of the number of times a particular species occurs in the group, expressed as a percentage.

Percent average cover

This is a percentage value of the average cover of each species within the sample area of the vegetation unit, after correcting for percent constancy (i.e. abundance) of the species in that area. It is calculated in the following way. The mean value of the cover abundance figure for the species in the area is calculated and this is then expressed as a percentage. This mean percentage value is then multiplied by the abundance of the species in the area and divided by the sample area of that vegetation unit. Thus

$$C = \frac{\bar{x} \cdot y}{A}$$

where C = corrected percent average cover

y = percent constancy (abundance)

$\bar{x}$ = mean percentage cover calculated from the cover abundance figures given

A = area of vegetation unit in the sample.

Using the Domin cover abundance scale; a + was used to represent 0.5% cover; values between 1 and 4 on the scale were rounded up to the nearest whole number (thus a mean value of 3.5 when calculated was taken to represent 4% cover on the ground). With calculated mean values of 5 and above the percent cover on the ground was calculated in the following way. If a value of 5.5 was obtained for the mean value of the cover abundance values of a particular species, then this was taken to represent 15% cover on the ground as it lies half way between 5% and 25%, roughly the upper limit of Domin value 5 and the lower limit of Domin value 6 respectively.

This method of expressing the percentage cover of a particular species in an area of vegetation, although somewhat inaccurate, offers a better way of expressing the relative proportions of abundance and cover of species present in a given area than the five classes of abundance (i.e. Dominant, Abundant, Frequent, Occasional and Rare) traditionally used by British ecologists. With a finer cover abundance scale many of the inaccuracies of this method would be eliminated and this technique would then provide a useful tool in assessing the importance of a particular species in a given community.

<u>The indicator value</u>

The value is calculated using Goodall's (1953b) method. Only values significantly different at the 0.05 level are shown. Those species which have indicator values shown were used to differentiate the vegetation units in this study while those species marked * were used in the hierarchical syntaxonomic classification described previously.

TABLE 1 : Species list from the Oxalido-Betuletum (Sub-ass. Vaccinetosum) (group 1) woodland of the valley sides of the South Burn

Tree and Sub-canopy layers	% constancy	% average cover	Indicator value
Acer Pseudoplatanus	12	3	11.200
*Betula pubescens	100	70	0.839
*Quercus petraea	36	1.8	7.296
*Sorbus aucuparia	24	1.2	1.44
Ground flora			
Anthoxanthum odoratum	20	3	20.96
Arrenatherum elatius	4	0.2	20.96
*Calluna vulgaris	20	0.8	20.96
Deschampsia flexuosa	80	36	5.344
Digitalis purpurea	32	1.28	11.200
Galium cruciata	8	0.32	6.320
Galium saxatile	12	0.48	3.070
*Holcus mollis	44	4.4	19.870
Lapsana communis	12	0.48	3.066
*Lonicera periclymenum	24	0.96	-
*Oxalis acetosella	28	1.12	-
Potentilla erecta	12	0.24	-
Rubus fruticosus agg.	52	2.08	-
Rubus idaeus	4	1.32	-
Stellaria holostea	20	4.00	1.44
Teucrium scorodonia	16	0.80	16.08
*Vaccinium myrtilis	20	3.00	6.32
Veronica chamaedrys	8	0.16	-
Athyrium filix-femmina	32	1.6	-
Dryopteris filix-mas	12	0.24	-
Equisetum sylvaticum	8	0.16	-
*Pteridium aquilinum	64	3.20	9.810
Acrocladium cuspidatum	8	0.16	-
Brachythecium rutabulum	8	0.16	-
*Pleurozium schreberi	12	0.36	11.200
Pseudoschleropodium purum	12	0.60	11.200
Sphagnum plumulosum	8	0.24	-
		67.2	

TABLE 2 : Species list from the Osmundo-Alnetum (Sub-ass. Chrysosplenietosum) (group 2) woodland of the South Burn Valley floor

