DOCTORAL THESIS

Plant ecology of lowland Alnus Glutinosa woodlands

The management implications of species composition, requirements and distribution

Helen Miller

PLANT ECOLOGY OF LOWLAND *ALNUS GLUTINOSA* WOODLANDS: THE MANAGEMENT IMPLICATIONS OF SPECIES COMPOSITION, REQUIREMENTS AND DISTRIBUTION

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Wet woodlands have been recognised as a priority habitat and have featured in the UK BAP since 1994. Although this has been acknowledged in a number of UK policies and guidelines, there is little information relating to their detailed ecology and management. This research, focusing on lowland *Alnus glutinosa* woodlands, aimed to address this data paucity through the analysis of species requirements and to develop a methodology to guide appropriate management for this habitat for the benefit of wildlife.

To achieve these aims data were collected from 64 lowland *Alnus glutinosa* woodlands and a review of the literature was undertaken to identify species associated with the target habitat. The groundflora species found to be associated with lowland *Alnus glutinosa* woodland were assessed in relation to their optimal environmental conditions (Ellenberg indicator values) and survival strategies (Grime CSR-Strategy) to determine the characteristics (Characters of a Habitat; CoaHs) and range of intra-site conditions (Niches of a Habitat; NoaH). The methodologies, using CSR and Ellenberg indicator values in combination, were developed to determine NoaHs and were tested both quantitatively and qualitatively at different lowland *Alnus glutinosa* sites. The existence of CoaHs and NoaHs in actual sites was verified by detailed quadrat data gathered at three *Alnus glutinosa* woodlands at Stonebridge Meadows, Warwickshire, UK and analysed using TWINSPAN and DCA ordination. The CoaHs and NoaHs and their component species were confirmed to have the potential to occur in a particular woodland.

Following a literature search relating to the management of small wet woodlands within the UK, in conjunction with the current research, broad principles and strategies were identified for the management of lowland *Alnus glutinosa* woodland. Using the groundflora composition, an innovative procedure is developed and described for identifying the potential variation within a particular site and determining its appropriate management. Case studies were undertaken on distinct woodlands and the methodology proved effective.

Key words: Riparian. Groundflora. Ellenberg. CSR. Wet.

DEDICATION

I would like to dedicate this thesis to Andy who sadly passed away a few days after my viva, although he will remain a constant source of inspiration, enthusiasm and motivation.

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LIST OF TERMS

A11	*Potamogeton pectinatus-Myriophyllum spicatum* community (NVC)
Ancient woodland	Woodland that occurs on land that has been continuously wooded since at least 1600
ASNW	Ancient semi-natural woodland
BAP	Biodiversity Action Plan A UK initiative in response to the Rio Summit 1992. Includes habitat action plans (HAP) and species action plans (SAP)
C	Competitors (see CSR Triangle)
C species	Competitor species. See CSR Triangle.
CBD	Convention on Biodiversity at the Earth Summit, held in Rio de Janeiro in 1992
CG3	*Bromus erectus* grassland (NVC)
Coupe	Management compartment within a woodland
CoaH	Characteristic of a Habitat – determined, as part of the research, through consideration of individual CSR-strategies and Ellenberg indicator values. Also see NoaH.
C/NoaH	CoaH and NoaH collectively

CR	Competitive ruderals (see CSR Triangle)
CS	Stress tolerant-competitors (see CSR Triangle)
CSR	Competitive, stress tolerant ruderals (i.e. generalists) (see CSR Triangle)
CSR Triangle	A way of describing a species position along a three way gradient of competition (C), stress (S) and disturbance (R). Grime (2001).
CVS	Countryside Vegetation System (Bunce *et al.* 1999)
DAFOR	A qualitative scale of abundance. D – dominant, A – abundant, F – frequent, O – occasional, R – rare, L – localised.
DCA	Detrended Correspondence Analysis
MDA	Minimum Dynamic Area (Pryor and Peterken, 2001)
DOMIN	A quantitative measurement of species cover along a scale of 1 to 10. (*sensu* Dahl, and Hadač, 1941)
EMGIN	East Midlands Green Infrastructure Network
ESC	Ecological Site Classification (Forestry Commission)
F	Ellenberg soil moisture indicator value
FC	Forestry Commission - UK Government Department for forest related issues
GBIF	Global Biodiversity Information Facility
HAP	Habitat Action Plan. See BAP
Inter-variation	Variation between sites
Intra-variation	Variation within a given site
ITE	Institute of Terrestrial Ecology
L	Ellenberg light indicator value
LAgW	Lowland *Alnus glutinosa* woodland
MCPEF	Ministerial Conference on the Protection of European Forests
MDT	Management Decision Tool
N	Ellenberg soil fertility indicator value
NE	Natural England - UK Government's advisor on nature conservation (formally English Nature).
NERC	Natural Environmental Research Council
NoaH	Niche of A Habitat (in this case niche of *Alnus glutinosa* habitat) determined, during the course of this research, through multivariate analysis. NoaHs are specific locations in a habitat described by a given set of environmental characteristics, defined by the preferred growing conditions and strategies of the habitat's component plants.
NVC	National Vegetation Classification. (Rodwell 1991 *et seq*.)
PCA	Principle component analysis
R	Ellenberg soil acidity indicator value
R	Ruderals (see CSR Triangle)
R species	Ruderal species. See CSR Triangle.
S	Stress-tolerators (see CSR Triangle)
S species	Stress tolerating species. See CSR Triangle.
S26	*Phragmites australis-Urtica dioica* tall-herb fen (NVC)
SD2	*Honkenya peploides-Cakile maritime* strandline community (NVC)
SR	Stress tolerant ruderals (see CSR Triangle)
SRC	Short rotation coppice, e.g. biofuel coppice systems
STW	Sewerage Treatment Works

W10	*Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland (NVC)
W13	*Taxus baccata* woodland (NVC)
W14	*Fagus sylvatica-Rubus fruticosus* woodland (NVC)
W18	*Pinus sylvestris-Hylocmium splendens* woodland (NVC)
W5	*Alnus glutinosa-Carex paniculata* woodland (NVC)
W6	*Alnus glutinosa-Urtica dioica* woodland (NVC)
W7	*Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland (NVC)
Wildwood	"*wholly natural woodland unaffected by Neolithic or later civilization; no longer exists in British Isles*" (Rackham, 1998. p.233)

Authorities for the flora nomenclature used in this thesis follow Stace (2001).

1. INTRODUCTION

1.1 Origins of Project

Woodlands are an important resource for biodiversity, often with other habitat types (such as grasslands, hedgerows and ponds) in the form of glades, boundaries and internal features enhancing the diversity. This was confirmed in an initial review of the literature in relation to woodlands as part of a contract with Severn Trent Water and The National Forest (Miller, 2004) with which the author was involved (see Appendix 1). This literature review also determined that wet woodlands, in particular, are of high ecological interest and had, in relation to other woodland types, a comparatively low knowledge base with respect to their character and management. As part of the above work a questionnaire was devised (see Appendix 2) and distributed to approximately 30 woodland owners and managers of small private woodlands, nature conservation reserves and commercial forests. The purpose of the questionnaire was to gain an overview of the current state of knowledge and use of wet woodland habitats in the UK in relation to their management. The results of the questionnaire also subsequently informed the direction of the current research project.

The results of the questionnaire and initial investigations were presented at the "Nutrient Cycling and Retention in Natural and Constructed Wetlands V" workshop held in Borová Lada, Czech Republic, in 2003 (Miller *et al.*, 2005). The conclusions included the following (other results of the questionnaire provide supporting evidence in Chapters 2-8):

- confirmation of the need for further research into what constitutes wet woodland and how the habitat should be managed in order to meet nature conservation policy targets;
- *Alnus glutinosa* dominated wet woodland is the most significant and frequent type of wet woodland, either as an individual habitat or forming a component of other woodland types;
- wet woodlands are generally of small spatial extent (64% of the responses indicated woodlands of less than 2 ha);
- management is likely to be highly influential in determining the survival and diversity of wet woodlands;
- upland and lowland wet woodland often have both very different characteristics and/or drivers determining their composition, and as such are likely to respond differently to management.

The general conclusions, in relation to extent and distribution of *Alnus glutinosa* woodland, concurred with Rackham (2003) who found that of 336 ancient woodlands (totalling 7087.5 ha) surveyed in Eastern England, only 1.3% of the total area comprised *Alnus glutinosa* woodlands and were recorded in 10% of woodlands surveyed.

Therefore, this research project focuses on lowland *Alnus glutinosa* woodland since not only will it result in a greater understanding of their composition, structure and management, but also the outcome is likely to be of practical use. This research will consider mechanisms by which management can be evaluated against ecological principles for the benefit of wildlife in the target habitat and will contribute to the gap identified by Lindenmayer *et al.* (2006. p.433) when they summarised their discussion on forest management and ecological processes as:

> "*Although the general ecological principles and associated checklist are intuitive, data to evaluate the effectiveness of many specific on-the-ground management actions are limited*".

As a result of the complexities and "*impossibility of measuring and monitoring the impacts on all species of various management practices*" (Lindenmayer *et al.,* 2006. p.434) this research focuses on vascular plants, notably the groundflora. Plants also form the foundation to all other groups, e.g. invertebrates, birds, and such groups are dependant on various plants and/or the structure that they create in the habitat.

1.2 Aims and Objectives of Research Project

The results of the questionnaire further guided the literature review (Chapter 2) and the following aims and objectives were developed:

> Aim: develop a tool that enables appropriate management decisions to be made based on the flora and basic knowledge (e.g. size, adjacent habitats, access) of a site

This aim will be achieved in the current research thesis through the following objectives:

Objective 1: identify the general character and intra-site variation within lowland *Alnus glutinosa* woodland using, and then combining, existing tools (CSR & Ellenberg)

Objective 2: relate the general character and intra-site variation to conditions created through management techniques

Objective 3: develop a tool that identifies the general character and intra-site variation using groundflora species.

1.3 Thesis Structure

In order to address the aim and objectives detailed in Section 1.2, a series of dependent steps and potential feedback loops need to be followed, see Figure 1.1.

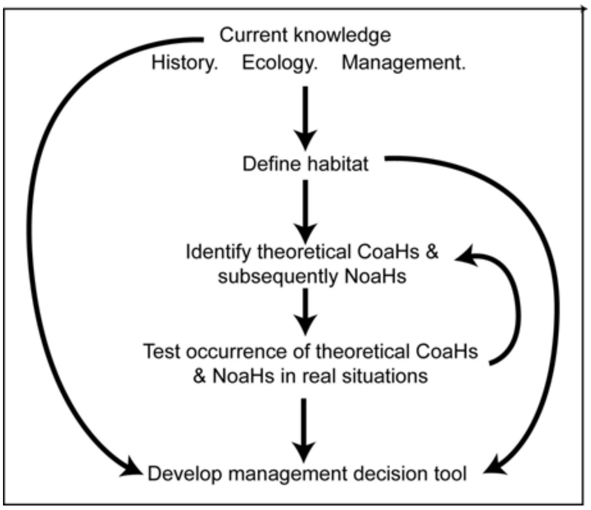

Fig. 1.1 Steps and processes followed during the course of this research to develop a management decision tool

As a result of the evolutionary developmental process (Figure 1.1) a typical structure for a PhD thesis has not necessarily been strictly adhered to. The following provides an overview of the structure and content of the thesis:

Chapter 2: Literature Review

Chapter 2 provides detailed background to the research topic through a literature review. The following topics are reviewed and discussed:

- Woodland habitats (focusing on wet and *Alnus glutinosa* woodlands and importance and how they have changed over the course of time)
- Management and how it is influenced by and itself can influence the characteristics of woodland
- Existing mechanisms used to help determine management of woodland habitats.

The literature review provides the foundation to which the methods, described in Chapter 3, have been developed.

Chapter 3: Development of Research Methodology and Justification

This chapter details the initial methods used during the course of the research. Although all are described in a single chapter for clarity of reading, the methods evolved and developed during the research with later methods depending on the outcome of the preceding ones. Therefore, in some instances the methods are refined in later chapters. Where this has been the case the reasons have been discussed in the appropriate chapter.

The method used in each step to develop the management decision tool is described in a 'recipe-style' format followed by a discussion on the justification of the approach taken. The discussion and justification includes a more focused review of the literature where necessary. Alternative approaches are also discussed and justification provided as to why they were not deemed appropriate to the current research. For clarity, results of methods that were investigated but dismissed are omitted from the main thesis but provided in the Appendices where appropriate.

Chapter 4: Defining Characteristics of Lowland *Alnus glutinosa* Woodland

Chapter 4 defines the research habitat in terms of the geographic and landscape situation. Potential component species are identified and used to describe the broad characteristics of the habitat as inferred by the component species' CSR-strategies and Ellenberg indictor values. The results of the methods described in Chapter 3 are provided and subsequently discussed in relation to specific examples from the literature and Chapter 2.

Chapter 5: Identifying Theoretical Niches of a Habitat in Lowland *Alnus glutinosa* Woodland

Following on from Chapter 4, this chapter subsequently identifies a series of characteristics (CoaHs – Characteristics of a Habitat) that have the potential to dominate any given site. The chapter uses the results of Chapter 4 to identify and define theoretical potential intra-site variation within lowland *Alnus glutinosa* woodland – termed NoaHs (Niches of a Habitat) in this current research. TWINSPAN classification and DCA ordination are used to identify groups of species with similar preferred growing conditions (Ellenberg values) and life-strategies (CSR) that potentially represent NoaHs within lowland *Alnus glutinosa* woodlands. These groups are considered in more detail in relation to the theoretical

CoaHs. The theoretical CoaHs and subsequent NoaHs are further refined through exploration of the component species and illustrated using qualitative data from a suite of sub-sites surveyed during the course of the research when defining the target habitat and supporting evidence/justification from the literature.

Chapter 6: Stonebridge Meadows

Chapter 6 describes three sub-sites where quantitative data were collected to test the validity of using theoretical data to develop a management decision process. Separate sites were used to test (see Chapter 7) the theories developed in Chapter 5 from quantitative and qualitative data to minimise pre-conceptions from the former in the latter.

Chapter 7: Verifying the Occurrence of Niches of a Habitat in Lowland *Alnus glutinosa* woodland

This chapter utilises data provided in Chapter 6 to verify the occurrence of C/NoaHs developed in Chapter 5, i.e. it applies and tests the theory of Chapter 5 in real situations from quantitative data. The theory is also considered using qualitative data from four sites along the River Rother, Hampshire, (studied during the course of the research to define the target habitat) and discussed in relation to the conditions on the ground.

Chapter 8: Managing Lowland *Alnus glutinosa* Woodland

Chapter 8 reviews the management options described in Chapter 2 in relation to the outcomes of Chapters 4-7. It goes onto identify management aims and objectives that are appropriate for managing lowland *Alnus glutinosa* woodlands for wildlife. In this chapter, knowledge gained from the literature review through the theory and subsequent testing is applied to develop a process/tool aimed at helping the decision process for management of such woodlands. It is then applied using qualitative data from the Stonebridge sites.

Chapter 9: Research Review

This chapter provides an overall review of the research undertaken and how it achieves the aims and objectives it set out to meet.

2. LITERATURE REVIEW[1]

2.1 DEFINING THE HABITAT

2.1.1 Woodlands

Woodland is defined, by The Oxford Dictionary (Soanes, 2006. p.885), as "*Land covered with trees*". This is a very simplistic definition as a woodland needs to have above and below ground structural and species diversity as well as trees. Woodland soils typically show more distinct stratification than other habitats, such as agricultural land that is regularly ploughed. However, such stratification can be less distinct in recent woodlands, for example those newly created on previous farmland. Woodland itself, including the soil communities, takes several decades to develop, and trees planted in a field or along a roadside do not immediately constitute a woodland habitat. The National Inventory of Woodland and Trees, Great Britain (Gilbert, 2007. p.46) provides the following definition:

> "*In Great Britain woodland is defined as land with a minimum area of 0.1 ha under stands of trees with, or the potential to achieve, tree crown cover of more than 20%. Areas of open space integral to the woodland are also included. Orchards and urban woodland between 0.1 and 2 ha are excluded. Intervening land-classes such as roads, rivers or pipelines are disregarded if less than 50 m in extent. 'Scrubby' vegetation is not included as a separate category but as Conifer, Broadleaved or Mixed tree types in Timber potential Class 3.*"

In much of the temperate zone, woodland is a climax community. Woodlands are structurally diverse and complex habitats, comprising several separate components or habitats, ranging from open grassy glades and dense closed canopies to small damp hollows and raised hummocks.

2.1.2 Types of woodland

Woodland habitat covers a vast array of different types and can be further defined depending upon the woodland's characteristics. In a broad sense, woodland can be considered in relation to the soil water status, i.e. dry, mesic or wet. The diversity and variation of woodlands within the UK is emphasised by a number of classifications describing this habitat; Table 2.1. provides a summary of different woodland types

[1] Sections 2.4-2.7 draw upon the contribution made by the author to a report written for Severn Trent Water and the National Forest (Miller, 2004) which was undertaken as part of the current research (See Appendix 1).

identified using the more influential classifications systems. Rackham (2006) in his consideration of classification systems, counted 83 types (up to 1992) of woodland when combining the three most significant systems, i.e. Rackham (2003), Peterken (1993) and Rodwell (1991).

Classification	Number of woodland types		
	All woodland	**Wet woodland**	***Alnus glutinosa* woodland**
Tansley (Tansley, 1965)	9	3	1
Merlewood National Classification of British Woodland (Bunce, 1982)	32	8	6
Peterken Stand Type Classification (Peterken, 1993)	39 with 38 sub-types	3 Groups within which are 5 Stand Types within which are 7 sub-types	3
National Vegetation Classification (Rodwell, 1991)	59 sub-communities within 19 communities	18 sub-communities within 7 communities	11 sub-communities within 3 communities
Rackham (Rackham, 2003)	31	3	3
Countryside Vegetation System (Firbank *et al.*, 2000)	15	7	3

Table 2.1 Woodland diversity within the UK

Such variety of woodland is at least in part a reflection of the historical use and varied environmental conditions of woodlands within the UK (further discussed in Section 2.2). The following quote from Rackham (2003, p.63) eloquently describes the complexities associated with woodland:

> "*A wood does not change into a different type of woodland every time someone fells the oaks. A single dominant species is often insufficient to define a tree community: thus hornbeam-woods are very heterogeneous and detailed inspection suggests that they should be divided into four woodland types.*"

2.1.3 Wet woodlands – *Alnus glutinosa*

The preceding section identified a wide diversity of woodland habitats within the UK but this thesis will concentrate on wet woodlands, in particular those dominated by *Alnus glutinosa*. Wet woodlands can be defined as being primarily pioneer and dynamic communities and the key species, e.g. *Alnus glutinosa*, *Populus* spp., require temporal continuation of the habitat and disturbance and exposed soils for regeneration (Hughes *et al.*, 2001). Wet woodlands are highly variable in terms of species composition and locality. Parrott and MacKenzie (2000) noted the high variability within and between riparian woodland (just one form of wet woodland) in terms of its vegetation composition, locality, soils, micro-climates and management. They recognised that this variability and mosaic nature of the habitat could account for the habitat's ability to support a diversity of wildlife. Hughes *et al.* (2005. p.7) described floodplain forests, which would include wet woodlands, as being:

> "*highly mobile mosaics of small scale habitats in various successional stages…*[with] *distinctive ecological characteristics that are strongly related to the variable flow regimes and sediment loads of their adjacent rivers*."