Tree and Sub-canopy layers	% constancy	% average cover	Indicator value
*Alnus glutinosa	100	80.00	2.63
Betula pubescens	25	1.25	-
Fraxinus excelsior	60	3.00	2.09
*Salix cinerea	10	0.20	-
*Salix pentandra	5	0.25	-
Sorbus aucuparia	20	0.80	-
Ground layer			
Ajuga reptans	15	0.36	4.16
Angelica sylvatica	15	0.36	-
Caltha palustris	75	4.46	16.95
Cardamine amara	5	0.24	-
Cardamine pratensis	45	2.14	1.28
Carex laevigata	40	2.38	14.48
Carex remota	35	2.08	4.75
*Chrysosplenium oppositifolium	10	3.45	8.29
*Cirsium palustre	20	0.48	-
Crepis paludosa	80	4.76	7.72
Dacthyllorhiza fuschii	15	0.36	-
Deschampsia cespitosa	15	0.89	-
Deschampsia flexuosa	5	0.05	-
*Eupatorium cannabinum	20	1.19	-
Filipendula ulmaria	100	5.95	5.68
Galium aparine	20	0.48	-
Geranium robertanium	15	2.14	-
Glyceria fluitans	15	11.60	14.48
Herecleum spondilium	5	0.12	-
Juncus conglomeratus	15	0.71	-
Juncus effusus	30	1.78	2.09
Lapsana communis	5	0.05	-
Lonicera periclymenum	10	0.36	-
Lysimachia nemorum	20	0.72	6.23
*Mentha aquatica	40	1.90	5.63
Mercurialis perennis	10	0.36	-
*Oenanth crocata	70	4.17	26.86
Oxalis acetosella	25	1.10	-
Phalaris arundinacae	20	0.72	3.33
Poa trivialis	35	1.66	-
Ranunculus repens	90	4.28	8.85
Rubus fruticosus agg.	20	0.72	-
Rumex conglomeratus	5	0.12	-
Scutellaria galericulata	5	0.05	-
Stachys sylvestris	35	2.08	1.68
Urtica dioica	5	0.05	-
Valeriana dioica	5	0.05	-
Valeriana officianalis	45	1.07	1.29
Veronica chamaedrys	10	0.36	-
Viburnum opulis	5	0.05	-

TABLE 2 : (Continued)

Viola palustris	5	0.05	-
Athyrium filix-femmina	35	1.25	-
Dryopteris dilatata	20	0.48	-
Dryopteris filix-mas	25	0.89	1.53
Equisetum fluviatile	10	0.05	-
Equisetum palustre	55	1.30	8.29
Equisetum sylvaticum	90	2.14	-
Acrocladium cuspidatum	30	0.71	2.78
Brachythecium rutabulum	30	1.07	5.81
Eurhymchium praelongum	10	0.05	8.29
Mnium hornum	5	0.05	-
Mnium undulatum	5	0.05	-
*Pellia epiphylla	35	0.42	4.75
Sphagnum plumulosum	5	0.05	-

TABLE 3 : Species list from the Osmundo-Alnetum (Chrysosplenietosum sub-ass.) (group 3) woodland of the South Burn valley floor

Tree and Sub-canopy layers	% constancy	% average cover	Indicator value
*Alnus glutinosa	100	100	1.53
Betula pubescens	10	0.25	-
Fraxinus excelsior	70	17.50	1.99
*Salix cinerea	10	0.25	-
Sorbus aucuparia	10	0.25	-
Ground layer			
Anemone nemorallis	20	1.50	3.56
Angelica sylvatica	10	0.75	-
Caltha palustris	20	1.50	-
Cardamine amara	10	1.00	-
Cardamine pratensis	90	6.75	4.62
*Carex paniculata	100	50.00	27.88
*Cirsium palustre	10	0.125	-
Crepis paludosa	20	1.5	-
Dacthyllorhiza fuschii	20	0.25	-
*Eupatorium cannabinum	40	4.00	4.91
Filipendula ulmaria	20	2.50	-
Galium aparine	10	0.50	-
Juncus conglomeratus	10	0.50	-
Lysimachia nemorum	20	1.00	-
Mentha aquatica	20	1.50	-
Mercurialis perennis	20	2.00	-
Oenanth crocata	10	1.00	-
Oxalis acetosella	40	5.00	-
Phalaris arundinacae	20	1.00	-
Poa trivialis	50	6.25	1.07
Potentilla erecta	20	2.00	-
Ranunculus repens	20	2.00	-
Rubus fruticosus agg.	60	6.00	-
Rubus idaeus	20	2.50	3.56
Stachys sylvestris	20	2.50	-
Vaccinium myrtilis	10	1.25	-
Valeriana officianalis	20	1.00	-
Veronica chamaedrys	10	1.00	-
Viburnum opulis	10	1.25	-
Athyrium filix-femmina	90	11.25	2.00
Dryopteris dilatata	30	3.00	2.45
Dryopteris filix-mas	20	2.00	-
Equisetum fluviatile	20	0.25	2.26
Equisetum palustre	20	1.00	-
Equisetum sylvaticum	90	4.50	-
Acrocladium cuspidatum	20	1.50	-
Pellia epiphylla	30	0.75	-
Sphagnum fimbricatum	10	0.25	-
Sphagnum squarrosum	20	2.00	-