The UK Biodiversity Action Plan (BRIG, 2008. p.81) describes wet woodland as occurring:

> *"on poorly drained or seasonally wet soils, usually with alder, birch and willows as the predominant tree species, but sometimes including ash, oak, pine and beech on the drier riparian areas. It is found on floodplains, as successional habitat on fens, mires and bogs, along streams and hill-side flushes, and in peaty hollows. These woodlands occur on a range of soil types including nutrient-rich mineral and acid, nutrient-poor organic ones. The boundaries with dryland woodland may be sharp or gradual and may (but not always) change with time through succession, depending on the hydrological conditions and the treatment of the wood and its surrounding land. Therefore wet woods frequently occur in mosaic with other woodland key habitat types (e.g. with upland mixed ash or oakwoods) and with open key habitats such as fens. Management of individual sites needs to consider both sets of requirements.*"

Within the broad description of wet woodland, there is much variation and biodiversity as a result of the history, location, management practices, soil and hydrological conditions. As a result, there are several distinct types of wet woodland within the Wet Woodland Priority Habitat Action Plan (HAP) (BRIG, 2008), including lowland *Alnus glutinosa* woodlands and woodlands dominated by, for example, *Salix* spp.

To provide a global context to *Alnus glutinosa* woodlands, Figure 2.1 illustrates the distribution of *Alnus glutinosa* as provided by the *Global Biodiversity Information Facility (GBIF) Data Portal* (2008). The figure shows that *Alnus glutinosa* is primarily a European species with a concentration in the north and west.

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Fig. 2.1 Global distribution of *Alnus glutinosa* (based on GBIF Data Portal, 2008)

Figure 2.2 provides a more detailed illustration of the distribution of *Alnus glutinosa* within Europe as provided by Eunis (2008). Tansley (1965) noted that in the past, during wetter climates, *Alnus glutinosa* woodlands were more widespread and extensive.

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Fig. 2.2 Distribution of *Alnus glutinosa*
in Europe (based on EUNIS, 2008)

Peterken and Hughes (1995) noted that, despite much land reclamation and river flow control, floodplain forests on Continental Europe have survived better than those in the UK, therefore, it is probable that *Alnus glutinosa* woodland are likely to be better represented in Continental Europe compared to the UK. However, continental *Alnus glutinosa* woodland may have a different character to those found in Britain. For example, as a result of geographical, climatic and topographic differences, as well as the complexities of British soils and geology, Rackham (2003) makes the observation that woodland communities considered typical of Britain are rarely found in continental Europe, despite their relatively close geographical proximity. Additionally, studies on continental *Alnus glutinosa* woodland (e.g. Döring-Mederake, 1990; Prieditis,1997; Härdtle *et al.*, 2003a; Douda, 2008) have shown that there is a wider variety of such woodland types compared to the three described by Rodwell (1991) for the UK.

Although *Alnus glutinosa* is generally more abundant in wetter climates, such as Wales and western Scotland, Tansley (1965) found that the most notable *Alnus glutinosa* woodland occurs in the Norfolk Broads region of Britain. Döring-Mederake (1990) commented that *Alnus* spp. fen woodlands are generally stable with climate, showing little floristic variation with changes in climatic conditions, and the groundflora being similar (comprising species adapted to wet soils and high air humidity) across Central Europe. However, as already illustrated by the number of different *Alnus glutinosa* woodland types (Table 2.1), within the UK these woodlands can be very different from each other. Appendix 3 provides a summary of the characteristics of the different *Alnus glutinosa* woodlands described by different authors.

Historically *Alnus glutinosa* was widely distributed across the landscape and until man had asserted a greater influence on vegetation by draining the marshes, *Alnus glutinosa* remained prominent in the British vegetation (Tansley, 1965). However, nowadays, wet woodlands (including *Alnus glutinosa* woodlands) have a fragmented distribution and are of small spatial extent (e.g. Rodwell, 1991; Peterken and Hughes, 1995; Miller, 2003) within the UK lowlands. *Alnus glutinosa* woodland typically occurs in the damp pockets of other woodland types, along streams and ditches and the periphery of standing water and is generally associated with more fertile soils. Many sites occur as remnants of floodplain forests in agricultural and urban areas, for example, traditionally floodplains were primarily agricultural land, but areas less suited for grazing or cultivation, e.g. swampy areas, field margins and banks of watercourses, were occupied by trees (Peterken and Hughes, 1995). *Alnus glutinosa* typically form secondary woodlands, although a few older and ancient woodlands remain in floodplains, such as Llanerch alder carr along the Afon Gwaun (south-west Wales) and the *Alnus glutinosa* woodlands along the Beaulieu River (Hampshire, England), (Peterken and Hughes, 1995).

Rackham (2003) found plateau and valley *Alnus glutinosa* woodlands to be associated with old *Betula* and non-coppice *Quercus*. The plateau woodlands were also associated with *Tilia-Fraxinus*, acidic *Tilia* and valley *Alnus glutinosa* woodlands. The valley *Alnus glutinosa* woodlands were associated with *Castanea – Carpinus*, *Ulmus*, *Fraxinus-Corylus* and pure *Corylus* woodlands. Tansley (1965) found *Alnus glutinosa* frequently scattered throughout *Quercus petraea* woodland, as well as being locally abundant where the soils are waterlogged. In Herefordshire, Barfield *et al.* (1984) found that in some cases *Alnus glutinosa* woodlands had a fairly restricted spatial extent, for example springline woods the woodland width depends on the extent of flushing. The Countryside Vegetation System (CVS) (Bunce *et al.* 1999 and 1999a and Firbank *et al*. 2000) found that the streamside plots had the most diverse species composition compared to other landscape types and included both ubiquitous and specialist species (Bunce *et al.* 1999a). This suggests that *Alnus glutinosa* woodlands that occur along stream sides have a diverse floristic composition.

Based on analysis of the Countryside Survey 1990, Table 2.2 summarises the characteristics of woodlands >0.25 ha with *Alnus glutinosa* as the dominant canopy species (Stark *et al.*, 1996). In brief, Stark's analysis showed that the majority of UK *Alnus glutinosa* woodlands are:

- between 20 – 100 years old (36%);
- unmanaged and thriving (43%);
- have no specific use (67%);
- have no specific features (44%).

This is comparable with data collected through the distribution of a questionnaire (see Section 1.1 and Appendix 2) at the start of this research project, which was aimed at gathering information on wet woodlands in general. Questionnaire results showed the following for wet woodlands:

- most dominant canopy species: *Alnus glutinosa*;
- most frequent size of woodland: <4 ha;
- main management: Non-intervention;
- use: Biodiversity/nature conservation.

Table 2.2 Characteristics of *Alnus glutinosa* woodland (from Stark *et al.* 1996)

2.2 IMPORTANCE OF WOODLANDS

Since the Ice Age, following the natural re-establishment of woodland across the UK, woodland cover has generally declined, dropping to *c*. 5% in 1990:

- 100% Post Ice Age
- 50% 500 BC (Rackham, 1990)
- about 15% 1086 (FC, 2010a)

However, since 1900 there has been a noticeable, albeit slight increase as illustrated in Figure 2.3.

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Fig. 2.3 Woodland cover in the UK 1900-2010 (sources Stebbings, 1919 and Forestry Commission, 2010a)

The reasons for such changes in woodland cover are reflective of the value and use of land at different periods in UK history.

2.2.1 Changes in the use and management of woodlands through the ages

Woodlands have been an important part of history in the UK. Since the start of human civilisation, following the last Ice Age, the use and value of woodlands has changed:

- *c.* 4000 – 750 BC (pre- and throughout the Neolithic and Bronze Ages): significant large-scale loss of woodland as a result of cultivation. (Rackham, 1990).
- Roman occupation: despite continued loss as a result of increased intensity of agriculture (Tansley, 1965; Rackham, 1990), woodland remained an important source for numerous resources, e.g. fuel (both domestic and industrial), pannage, hunting, construction.
- 400 AD (Saxon period): further woodland clearance with the most fertile soils, such as floodplains, likely to have been cleared first as they had greater value for the rise in agriculture; the marshy and heavy clay soils being less workable.
- 11th – 13th centuries: the advent of The Royal Forests and ‘Forest Law’ with tracts of open land, heath and woodland being protected primarily for the use by nobility for hunting. This law overrode Common Law and ‘Commoners’ were excluded from the woodlands. Although cultivation was discouraged within The Royal Forests and the open areas enabled woodland regeneration, outside the boundaries cultivation expanded and subsequently woodland loss continued. However, further loss was later prevented with woodlands being enclosed.

Woodlands began to be purposely and actively managed, e.g. 'coppice-with-standards' (Tansely, 1965; Rackham, 1990). The management and protection of woodland from cultivation indicates woodlands were considered important.

- 16th century: first records of tree planting in England (Tansley, 1965). This was more than a century after the first records in Scotland, where there are historic data to suggest that three saplings had to be planted for every *Betula* spp. damaged. Rackham (1990), however, suggests that evidence of planting in England occurred 300 years earlier in the 12th century, albeit on a relatively small scale.
- 1509 – 47 (reign of Henry VIII): significant amount of woodland was felled when Henry "*seized upon the church lands and converted them, together with their woods, to his own use,*" (Stebbings, 1916. p.xxi), including the building of naval ships.
- 1642 (Civil War) – 18th century: although further fellings took place, as noted by Tansley (1965), if the demand for wood was absent, the woodlands were likely to have been cultivated. England lost the last of her forest reserves and became almost entirely dependant on imports for timber (Tansley, 1965).
- 18th and 19th centuries: significant creation of plantations, of both native and introduced species, and included both coppices and timber (Rackham, 1990). Stebbings (1916. p.xiii) goes so far as to say that such plantings,

  > "*safeguarded the nation from invasion by Napoleon, enabled Trafalgar to be fought and won, and thus gave us security from invasion for a whole century thereafter.* "

  The Royal Society of Arts, founded in 1754, encouraged large scale planting by awarding premiums and medals for sowing and planting trees (Stebbings, 1916). However, by the mid 1800s, plantings had begun to decline.
- 1911: although large amounts of timber were required for the War effort, Britain was almost entirely reliant on timber imports. Stebbings (1916. p.xix) noted "*we were caught totally unprepared and the results, from a financial point of view, were deplorable.*" Consequently, by the early 20th century there was again a need for planting.
- 1919 (post WWI): Forestry Act was passed and the Forestry Commission was established, by UK Government, to promote forestry and afforestation,

producing timber and making grants available to private landowners (Forestry Commission, 2009). As a result, extensive areas of land, including heath, grassland and woodland, were planted up with softwoods, both native and non-native species, notably *Pinus* spp. *Larix* spp., *Picea* spp.