TABLE 4 : Species list from the Crepido-Salicetum pentandrae association (group 4) of the South Burn valley floor

Tree and Sub-canopy layers	% constancy	% average cover	Indicator value
*Betula pubescens	30	5.36	-
Crataegus monogyna	15	2.68	-
Quercus petraea	30	16.07	-
*Salix cinerea	85	88.04	16.74
*Salix pentandra	45	40.18	10.29
Ground layer			
Agrostis tenuis	15	0.27	-
Angelica paludosa	15	0.27	-
Angelica sylvatica	70	10.00	5.77
Arrenatherum elatius	60	8.57	25.33
Cardamine pratensis	15	0.27	-
Cirsium palustre	15	0.27	-
*Crepis paludosa	30	2.14	-
Deschampsia cespitosa	45	8.04	7.06
Digitalis purpurea	15	1.07	-
Epilobium angustifolium	15	26.79	10.29
Festuca rubra	15	0.27	-
Filipendula ulmaria	45	24.10	-
Galaeopsis tetrahit	15	0.27	-
Galium aparine	70	10.00	6.81
Geranium robertanium	45	8.04	15.12
Herecleum spondilium	45	3.21	25.08
Holcus lanatus	30	42.85	3.84
Oxalis acetosella	15	13.39	-
Poa trivialis	100	14.28	4.06
Rubus fruticosus agg.	45	8.03	-
Rubus idaeus	15	2.14	-
Rumex acetosella	15	0.27	10.29
Stachys sylvestris	70	37.50	4.35
Stellaria graminae	15	0.27	10.29
Stellaria holostea	60	8.57	6.18
Urtica dioica	60	10.71	25.33
Valeriana officianalis	60	8.57	-
Athyrium filix-femmina	15	17.67	-
Equisetum sylvaticum	30	3.21	-
Pteridium aquilinum	15	26.78	-

TABLE 5 : Species list from the Beluletum pubescentis association (group 5) woodland of the South Burn valley floor

Tree layer	% constancy	% average cover	Indicator value
*Betula pubescens	100	85.00	0.397
Ground layer			
Agrostis canina	43	4.61	5.27
*Deschampsia flexuosa	86	12.28	1.85
Holcus mollis	14	0.25	-
Juncus acutiflorus	28	4.00	5.77
Juncus effusus	57	6.10	4.27
Lotus uliginosus	14	1.50	10.29
Molinia caerulea	28	5.00	-
Potentilla erecta	28	3.00	-
Rubus fruticosus agg.	14	1.00	-
Athyrium filix-femmina	14	1.00	-
Dryopteris dilatata	14	1.50	-
Equisetum palustre	14	1.00	-
Equisetum sylvaticum	100	10.71	-
Pteridium aquilinum	14	0.25	-
*Polytrichium commune	57	20.36	5.08
*Sphagnum fimbricatum	57	10.18	4.27
*Sphagnum palustre	28	4.00	3.84
*Sphagnum plumulosum	14	2.50	-
*Sphagnum recurvum	43	7.68	17.81
*Sphagnum squarrosum	100	17.87	6.72

TABLE 6 : Species list from the Osmundo-Alnetum association (group 6) of the South Burn valley floor