- Recent history (1940s – present day): Traditional, labour intensive, management of broadleaved woodlands (e.g. coppice/coppice-with-standards) declined (Mason, 2007). Native broadleaf species are generally favoured over non-native species. Biodiversity and nature conservation have become significant management considerations, both as a management objective as well as a constraint, e.g. Miller (2003). Another aspect of woodlands in recent times is the interaction with social and community regeneration. For example, in 1990 The Community Forest Programme was established in England, focusing on multi-purpose woodland for urban, economic and social regeneration as well as the natural environment (England's Community Forests, 2005). Such woodlands have and continue to be established around England's major cities and towns. These changes in attitude towards woodlands and their uses, subsequently reflected in policy, has seen a shift in the predominant management techniques used in large scale forest, e.g. from clear-fell, to continuous cover forestry and group felling (Mason, 2007).

  Wet woodland, including lowland *Alnus glutinosa* woodland, generally have little commercial value and receive little management. However, in the 1950s and 1960s, a strong matchstick industry lead to wet areas (potentially suitable for *Alnus glutinosa*) being planted with *Populus* spp. The industry collapsed in the 1970s and many *Populus* spp. plantations were neglected (Broad, 2003). Today, some types of wet woodland, such as *Salix* spp., are managed for their use as biofuel.

These changes in British forestry over the last 50-60 years have been recorded by national woodland censuses:

1947 – showed the impacts of extensive exploitation during the War;
1965 – indicated the early stages of afforestation;
1982 – reflected the later stages of the afforestation era;
2000 – showed the move towards multi-purpose forestry and abandonment of large-scale afforestation (Mason, 2007).

The Forestry Commission's current mission and aims also reflect this change.

> "*Protect and expand Britain's forests and woodlands and increase their value to society and the environment*" (Forestry Commission, 2011).

This mission is implemented by specific in-country (England, Scotland and Wales) objectives which reflect the particular requirements of each country's' forestry strategy. However, all (Forestry Commission 2009a, 2011a, 20011b) have objectives pertaining to the economy, community and people (including recreation) and the environment (including sustainability, diversity and climate change).

Historic changes in woodland have not necessarily occurred evenly across all woodland types. Mason *et al.* (1984) suggest that much historic loss of the woody component of riparian habitats reflects land drainage, to benefit agriculture, flood prevention requirements and more recently providing access for waterside recreational activities and river management. For example, Street (2003) puts British floodplains and their associated woodlands into their historical context:

- Pre AD 400: numerous floodplain forests;
- AD 400: only fragments remained with many being cleared;
- 1940 to 1982: 20,000 km^2 of riverside land was drained for flood defence and agriculture;
- Current day: 89% of UK rivers are now regulated and controlled; 25% of which have been canalised, straightened, degraded or cut off from the former floodplain.

Throughout history woodlands have provided products for a variety of uses and subsequently different types of woodland being managed differently to promote or optimise timber for different products. The need and use of different products has also changed which in turn influenced the way woods are managed and consequently their ecological and physically characteristic. Rackham (2003) suggests that, historically, in the majority of cases, *Alnus glutinosa* woodlands were likely to have been treated as underwood, although some may have been managed on long-rotation coppice systems for the provision of poles and small timber products. Rackham (2003) notes that, although, in post-medieval history the value of *Alnus glutinosa* was low (when compared to other timber species), the high yields offset this shortfall and it may have been planted and managed by coppicing to produce charcoal for the gunpowder industry. In the Middle Ages, he suggests that *Alnus glutinosa* may have been used as softwood conifers are used today (e.g. temporary carpentry and furniture, crossbows as a result of its lightness, straightness and ease of sawing), as well as for underwater piles as the wood does not rot readily under water.

2.2.2 Natural change and nature conservation value of wet woodlands

This series of events through history, described in Section 2.2.1, indicate that while woodland has been considered an important resource its use and value has changed: in general terms from primarily being used as a resource commodity (timber, food, hunting) to, in relatively recent decades, one of conservation and recreation. Such changes in use and value would also cause changes in the woodland distribution and ecosystem. However, certainly following the last Ice Age, changes were also a result of more natural causes, e.g. climate change. Even before significant human influences, Brown (1988) suggests that the ecological history of floodplains, and therefore wet woodland, differs from those on dry-land and hydroseres and that in the postglacial period formed an important ecotone. For example, more specifically pertaining to *Alnus glutinosa*, pollen records indicate that *Alnus glutinosa* began to colonise Britain about 8000 BC, following the last Ice Age. However, it is likely that the species only became widespread and abundant, forming a significant component to the woodlands, between 8000 and 4000 BC when the climate became warm and wet (Peterken and Hughes, 1995; Brown, 1988; Tansley, 1965). Brown (1988 p.435) found that between 1300 and 600 BC there was a "*dramatic hydrological change*" and speculates that this can be attributed to large, sediment laden floods rather than a general rise in water table. Using data primarily from the West Midlands (UK), Brown (1988) suggests that the dominance of *Alnus glutinosa* in floodplains resulted in a change in edaphic conditions, e.g. soil stability, pedogenesis and decreasing free drainage, that gave the species competitive advantage over its predecessors and noted the following changes through history:

- Late glacial: open/treeless followed by pioneer *Betula* spp.
- Boreal: *Betula* spp. are replaced by *Salix* spp. before *Alnus glutinosa* became the dominant tree species.
- Mid-Postglacial period: *Alnus glutinosa* was the dominant taxon and "*formed an invasible stable floodplain corridor community*" (p.433).
- Late postglacial: *Alnus glutinosa* declines and *Salix* spp. increase as a result of deforestation and utilisation of the floodplains.
- Bronze Age: Floodplains were managed; early clearance in 4000 – 750 BC onwards: drier areas and later clearance/coppice in wetter areas.

- 1100 – 500 BC: *Alnus glutinosa* declines.
- Post 1100 BC: Second decline of *Alnus glutinosa*, followed by a subsequent rise.
- Medieval Times (500 – 1500 AD): Arable (generally on drier slopes/terraces), pasture and meadow cultivation.

Brown (1988) attributes the declines in *Alnus glutinosa* post 1500 BC to deforestation and management with subsequent rises due to abandonment of management. In addition, during these declines pollen analysis showed an increase in *Salix* spp., which were commonly planted along watercourses and ditches, and were important in industry (Brown, 1988), including basketry, fencing and hurdles.

Although woodland has a number of valuable aspects, this current research is going to concentrate on the nature conservation aspects of woodland. On reviewing management of forest biodiversity, Lindenmayer *et al.* (2006) reported that The World Commission on Forest and Sustainable Development (1999) stated that *c.* 65% of the world's terrestrial taxa is associated with forests and, that forests support the highest species diversity of several taxonomic groups ranging from microbes to birds.

In terms of nature conservation, within the UK, the current importance and value of woodlands is reflected in their inclusion in the UK Biodiversity Action Plan (BAP) (UK National BAP, 2008). The Countryside Survey (NERC, 2008) reports that there are 1,406,000 ha of broadleaved, mixed and yew woodlands in Great Britain (excluding Northern Ireland), as described by the corresponding Broad Habitat type in the UK BAP (BRIG, 2008). Within this Broad Habitat type are several Priority Habitats, one of which is Wet Woodland, which contributes 5% of the total. Priority Habitats are those that are considered to require priority conservation action to safeguard UK biodiversity; Broad Habitat types provide context for Priority Habitats within the landscape.

Although the UK Habitat Action Plan (HAP) for Wet Woodland acknowledges that there is not a precise figure for the extent of wet woodland in the UK, the Countryside Survey (NERC, 2008) reported there to be approximately 75,000 ha as defined by the UK Priority HAP. Table 2.3 puts the extent of wet woodland within Great Britain in context with other UK BAP Priority and Broad woodland habitats.

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Table 2.3 Extent of UK BAP Priority and Broad woodland habitat types (NERC, 2008)

In support of the BAP recognising the importance of the nature conservation value of wet woodland, Peterken (2003) described floodplain habitats as a mosaic of woodland, open water and marshland and being the closest that the temperature zone has to tropical forests; i.e. highly productive with distinctive characteristics such as emergent trees, buttress roots and high density lianas. Street (2003) suggests that the dynamic nature of floodplain habitats, as a result of flood events, makes floodplain forest ecosystems some of the richest in Western Europe with high ecological diversity.

Wet woodlands, including *Alnus glutinosa* dominated, are therefore now considered of great value for their nature conservation rather than their products.

2.2.3 Woodlands in policy

A change in emphasis of the value and importance of woodlands (from resources to wildlife, recreation and ecosystem services) is borne out by UK Policy, which is drawn up by the UK Government with advice from, among others, the Forestry Commission and Natural England (formerly English Nature).

The 1985 Broadleaf Policy was a significant turning point in woodland management in the UK;

> "*application of this policy dramatically reduced loss and damage to ancient woodlands. The Forestry Commission, which over many previous decades had converted the majority of its ancient woods to conifer and beech plantations, slowly began to consider their restoration back to native broadleaves*"
> (Spencer, 2002. p.3).