Tree and Sub-canopy layers	% constancy	% average cover	Indicator value
*Alnus glutinosa	48	50	-
Betula pubescens	100	100	0.424
Fraxinus excelsior	32	6.6	-
*Salix pentandra	16	3.3	-
Ground layer			
Ajuga reptans	16	0.33	-
Anemone nemorallis	32	4.00	7.00
Angelica sylvatica	48	4.00	2.51
Betonica officianalis	16	3.33	12.33
Cardamine amara	16	2.66	-
Cardamine pratensis	16	0.33	-
Carex laevigata	16	2.66	-
Carex nigra	16	2.66	12.33
Carex remota	48	8.00	3.44
*Cirsium palustre	90	7.50	8.23
Crepis paludosa	16	2.66	-
Dacthyllorhiza fuschii	32	2.66	2.64
*Eupatorium cannabinum	32	80.00	-
Filipendula ulmaria	66	11.00	-
Holcus lanatus	48	1.00	12.33
Holcus mollis	16	0.33	-
Juncus acutiflorus	16	22.00	-
Juncus conglomeratus	16	1.33	-
Lonicera periclymenum	66	1.38	3.91
*Mentha aquatica	16	22.00	3.44
Poa trivialis	16	0.33	-
Potentilla erecta	16	0.33	-
Ranunculus repens	50	8.33	-
Rubus fruticosus agg.	16	0.33	-
Scrophularia aquatica	16	0.33	12.33
Scrophularia nodosa	16	2.66	12.33
Succisa pratensis	16	1.33	12.33
Symphytum officianalis	16	0.33	12.33
Tussilago farfara	16	2.66	12.33
Valeriana officianalis	90	15.00	-
Athyrium filix-femmina	32	5.33	-
Equisetum fluviatile	16	0.33	-
Equisetum sylvaticum	90	11.25	-
Pteridium aquilinum	16	3.33	-
Polytrichium commune	16	3.33	-
Sphagnum fimbricatum	16	16.66	-
Sphagnum squarrosum	32	5.33	-

TABLE 7 : Species list from the Molinia society group (group 7) of the South Burn valley floor

Trees	% constancy	% average cover	Indicator value
Alnus glutinosa	30	11.25	-
*Betula pubescens	100	87.50	0.52
Fraxinus excelsior	10	1.25	-
Ground layer			
Agrostis canina	40	4.00	6.6
Galium saxatile	10	15.00	-
Holcus mollis	10	1.25	-
Juncus acutiflorus	10	1.00	-
Juncus effusus	10	0.125	-
Lonicera periclymenum	10	0.125	-
*Molinia caerulea	100	100.00	19.63
Oxalis acetosella	10	1.00	-
Potentilla erecta	10	1.00	-
Rubus fruticosus agg.	60	7.50	-
Athyrium filix-femmina	20	2.00	-
Equisetum sylvaticum	50	2.50	-
Aulacomnium palustre	20	0.25	21.80
Mnium hornum	20	1.50	5.91
Polytrichium commune	50	37.50	5.22
Sphagnum fimbricatum	50	6.25	4.26
Sphagnum palustre	30	3.00	2.26
Sphagnum plumulosum	20	1.00	-
Sphagnum recurvum	10	0.75	-
Sphagnum squarrosum	50	45.00	1.97

APPENDIX 2

ADDITIONAL METHODS USED IN THE STUDIES OF THE ENVIRONMENTAL FACTORS

Determination of the concentration of HCO_3^-

Bicarbonate is hydrolysed:

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$$

and OH^- ions are produced. The concentration of bicarbonate ions in solution can therefore be determined by titrating the sample with standard acid (thereby removing OH^-) until the equation has moved completely to the right. This is known as the alkalinity. BDH 4.5 indicator is used as an indicator of the end point, the colour change being from blue grey. N/100 HCL is used as the titrant.

Determination of field capacity

When a soil is at field capacity it is saturated after drainage by gravity. It can be determined in the following way. A filter tunnel is weighed and then plugged with cotton wool which has been soaked in alcohol. The tunnel is then placed over a beaker and a known weight of oven-dried soil is placed in it. 50 ml of water is then added and left until the soil is saturated. The cotton wool plug is then removed and the water allowed to drain away. When water movement has ceased the funnel and its contents are weighed. Percent moisture at field capacity can then be calculated from

$$\frac{\text{Increase in weight of soil}}{\text{Weight of oven dry soil}} \times 100$$

Determination of the concentration of dissolved bases in the groundwater of the organics soils.

To obtain these measurements an Atomic Absorbtion Spectrophotometer was used.

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TABLE 8 - DIFFERENTIATED SPECIES TABLE OF THE VEGETATION OF THE SOUTH BURN VALLEY.