The Convention on Biological Diversity (CBD), which was held at the Earth Summit in Rio de Janeiro in 1992, was another influential turning point for woodlands with emphasis on biodiversity. In brief, in signing the CBD, the UK Government agreed:

> "*The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding*" (United Nations, 1993, p.146).

The CBD was adopted in 1993 and called for the signatory governments to enforce procedures (e.g. strategies and action plans) that would conserve, protect and enhance biodiversity and, in 1994, the UK BAP was subsequently published. The UK BAP is implemented through local (county) BAPs; both BAPs are material considerations in a number of UK policies, e.g. Planning Policy Statement 9 (ODMP, 2005), Natural Environment and Rural Communities Act (HMSO, 2006), Countryside Rights of Way Act (HMSO, 2000) and Local Development Frameworks. In addition to being guided by policy, the UK BAP also informs local and national policy.

The primary aim of the UK BAP is:

> "*To conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all appropriate mechanisms*" (HMSO, 1994, p.15).

Table 2.4 summarises the targets set specifically for wet woodland and their status as reported in 2008. Following the 2007 revision and update of the UK HAPs, the woodland Action Plan targets, including Wet Woodlands, were combined in acknowledgement of the complex and successional continuum between all woodland types. Table 2.5 summarises the current objectives for the combined woodland within the UK.

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Table 2.4 Wet woodland targets as of 2008 UK BAP review (BARS, 2009)

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Table 2.5 Overview of quantitative woodland targets set for 2015 (From BRIG, 2006)

In September 2010, The Lawton Review, was submitted to the Secretary of State, Department for Environment, Food and Rural Affairs. Although, itself not policy, this review had much influence on the subsequent Nature Environment White Paper (HM Government, 2011), through consolidating knowledge and reviewing the current state of England's wildlife sites and ecological networks. A series of recommendations are made that stem from the "*need to embrace a new, restorative approach which rebuilds nature and creates a more resilient natural environment for the benefit of wildlife and ourselves*" (Lawton *et al.*, 2010. p.v).

Although the first Ministerial Conference on the Protection of European Forests (MCPEF) (Strasbourg, 1990) took place prior to the CBD, it was the second conference (Helsinki, 1993) that acknowledged, through the conference declaration and resolutions, "*that the conservation and appropriate enhancement of biological diversity is an essential element of sustainable management of all kinds of forests and forest ecosystems*" (MCPEF, 1993. p.2).

The first MCPEF concentrated on the "*technical and scientific co-operation in order to provide the necessary data for common measures concerning European forests"* (MCPEF liaison unit, 2009a. p.1). This, and subsequent conferences (totalling five to date), defined and continuously developed, the concept of sustainable forest management at the pan-European scale. The commitments provide a framework with three main themes (Ecology, Economy and Social-culture) for "*implementing sustainable forest management in the European countries*" (MCPEF liaison unit, 2009. p.1). The second resolution (H2 General Guidelines for the Conservation of the Biodiversity), identified at the second conference, is of significance to this current research project and the four general guidelines of this resolution were as follows:

1. *The conservation and appropriate enhancement of biodiversity should be an essential operational element in sustainable forest management and should be adequately addressed, together with other objectives set for forests, in forestry policies and legislation.*
2. *The conservation and appropriate enhancement of biodiversity in forests should be based both on specific, practical, cost-effective and efficient biodiversity appraisal systems, and on methods for evaluating the impact on biodiversity of chosen forest development and management techniques.*
3. *Where possible the size and degree of utilisation of forest compartments and other basic management units should take account of the scale of variation of the site, in order to better conserve and manage the diversity of habitats. Management should aim at increasing the diversity of forest habitats.*

4. *Where possible, the establishment of taxa which are naturally associated with those that occur most frequently in the forest should be encouraged, and a variety of structure within stands should be favoured where the natural dynamics of such associations permit.* (MCPEF, 1993a. p.2)

At the third MCPEF (held in Lisbon, 1998) the conference signatories declared their continued commitment to the conservation of biological diversity. Pan-European Criterion 4 (Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems) is of relevance to the current research and comprises seven quantitative indicators under the following headings (MCPEF, 1998):

1. Representative, rare and vulnerable forest ecosystems
2. Threatened species
3. Biological diversity in production forests.

In response to Resolution H2 made at the preceding MCPEF in Helsinki, six pan-European criteria for sustainable forest management were identified in relation to maintaining, and where appropriate, enhancement, of forest (MCPEF, 1998a):

1. resources and their contribution to global carbon cycles;
2 ecosystem health and vitality;
3. productive functions (wood and nonwood);
4. ecosystem biodiversity;
5. protective functions (notably soil and water);
6. other socio-economic functions and conditions.

The fourth (Vienna, 2003) and fifth (Warsaw, 2007) MCPEF continued to endorse the Resolutions made at previous conferences and to support, promote and contribute to global actions and initiatives (e.g. CBD and Kyoto Protocol). However, the emphasis of these conferences was generally on other aspects of forest protection, e.g. economy and social-culture.

As a result of the UK Government signing the CBD agreement in 1992 and subsequent conferences, in addition to the development of the BAPs, Sustainable Forestry – the UK Programme (HMSO 1994a) was published. As well as consolidating existing policies pertaining to forestry, biodiversity and conservation, the report identified new targets. The UK Forestry Standard was subsequently published by the Forestry Commission in 1998 (updated in 2004), and details the UK Government policies for sustainable forest management.

This change in attitude and policy towards the value of woodlands in general can be seen in the evolution of the UK Forestry Commission (FC) since its establishment in 1919. At its conception, one of the main tasks for the FC was to replenish the timber supplies of Britain following significant depletion during WWI. Now, 90 years on, the FC is a multi-disciplinary agency that balances timber production with recreation and, most significantly, nature conservation. Although wet woodlands are generally still neglected and rarely managed, their importance has begun to be realised and there are several initiatives that promote this habitat, e.g. The Bedfordshire Wet Woodland project.

2.3 Diversity of Woodland

The diversity of woodlands can be described using a number of different approaches. Rackham (2003. p.65) suggests that "*we must suppose that the complexity of vegetation is determined mainly by soil variation*", although acknowledges "*it would take much research to show detail that this was so.*" However, variation in plant species composition is influenced by both abiotic and biotic factors as well as interactions between and within them. Abiotic factors can have a clear influence on biotic factors, for example a steep gorge may exclude grazing animals from a site. Biotic factors, although less obvious, may also influence the abiotic factors at a site, for example, coniferous leaf litter has an acidifying effect on the soils (e.g. Ferris and Simmons, 2000). From a literature review, Peterken and Hughes (1995) noted that different species have different effects on the soil and water chemistry, for example, *Alnus glutinosa* fixes nitrogen providing a nitrogen source in low nitrogen areas. Another example they provide is the nutrient filtering effect of a narrow (10 m) strip of *Alnus* spp. and *Salix* spp. between a field and a stream; these species can absorb most phosphorous and about 50% nitrogen, lead and calcium before it enters the stream. Equally fauna using woodland can have influences on the soil characteristics; for example Tansley (1965) noted that in an *Alnus glutinosa* woodland in Norfolk, *Urtica dioica* was particularly abundant and had luxuriant growth below a heronry as a result of the high influx of nitrogen.

Abiotic factors are significant in determining whether a species arriving at a given site is successful in maintaining a viable population. Firbank *et al.* (2000) found that fertility followed by light and then wetness were the three main environmental gradients for British vegetation. Equally, Rodwell (1991) reported that, in *Salix cinerea-Galium palustre* woodlands (W1), the variation in the groundflora commonly reflects gaps in the canopy (i.e. differences in light penetration), wetter and drier soils resulting from undulations in the ground level and whether livestock have access to the woodland.

Both abiotic and biotic factors will have influences, positively and negatively, on the long-term success of a species and its contribution to the flora of a site and the intra-site variations. Rackham (2003) noted that the majority of native trees can grow on any soil or in any climatic condition provided that conditions were suitable during seedling establishment and that the species has a competitive advantage. Management will also have significant implications with regards to competition. In addition to physical factors, Peterken (1993) included time as a factor influencing the variation within woodlands. Time is inherently related in that it provides a setting for which the effects can occur and a basis against which they can be measured.

Woodlands are complex habitats in terms of species composition, spatial and temporal extent and structural diversity. Peterken (1993) notes that as the canopy layer and groundflora may respond differently to the same environmental conditions; it cannot be assumed that the two are always strongly correlated. Indeed, he stated (p.10) that groundflora communities "*generally respond as communities to microtopographical features to which tree and shrub species can only respond as individuals.*" Additionally as a result of the strong historic association between man and woodland (notably the canopy composition) for the provision of a wide range of resources, any natural correlation between the canopy and groundflora will be weakened if one factor changes, e.g. the planting of monocultural plantations of species from other parts of the world.

In reality the floristic composition of a habitat is influenced by a number of factors, both biotic and abiotic, and usually in combination. For example, Tansley (1965) noted that in damp *Quercus robur* woodlands, where wetter soils coincided with high light levels, *Deschampsia cespitosa* was co-dominant while, where soils were both damp and fertile, *Urtica dioica* can dominate to the exclusion of other species.

Factors influencing floristic composition can have limiting effects on both habitats and species, although there may also be positive effects, e.g. plant facilitation. For example, Levine (2000. p.3431) stated "*ecologists are increasingly finding that complex combinations of competitive and facilitative interactions influence the distribution and abundance of plants*". Xiong *et al.* (2003) considered the interaction of ground-water availability, vegetation canopy, leaf litter and seed availability in relation to species richness of wet grasslands and showed that some variables, when the effects were studied in isolation, had no effect on species but did when they interacted with other variables. For example, canopy cover and elevation alone showed no effect, but when elevation was studied in conjunction with leaf litter at high elevation, seed emergence was favoured while at lower elevations seed emergence was limited. Xiong *et al.* (2003) referred to several studies when concluding that in frequently flooded areas (i.e. low elevation) species richness was controlled by abiotic factors, while at higher elevation and less frequently flooded areas, species interactions were more important.