GROUP 1 (relevés 1–25) · GROUP 2 (26–46) · GROUP 3 (47–56) · GROUP 4 (57–63) · GROUP 5 (64–69) · GROUP 6 (70–75) · GROUP 7 (76–86)

Relevés: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86

Species	Upper row (left to right)	Lower row (left to right)
CANOPY AND SUB-CANOPY LAYERS		
BETULA PUBESCENS	10 9 9 9 9 9 10 3 8 7 8 + 10 10 8 10 7 7 5 4 9 8 9 9 | 5 | 5 3 | 4 | 5 | 1 | 5 | 8 8 7 8 8 7 9 9 7 8 7 9 7 7 9 8 8 9 7 8 8 6 8	3 1 3 3 3 3 4 1 1 1 1 1 1 3 3 1 1 1 1 1 3 3 1 3 | 1 | 1 1 | 1 | 1 | 1 | 1 | 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
QUERCUS PETRAEA	+ 4 5 5 5 5 7 8 4 | 5 | 8	2 2 2 1 1 1 1 1 | 1 | 1
ALNUS GLUTINOSA	9 8 8 9 8 9 7 7 8 9 9 10 8 10 10 8 7 7 9 8 8 10 8 9 9 8 9 7 8 7 8 | 8 | 6 7 5 | 6 6 5	3 1 2 1 1 1 1 1 2 1 1 2 1 1 1 1 1 1 1 2 1 1 1 1 2 2 1 1 1 1 1 | 1 | 1 1 1 | 1 1 1
FRAXINUS EXCELSIOR	5 5 4 5 5 5 3 4 3 9 5 5 5 5 3 4 6 7 7 | 6 3 | 5	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 | 1 1 | 1
SALIX CINEREA	3 + | 4 | 6 8 7 6 6 6	1 | 1 | 2 3 1 2 1 1
SORBUS AUCUPARIA	4 + 5 4 4 2 2 4 2 5 2	1 1 1 1 1 1 1 1 1 1
SALIX PENTANDRA	6 6 6 | 5	1 1 2 | 1
CRATAEGUS MONOGYNA	5	1
ACER PSEUDOPLATANUS	7 6 6 4	1 3 2 1
SHRUB AND GROUND LAYERS		
DESCHAMPSIA FLEXUOSA	9 2 9 9 6 10 9 9 4 7 8 6 5 7 7 6 + 8 9 6 | 5 5 + + 5 4	4 1 4 4 3 5 4 3 2 3 3 1 2 2 4 3 3 4 3 | 1 1 1 2
PTERIDIUM AQUILINUM	4 2 2 5 5 7 8 6 3 6 7 + 8 + 2 + | 8 | + 5	1 1 1 2 1 3 3 2 1 1 3 3 1 | 3 | 1
HOLCUS MOLLIS	4 4 3 8 + 8 4 6 6 4 6 | 4 + 5	1 1 2 4 3 1 2 3 1 2 | 1 2
FILIPENDULA ULMARIA	3 4 3 + 7 4 6 6 4 8 6 8 5 2 5 4 3 + 6 6 5 | 5 4 | 4 8 5 | + 4 6 4	1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 2 1 | 1 1 | 1 1 1 | 1 1 1
RANUNCULUS REPENS	+ 5 4 5 2 1 4 5 5 5 2 2 + 6 3 7 2 5 | 4 | 4 | + 5 4	1 1 1 1 1 1 1 1 2 1 2 3 1 1 1 2 | 2 | 1 | 1 1
CREPIS PALUDOSA	2 3 7 3 + 2 5 5 4 3 2 2 6 5 1 6 | 3 2 | + 3 | 4	1 1 2 1 1 1 1 1 1 1 1 2 1 1 | 1 1 | 1 | 1
VALERIANA OFFICIANALIS	2 2 + 2 + + 2 4 4 | 3 + + 6 5 4 | 5 4 5 + 5	1 1 1 1 1 1 | 1 1 1 1 | 1 1 1 2
OENANTH CROCATA	5 7 5 + 3 3 5 3 3 5 5 4 8 5 | 4	1 3 1 2 2 1 1 2 2 2 2 3