Competition in plants is known to affect the structure of a community and it is acknowledged that there are a number of theories pertaining to competition, floristic composition and environmental conditions (e.g. Grime, 2001; Tilman, 1982). Competition in its simplest form can be described as one species or individual (Specimen A) occupying the space and/or resources that could be utilised by another species/individual (Specimen B) but because of the presence of Specimen A, Specimen B cannot occur. Competition can take different forms, e.g. direct competition where species/individuals are competing for the same resource, or indirect competition where one species/individual may influence another.

The following sections review a number of approaches that have tried to explain diversity and variation in natural habitats.

2.3.1 Describing characteristics of habitats

The characteristics of habitats in relation to their floristic composition can be described in a variety of ways based on how different species of plant respond in different situations and by their optimal growing conditions. Examples include environmental conditions (e.g. light, soils), responses to stress/disturbance and plant traits (e.g. morphological adaptations).

<u>Ellenberg indicator values</u>

Ellenberg (1991) grouped over 2000 plants along gradients according to their optimal environmental conditions and from this devised seven scales:

1. light (L);
2. soil moisture (F);

3. soil acidity (R);
4. fertility (N);
5. salt tolerance (S);
6. temperature (T);
7. continentality (K).

Salt tolerance is insignificant for the majority of woodland habitats, particularly wet woodlands, and as such is not considered further in this thesis. Similarly, it has been shown that temperature and continentality are of low relevance to British habitats, for example Hill *et al.* (2004 p.14) noted that:

> "*Neither T nor K values are satisfactory in an oceanic climate such as that of Britain; those for K are particularly unreliable, especially as Ellenberg's definition was geographic rather than climatic*".

The values on each scale point to the ideal growth conditions associated with each species. However, species may show a range of associated conditions in different circumstances; the values provide an average, or indication, of the more typical environmental associations. Therefore, since the values are indicators and not precise characteristics, the soil acidity values, while reflecting the pH scale, do not correspond directly to this scale. Fertility is represented by the nitrogen preferences of the species as there is a general correlation between soil fertility and nitrogen. Schaffers and Sýkora (2000) suggest that Ellenberg's R and N values are better correlated with other parameters, such as calcium content and vegetative biomass respectively, than soil acidity and fertility. Hill *et al.* (2004) recalibrated Ellenberg's original values (light and soil) for British conditions. Their results are summarised in Table 2.6, which provides an explanation for each numerical value for light (L), soil moisture (F), acidity (R) and fertility (N).

Table 2.6 Ellenberg indicator value descriptions (from Hill *et al.* 2004)

Stress and disturbance

A habitat can be described by the survival traits of the component species, for example stress and disturbance. Competition is a significant factor influencing the floristic composition and structure of a habitat. There are two main theories that consider this element of communities: CSR model (Grime, 2001) and Resource Competition (Tilman, 1982). While Grime, principally described how floristic composition relates to competition through disturbance and stress, Tilman described it through resources, including space, following a study on freshwater algae. Tilman considered the trade-offs for nutrients with the different thresholds of requirements by different species which subsequently influences the species present and their distributions. He equates space to nutrients which is created by disturbance and therefore linking competition with disturbance and subsequently suggested that "*moderate levels of supply of disturbances facilitate the highest diversity*" (Pimm, 1983. p.1045).

Grime (2001) described the limitations to plant growth by stress (factors which restrict growth) and disturbance (factors that destroy growth). In the absence of both stress and disturbance, species occurrence and vegetation composition is determined by competition between species. These limiting conditions can occur in any number of proportions and plants have evolved to survive at different points along this three-way interaction. Grime illustrates this phenomenon in the form of a triangle, (Figure 2.4) where Competition (C), Stress (S) and Disturbance (R) form the vertices of the triangle.

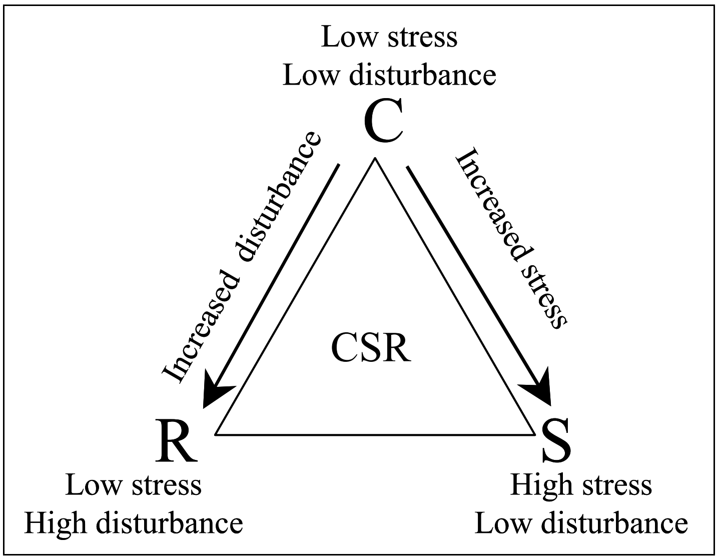

Fig. 2.4 CSR Triangle (based on Hunt, 2007)
(where C – Competitors, R – Ruderals, S – Stress tolerators)

Although there are an infinite number of strategies, there are three main strategies (C, S and R) with four key intermediates (SC, SR, CR and CSR). In addition a further 12 are readily recognised (C/CR, C/CSR, C/CS, CR/CSR, CR/R, CS/CSR, CS/S, R/CSR, R/RS, RS/CSR, S/RS, S/CSR). These strategies can be applied at species or plant community level; Table 2.7 provides a summary of the interpretation of the main strategies in terms of species and community character.

CSR category	Species character	Community character	Example habitat
C	Actively seek out resources. Slow reproduction. Constant new growth/replacement of individual parts. Dominate communities through suppressing growth of other plants. Adapted to low stress, low disturbance.	Vigorous growing, tall plants. High productive environment with low disturbance where there is constant/predictable resources (i.e. water, light & nutrients).	Tall grassland/herb Woodlands
SC	Adapted to conditions of low disturbance and moderate stress.	Communities typically comprise herbaceous and woody species. Undisturbed and unproductive habitat.	Heath/bog
S	Able to capture and retain resources when they become available. Can persist where conditions are too harsh for other species. Adapted to low disturbance, high stress.	High proportion of stress-tolerators, e.g. those that can withstand continued low productivity imposed by light, moisture or nutrients.	Moorland grass/mosaic & heath/bog
SR	Adapted to moderate disturbance, unproductive conditions.	Occur in habitats that experience moderate intensity of stress and disturbance where stress occurs during the growing season and unpredictable. Community comprises small herbs (annuals/short-lived perennials) and bryophytes.	Habitats of shallow or sandy soils prone to desiccation during summer
R	Able to rapidly capture and utilise resources. Establish, reproduce and disperse on disturbed ground before competitors establish and dominate. Adapted to low stress, high disturbance.	Adapted to colonisation of bare ground. Species colonise areas rapidly and have short life spans. High productivity and disturbed habitat.	Crops/weeds Strandlines
CR	Adapted to conditions of low stress and moderate competition as a result of disturbance.	High productivity, moderately disturbed habitat. Disturbance may be severe but infrequent or less severe but more frequent. Communities include annual, biennial and/or ruderal perennial herbs.	Grasslands which are ploughed & reseeded every few years Seasonally grazed grasslands Habitats affected by seasonal flooding
CSR	Generalists – adapted to conditions of moderate stress and disturbance.	Communities may comprise a number of species with contrasting strategies.	Infertile grassland Moorland grass/mosaic

Table 2.7 Main CSR categories in relation to species and community characteristics (produced from data in Firbank *et al.*, 2000; Grime, 2001; Grime *et al.*, 2007; Hunt *et al.*, 2004; Bunce *et al.*, 1999a).

As suggested in Table 2.7, if a community or site has a high proportion of R-species, it suggests that there is much disturbance, such as mowing, grazing, trampling, drought or erosion, as the species have evolved strategies to tolerate frequent disturbance. If the community or site has a high proportion of S-species, it suggests that the site or community is subjected to a high level of stress, such as lack of water, light or nutrients, so that the majority of species are those that have evolved to tolerate such conditions. Furthermore, changes in the relative proportion of species associated with each CSR-strategy can provide an indication of temporal change within a site or community. Firbank *et al.* (2000. p.60) provides some examples:

> *"Shifts towards competitors from ruderals can indicate natural succession (perhaps a sign of reduced management or disease), while shifts to competitors from stress-tolerators implies that the stressing factor is being relieved (perhaps water or nutrients are becoming more available)."*

As previously inferred, communities have different characteristics reflecting environmental conditions and subsequently species composition. Grime *et al.* (2007) reported that a plant community would comprise dominants, subordinates and transient species. Dominants "*monopolise resource capture, occupy high proportion of above- and below-ground environment, and exercise controlling effects on the abundances and niche-dimensions available to subordinate species"* (Grime, 2001. p.205-206). Dominants and subordinates are the consistent components of a community while transient species are unlikely to regenerate and therefore do not persist in a given community. However, transient species have the potential to become dominants if conditions were to change, for example, through management. These three components of a community may consist of species with different CSR-strategies, e.g. see Table 2.8, therefore although a single or few strategies may dominate a community, species representing several different strategies will be present and co-exist.

Primary species group	Secondary species group	Group characteristics
Dominants	C-strategists	Dominate only in highly productive, undisturbed environments
	CR-strategists	Dominate in productive environments if subjected to a major single, annual disturbance event such as flooding or ploughing
	CS-strategists	Dominate in moderately productive but undisturbed environments
Subordinates	R-, S- and SR-strategists	Will occur where there is extreme stress and/or disturbance where dominates will not survive
	R/CR- S/CS-, SR/CSR-strategists	Will co-exist with dominates avoiding, notably through physiological adaption, or tolerating the impacts/stresses created by the dominant species
Transients	Any depending on circumstances	Originate from either adjacent habitats or within the seed-bank from a preceding community. Are likely to be less adapted to the current conditions and as such are less likely to form a significant component to the community in terms of abundance; they may not even reach maturity. May be dominant in adjacent community.

Table 2.8 Components of plant communities in terms of the CSR-model (based on Grime *et al.*, 2007 and Grime, 2001)

From a variety of case studies utilising the CSR-model, Grime *et al.* (2007) concluded that in order to maintain diversity, it is necessary to restrict a particular group, notably the dominants, from becoming the principle component of a community. In support of Grime, the effects of strong dominance and extreme disturbance were considered by Wulf (2003) and Graae and Heskgær (1997) respectively. Wulf (2003) suggested that competitive and vigorous species may hinder the immigration of other species, and Graae and Heskgær (1997) found that high disturbance resulted in reduced species diversity, with greatest diversity occurring where there was intermediate disturbance. The relative proportion of particular components of a woodland vegetation community can also be influenced by management.

From these observations the following could be expected:

- unproductive environments would have a relatively low proportion of C-strategists in relation to S-strategists;
- highly productive environments would have a relatively high proportion of C-strategists in relation to S-strategists;
- highly disturbed environments would have a low proportion of C-strategists in relation to R-strategists;
- diverse environments would show a range of strategists with no particular group being overwhelming dominant; such diversity may be reflected in intra-site variation.

Wulf (2003) noted that, although plant species diversity generally increases with disturbance whilst frequency and abundance decline, some woodland species have adapted to such disturbance.

Comparative Plant Ecology

From work undertaken in the Sheffield region, UK, Grime *et al.* (2007) gathered and determined an array of data pertaining to individual species, e.g. a species association with the degree of bare ground, affinities to wetland habitats, soil pH, altitude, slope, aspect, common associates and habitats. The two of most relevance to wet woodlands are bare ground (Table 2.9) and hydrology (Table 2.10).

While the extent of bare ground reflects the degree of disturbance from a variety of causes, such as grazing, floods, drought, agricultural and industrial processes and recreation, it "*provides a useful index of vulnerability to, or dependence upon, habitat disturbance…*[but] *not a direct measure of overall intensity of disturbance*" (Grime *et al.*, 2007. p.58).

Class	% of bare soil	Notes
A	0% bare soil	No soil exposed for colonisation, includes: 1) skeletal habitats such as bare rock, spoil where there is minimal available soils (e.g. rubble/demolition sites) 2) ground covered by lower plants 3) ground covered by plants (e.g. *Pteridium aquilinum*)but the canopy is so dense that the soil below is not physically exposed for further colonisation
B	1-10% bare soil	-
C	11-25% bare soil	-
D	26-50% bare soil	-
E	51-75% bare soil	-
F	76-100% bare soil	Much exposed soil for colonisation, includes: 1) recently ploughed/dug or disturbed earth 2) rapidly decomposing leaf litter such as found below some woodland canopies

Table 2.9 Bare soil classes and descriptions (adapted from Grime *et al.* 2007)

Class	Hydrological conditions	Description
-	Absent from wetlands	'Dry land specialists', often deep rooted
A	$>5^{o}$ slope. No standing water	Plants typical of mire habitats but not exclusive to wetland habitats
B	$\leq 5^{o}$ slope. No standing water	
C	$\leq 5^{o}$ slope: No standing water but marginal to open water	Likely to experience wetter and drier periods such as wet in winter and drier in summer
D	Flat. <100 mm water depth above surface	Plants capable of exploiting shallow water during the growing season
E	Flat. 101-250 mm water depth above surface	
F	Flat. >250 mm water depth above surface	Hydrophytes

Table 2.10 Hydrological classes and descriptions (adapted from Grime *et al.* 2007)

Ecoflora

The Ecological Flora of the British Isles (Fitter and Peat, 1994) is a database of 2200 species and over 130 plant attributes. Data have been collated from a wide range of sources and as such is not consistent across all species. Attributes include those pertaining to hydrology, drought, soils, temperature, morphological and physiological characters.

Attributes likely to be of relevance to wet woodlands include those concerning hydrology and drought. Table 2.11 details the primary and secondary hydrological attributes and response to drought. How a plant responds to drought conditions provides an indication of the hydrological conditions within a site.

Aston University

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Table 2.11 Hydrological attributes from the Ecological Flora for the British Isles (Fitter & Peat, 1994)

2.3.2 Classification

Ecologists have sought to classify habitats to understand and interpret the diversity of nature. Classifying habitats according to, for example, the component species, history or structure, is an alternative way of describing a habitat than those detailed in the previous section. This section reviews, with emphasis on British lowland *Alnus glutinosa* woodland, some of the more influential classification systems that have been used to describe UK woodland over the last 100 years. As Rackham (2003) points out, woodland classification can be based on a number of characteristics including:

- historical, e.g. ancient or secondary;
- structural, e.g. high forest, coppice;
- biological, e.g. species composition.

Classification systems may also use different factors as the main defining component including:

- based solely on plants, e.g. the NVC (Rodwell, 1991);
- landscape and plants, e.g. Stand types (Peterken, 1993);
- climatic conditions and composition, e.g. Tansley (1965);
- statistical analysis, e.g. Countryside Vegetation System (Firbank *et al.,* 2000).

Braun-Blanquet (1932) was influential to the classification of plant communities detailing a mechanism by which different communities should be determined and named. He noted that "*Every natural aggregation of plants is the product of definite conditions, present and past, and can exist only when these conditions are fulfilled*" (p.vii). Differences in vegetation classifications and descriptions are often reflective of the purpose of the study. There is also a distinct difference between the British and continental approaches; the former usually utilise the presence of dominant species and soil types, while the latter take a more floristic approach (the combinations and associations of species in relation to their ecological preferences) (Rackham, 2003). Rackham indicates that in general these different approaches may be reflective of the fact that British woodlands, compared to European woodlands, are inherently more complex on subtle scales, as a result of the complexities in the soils in relation to the underlying geology and topography. He points out that in continental Europe changes in soils, slope and climate are more abrupt than in Britain and the canopy and groundflora of the former are more intrinsically linked and change at confluences of environmental factors. By contrast in Britain there is a more subtle, and not necessarily in parallel, gradation of environmental conditions which do not necessarily affect all layers simultaneously.

Tansley

Tansley (1965) used a hierarchical system, based on climate and dominant species, to describe the vegetation of Britain. Table 2.12 provides an overview of the hierarchy, using *Alnus glutinosa* woodlands as an example.

Unit	Description	*Alnus glutinosa* woodland example
Formation-type[1]	Described and differentiated by the dominant life form (vegetational difference)	Summer deciduous forest
Formation (climatic, edaphic or biotic)[1]	Divisible of formation-type by geographical (climatic), edaphic or biotic factors	European summer deciduous forest – summer deciduous forests located in Europe
Association	Described and differentiated by the dominant species (floristic difference) and relates to different ecological requirements of the dominant species	*Quercus* –*Fagus* forest – European summer deciduous forests dominated by *Quercus* sp. and *Fagus* sp.
Consociation	The community formed "*where a single species dominates a portion of an association*" (p.230)	*Quercus* – part of a *Quercus* –*Fagus* forest dominated by *Quercus* sp.
Society	A constituent of an association or consociation, i.e. a subordinate community, dominated by species which are not dominant in the main community. In complex associations, such as woodland, there may be: a) *Layer societies* - localised concentration of particular species in the shrub or field layer b) *Aspect societies* – the "*dominants vegetate actively during a part only of the growing season*" (p.230)	Society: *Alnus glutinosa*– part of a *Quercus* forest where the ground is wetter Layer society: *Corylus avellana* Aspect society: *Anemone nemorosa* and *Ranunculus ficaria* in spring
Clan	"*small aggregations of subordinate species, brought about by locally active social vegetative growth or gregarious establishment of seedlings*" (p.231)	*Urtica dioica*
Notes **1.** Formation: "*A plant formation is a unit of vegetation* formed *by habitats and* expressed *by distinctive life forms*" (p.229) and is composed of Associations		

Table 2.12 Tansley's vegetation classification hierarchy (based on text in Tansley, 1965)

Although based on the dominance of canopy species, Tansley (1965) acknowledges the complexities and layers that occur in woodland habitats. Since this classification is based on canopy species it is highly sensitive to management history, e.g. species planted or those favoured through felling. A mixed woodland which is subsequently harvested for only one of the dominant species will almost instantly change to a different woodland type. In addition, its long-term classification would be altered (and potentially that of nearby woodland) on account of the loss of parent seed source (Tansley, 1965).

<u>Merlewood National Classification of British Woodlands</u>

In 1969 an extensive survey of British woodlands was initiated to capture a variety of data to enable the complexities pertaining to the trees and groundflora of British woodlands to be classified (Bunce, 1982). The resultant classification took account of tree species and groundflora; Bunce considered the latter to be more ecologically meaningful. To determine the different woodland types, a numerical indicator species analysis approach was taken, where all species are treated equally and which does not assume the presence of dominant species or a homogenous nature to the stand (Bunce, 1982). Bunce (p.4) makes the following comments with regards to this classification compared to other forms of classification:

> "*It is based on a survey using a standardised sampling system, with randomly placed plots, covering a wide range of British Woodlands. The classification is minimally dependant on subjective judgements. The classification depends, at one and the same time, on the arrays of i) trees and ii) other plant species (understorey species and ground vegetation).*"

The following data were collected in 200 m^2 plots for this system:

- species list of all species with percentage cover (in 5% categories);
- tree diameter at breast height (DBH) (provides an indication of age);
- a variety of habitat attributes (tree management, regeneration, deadwood, epiphytes and lianes; habitats – rock, aquatic, open, human, vegetation; evidence of animals).

This classification recognises 32 woodland plot types across Britain, of which six contain *Alnus glutinosa* as a significant component.