CALTHA PALUSTRIS	7 6 5 4 6 5 2 6 5 4 2 5 4 + 6 | 4 | 2	3 1 1 2 2 2 2 3 1 2 2 2 2 2 | 2 | 1
EQUISETUM PALUSTRE	2 + 2 + + + 2 2 + 6 2 | + | 2 | 2	1 1 1 1 3 1 | 1 | 1
CAREX PANICULATA	6 5 5 6 + 5 8 7 9 5 | 5 5	1 1 1 2 2 1 1 2 1 | 1 2
CARDAMINE PRATENSIS	5 5 5 5 2 2 4 + 1 | + 4 2 1 5 3 3 4 4 | + | +	1 1 1 2 1 1 1 1 | 1 1 1 1 1 1 2 1
POA TRIVIALIS	+ 6 1 3 4 4 4 2 4 5 2 6 4 | 5 + 6 4 6 5 + | +	1 1 2 1 2 2 1 1 1 1 2 1 | 1 1 2 1 1
ANGELICA SYLVATICA	+ + 2 3 | 5 5 + 5 + | + + 5	1 1 | 1 1 1 | 2
STACHYS SYLVESTRIS	5 2 3 6 6 4 4 8 2 | 5 6 5 6 6	3 1 1 2 1 1 2 4 1 | 1 1 1 1 1
STELLARIA HOLOSTEA	5 4 5 9 6 | 4 + + | + 5 6 4	2 2 2 4 3 | 2 | 1 3 1
GALIUM APARINE	3 + | 2 4 3 5 5 +	2 | 1 1 2 1 3
ARRENATHERUM ELATIUS	4 | + 4 4 4	3 | 2 1 2
UTRICA DIOICA	+ | 6 + 5 5	2 1 2
SPHAGNUM SQUARROSUM	3 4 | 6 6 5 5 9 7 6 | 3 4 | 6 6 6 8 5	2 2 | 4 3 2 4 4 3 2 | 2 2 | 3 3 3 4 3
SPHAGNUM FIMBRICATUM	1 | 5 4 5 5 | 6 | 4 4 4 4 6	2 | 4 2 2 4 | 3 | 2 2 3 2 4
POLYTRICHUM COMMUNE	4 5 6 6 | 5 | 5 6 4 8 6	2 4 2 3 | 3 | 3 3 2 5 3
JUNCUS EFFUSUS	6 7 6 2 + 2 | 6 5 6 5 | +	2 2 2 2 2 | 2 2 2 2
MOLINIA CAERULEA	6 4 | 9 9 7 5 7 3 9 8 9 9	2 2 | 3 5 2 2 2 2 3 3 4 4
CIRSIUM PALUSTRE	+ + + 3 + + | + + + + 4	1 | 1
LONICERA PERICLYMENUM	+ 3 + 2 + 6 4 + | + + + + | +	1 1 3 2
CAREX REMOTA	4 4 4 5 5 5 2 | 2 4 6	2 2 2 2 2 2 2 | 2 2 2
OXALIS ACETOSELLA	4 + + 3 5 7 3 | 3 1 5 2 5 6 6 1 5 6 | 7	1 4 2 1 4 | 2 2 2 1 3 3 3 2 2 2 | 1
DIGITALIS PURPUREA	2 1 3 3 + 4 3 + | 2	1 1 1 1 1 1 | 1
ANTHOXANTHUM ODORATUM	4 4 5 5 7	3 1 2 3 2
CALLUNA VULGARIS	2 2 5 6 +	2 1 2 2
VACCINIUM MYRTILIS	6 2 8 6 5 | +	3 2 3 2 2
TEUCRIUM SCORODONIA	2 8 2 5	1 4 1 1
GALIUM SAXATILE	1 4 2 | 8	1 3 2 | 3
PSEUDOSCHLEROPODIUM PURUM	2 5 5	2 2 2
PLEUROZIUM SCHREBERI	3 4 +	2 2 +
QUERCUS PETRAEA	+ + +	
GALIUM CRUCIATA	6 3	3 2
CAREX LAEVIGATA	3 6 5 8 5 8 5 4 | 4	2 1 2 1 3 3 2 2 | 2
MENTHA AQUATICA	3 4 3 6 4 2 4 4 5 +	1 2 1 1 2 1 2 1 1
PELLIA EPIPHYLLA	+ + + + + 2 + + 2 +	2 2
ACROCLADIUM CUSPIDATUM	1 1 | 2 2 1 1 3 2 4 2	2 2 | 2 2 2 2 2 2 2 2
BRACYTHECIUM RUTABULUM	1 3 | 4 3 4 2 1 3 5 5 + | 3	2 2 | 2 1 2 2 2 2 2 2 | 1
DRYOPTERIS FILIX-MAS	+ + | 2 4 2 2 + + 6	1 2 1 2 1
LYSIMACHIA NEMORUM	4 + 4 2 + 3	1 2 1 2
PHALARIS ARUNDINACEAE	+ 2 2 5 2 1	1 1 2 1 1
AJUGA REPTANS	2 + +	1
GLYCERIA FLUITANS	9 8 9	4 4 4
CHRYSOSPLENIUM OPPOSITIFOLIUM	7 5	3 3
EUPATORIUM CANNABINUM	6 1 8 1 3 6 1 5 | 9 9	3 1 3 1 1 2 1 2 | 4 4
DRYOPTERIS DILATATA	2 + 2 +	1 1
DESCHAMPSIA CESPITOSA	4 5 4 | 5 4 4	1 2 2 | 2 2 2
GERANIUM ROBERTIANUM	5 7 4 | 5 7 +	1 1 2 | 2 1
HERECLEUM SPONDILIUM	2 | 5 + +	1 | 1
AGROSTIS CANINA	4 5 + | 6 + 4 +	2 1 | 1 2
SPHAGNUM RECURVUM	5 4 4 | 3	2 2 2 | 2
JUNCUS ACUTIFLORUS	6 8 | 7 | 4	2 2 | 2 | 2
SPHAGNUM PALUSTRE	4 3 | 4 4 3	2 2 | 2 2 2
HOLCUS LANATUS	9 6 + + +	5 2
AULACOMNIUM PALUSTRE	+ +	
MNIUM HORNUM	1 | 3 2	2 | 1 2
EQUISETUM SYLVATICUM	2 + + + + + + 4 + 5 1 + 5 1 4 + 2 3 + 2 + + 6 + + + 1 2 + + 1 2 4 + 2 + + 4 5 5 + + 5 4 + 5 + 5 + 4 + 4 + +	1 2 2 1 2 1 2 1 1 1 3 1 1 1 1 2 1 1 1 1 1 2 3 1 1 1
RUBUS FRUTICOSUS AGG	2 6 + 3 + + 4 4 5 5 2 5 4 4 1 3 + 4 1 5 + 5 5 5 7 + 4 + 4 + 6 4 5 5	1 2 2 1 1 1 3 1 1 1 2 1 2 2 1 2 1 2 1 2 1 1 1 1 1 1
ATHYRIUM FILIX-FEMINA	4 5 7 3 7 4 5 + 2 2 2 1 4 4 3 5 4 3 3 5 6 4 2 7 7 2 + 6 5 3	2 2 1 2 1 2 2 1 2 1 1 2 2 1 1 2 2 2 2 2 2 2 1 2 2 1 2 1
POTENTILLIA ERECTA	+ 2 2 3 4 6 5 + 4	2 1 1 2 2 2 2
DACTHYLLORHIZA FUSCHII	3 + + + + + 3	1 1
FRAXINUS EXCELSIOR	+ + + + + + + +	
SPHAGNUM PLUMULOSUM	3 2 4 3 2 +	3 2 2 1 2
EQUISETUM FLUVIATILE	+ + + + +	
JUNCUS CONGLOMERATUS	2 2 5 2 2	2 1 2 1 2
VERONICA CHAMAEDRYS	+ + + 5 4 +	3 1
ANEMONE NEMORALLIS	2 3 + 5	1 2 1
LAPSANA COMMUNIS		
MERCURIALIS PERENNIS	2 2 3 4	2 3 2 2 2
RUBUS IDAEUS	5 4 4	2 1 1
CARDAMINE AMARA	2 4 4	1 2 2
EURHYNCHIUM PRAELONGUM	+ + 5	
SORBUS AUCUPARIA	1 + +	1
VIBURNUM OPULIS	+ +	
ACER PSEUDOPLATANUS		
AGROSTIS TENUIS		
ANGELICA PALUDOSA	8 5	4 2
BETONICA OFFICIANALIS	+ 4	1
CAREX NIGRA	+	
EPILOBIUM ANGUSTIFOLIUM	6	2
FESTUCA RUBRA	+	
GALAEOPSIS TETRAHIT		
LOTUS ULIGINOSUS		
MNIUM UNDULATUM	+	
RUMEX ACETOSELLA	2	1
RUMEX CONGLOMERATUS	+	
SCROPHULARIA AQUATICA		
SCUTELLARIA GALERICULATA	+	
STELLARIA GRAMINAE	4 2	1 1
SUCCISA PRATENSIS	4 +	1
SYMPHYTUM OFFICIANALIS		
SCROPHULORIA NODOSA		
TUSSILAGO FARFARA		
VALERIANA DIOICA	1	1
VIOLA PALUSTRIS	6	4