Peterken Stand Type Classification

In the 1970s Peterken (1993) devised a classification system for semi-natural woodlands based on their tree and shrub components, while taking the site's management history, geographic location and soils into consideration. The Peterken Stand Type Classification built upon previous classifications, such as Tansley, and resulted in 39 Stand Types with an additional 38 Sub-types. Stands with similar species characteristics are grouped into 12 Stand Groups depending on the presence or absence of 13 defining woody species. The Stand Groups are sub-divided into Stand Types and Sub-types according to associated species, soils, geology and, on occasion, topography. Topography is used to classify the *Alnus glutinosa* Stand Types because the main species has a universal preference for wet conditions.

Of the 39 Stand Types, five have *Alnus glutinosa* as a diagnostic feature; within these five Stand Types there are seven Sub-types.

National Vegetation Classification (NVC)

In the 1990s the National Vegetation Classification (NVC) (Rodwell, 1991 *et seq.*) was published and is currently the popular classification system for British vegetation; Latham (2003. p.18) stated that "*the NVC is now the standard classification used in woodland conservation management*" and forms the basis for SSSI selection and is "*widely used for general site descriptions and as a basis for management plans*". The NVC is a "*systematic and comprehensive classification of British plant communities*" (Rodwell, 1991. p.4) according to vegetation type, and provides a descriptive account of the vegetation types with an ecological interpretation of factors causing variation within them, e.g. succession and management. Each vegetation type is described by a series of communities which, where appropriate, are further defined by sub-communities. Two hundred and eighty six communities are recognised in this classification of which 19 are woodland.

Although the communities and sub-communities are defined by the abundance and frequency of the species which occur, there is a clear relationship with abiotic factors. For example, within the mixed deciduous, *Quercus* spp.-*Betula* spp., *Fagus sylvatica* and *Taxus baccata* woodlands, variation in soils accounted for the most variation among the floristic composition of the woodlands. The second level of variation was described by climatic conditions, notably a south-east – north-west divide across Britain. The variation between the wet woodland communities is primarily described by the "*interactions* *between the amount of soil moisture, the degree of base-richness of the soils and waters and the trophic state of the system*" (Rodwell, 1991. p.30).

To devise the classification system, data were collected from a variety of sources and the vegetation across Britain was unsubjectively sampled. The data were transposed into similar formats with species cover being recorded using the DOMIN scale (*sensu* Dahl & Hadač, 1941) to allow thorough multivariate classification to sort the samples on the basis of their similarity. Only the quantitative floristic data were used in the analysis with environmental data being used as part of the ecological interpretation.

Of the 19 woodland communities, *Alnus glutinosa* forms a significant component in three.

Ecological Site Classification (ESC)

The Ecological Site Classification (ESC) uses climate and soil quality (moisture and nutrient regimes) to describe forest sites and guide management (Wilson, 2003). Climate is determined by site location. The soil quality is determined by soil type (to assess wetness) and percentage cover of plant indicator species (to predict soil fertility) (Forestry Commission, 2001). This system compliments the NVC in focusing on plantation woodlands where there is often a paucity of groundflora which can make classification using the NVC problematic. The ESC was also developed to be simpler than the NVC in determining communities within plantation situations and initially identified 10 '*visually dominant vegetation types*' of plantation woodlands (Wilson, 2003):

- Type A: characterised by *Calluna vulgaris, Erica* spp.
- Type B: characterised by *Molinia caerulea*
- Type C: characterised by *Deschampsia flexuosa*
- Type D: characterised by *Pteridium aquilinum*
- Type E: characterised by *Rubus fruticosus* and *Pteridium aquilinum*
- Type F: characterised by *Rubus* spp./*Dryopteris* spp./*Oxalis acetosella*
- Type G: characterised by *Agrostis* spp./*Holcus* spp.
- Type H: characterised by species-rich vegetation
- Type I: characterised by *Mercurialis perennis*
- Type J: characterised by *Urtica dioica*.

Although an abundance-weighted mean of species Ellenberg values was used to determine the soil nutrient status of plantation woodland, Wilson (2003. p.56) found that groups of indicator species could equally be used for "*Rapid appraisal of sites, where it is not possible to carry out detailed quadrat vegetation survey*".

Rackham

Woodlands are variable and will often comprise more than one vegetation community. Rackham's (2003) classification of woodlands, taking a similar approach to that of Peterken (1993), focused on ancient woodlands and was designed to allow interpretation by non-botanists. Key features of this classification include:

- the recognition of wood-pasture being separate and distinct from woodland;
- the use of underwood, rather than the canopy trees;
- trees and groundflora being treated as separate communities as Rackham considered that the trees form part of the environment in which the groundflora could occur.

The three *Alnus glutinosa* woodlands described by Rackham (2003) are differentiated by their location in the landscape.

Countryside Vegetation System (CVS)

One of the outputs of the ECOFACT research programme (Bunce *et al.*, 1999; 1999a and Firbank *et al.*, 2000) was a new classification of the British countryside since it was considered that:

> "*analysing the vegetation of the wider countryside at the national scale would have been difficult using existing tools, as no classification can handle the full range of variation of the many highly disturbed situations. Furthermore, classifications split according to habitats and landscape elements run into the problem that similar assemblages of species, e.g. dandelions (*Taraxacum *spp.), daisies (*Bellis perennis*) and rye-grass (*Lolium perenne*), can grow in a range of situations, such as roadsides, along streamsides, or in fields…*" (Bunce *et al.*, 1999. p.4)
>
> [The] *CVS provides a statistically valid means of describing vegetation character and its distribution in the wider countryside across GB, both over broad landscape types and among the individual landscape elements within them. It also summarises the vegetation in a manner which is directly interpretable with respect to the key environmental drivers of nutrients, disturbance and water availability. CVS has the potential to assist in the interpretation."* (Bunce *et al.*, 1999a. p.28)

The CVS studies concluded that variation in British vegetation is primarily a result of, in descending order, fertility, available light and wetness (Firbank *et al*. 2000).

The CVS used multivariate analysis, TWINSPAN (Hill, 1979) and ordination, to group vegetation samples based on their similarity. The ordination grouped the vegetation samples solely by their floristic composition; environmental data were used in the interpretation of the groupings. Calibrated Ellenberg indicator values (Hill *et al*., 2004) and plant strategy theory were used in the interpretation of the groups' characteristics.

Of the 100 vegetation classes determined by the CVS, three could be considered as *Alnus glutinosa* woodland, all of which occur along stream sides.

2.4 MANAGEMENT FOR NATURE CONSERVATION

As there is limited information in the literature specifically pertaining to wet or *Alnus glutinosa* woodlands, the following discussions are based on woodlands in general but the concepts are equally applicable to the target habitat of this research. Where information specific to wet/*Alnus* woodlands is available it has been included.

Although, as discussed in Section 2.2.2, wet woodlands are likely to have been managed and marketable products obtained from them in the past, such woodlands are rarely purposely managed today. For example, Kirby and Reid (1997) suggested that most wet woodlands would benefit from minimal intervention, except where there is a recent history of coppice, in which case coppice management should be reinstated. Since wet woodlands in the UK are generally fairly small and often form part of larger woodland, they consequently receive the same management as the adjacent woodland. The FC (2003. p.13) went so far as to state that:

> "*Systematic management of wet woodland for wood production is not a realistic option, because of small tree size, poor form and difficult ground conditions.*"

Consistent with the limited information found in the literature, the results of the questionnaire (see Appendix 2) indicated the following in relation to the management of this habitat:

- the most common management practice is minimal-intervention;
- management is primarily driven by legislation and site access;
- the main management objective and 'products' obtained from wet woodland habitats are biodiversity and conservation;
- management is undertaken by hand or using 'small' machinery, such as tractors;

- one of the main constraints dictating the choice of management practice is also biodiversity and conservation.

However, *Alnus glutinosa* is a relatively short-lived tree, living to 100-120 years (McVean, 1954), and so some form of management may be necessary to retain *Alnus glutinosa* woodlands since they do not readily regenerate under their own canopy; regeneration tending to occur at the periphery of woodlands (McVean, 1954). Additionally, in some instances it may be possible to obtain marketable products; for example, Peterken and Hughes (1995) suggested that production of high quality timber (i.e. straight, clean stems with high density wood) is possible in floodplain woodlands except where the water table is at, or above, ground level in summer. The FC (2003) also noted that *Fraxinus excelsior* within *Alnus glutinosa* stands has greater potential market value than the other species, particularly if grown on fertile floodplains. Within coppice systems *Fraxinus excelsior* can be promoted as standards. The FC (2003) suggest that some of the drier *Alnus glutinosa* woodland sites (e.g. NVC W6 and W7), have potential for timber production and indicate that coppice management, at 10 – 25 year rotations depending on the purposes of management, is usually the most appropriate. They also reported that with careful management (e.g. stools cut at least 0.25 m above ground level to ensure good regrowth) harvests of 100 – 150 cu m ha^{-1} can be achieved in these woodlands where annual growth rates can be between 6-12 cu m ha^{-1}. Harmer (1995) indicated that *Alnus glutinosa* coppice is less susceptible to browsing than other species.

In the past *Alnus glutinosa* woodlands would have been able to expand and contract cyclically along river corridors, however, today this natural cycle is constricted by urbanisation and agricultural use of floodplains. Therefore, the long-term survival of natural regeneration of this habitat can be considered at risk as the main canopy component does not regenerate under its own canopy. In terms of woodland management, Mason (2007. p.42) commented that a

> "*long term perspective is essential because forests can take several decades to respond to changes in management and the habitats that they provide today are often a function of decisions made years ago.*"

Hughes *et al.* (2005. p.3) take an even bolder view and reported that vegetation types and their species diversity, no matter how described or classified, are a consequence of "*combined human activities and natural processes over millennia*". Section 2.2.2 showed how British woodlands have been shaped, by both natural processes and intervention by man, and have traditionally been managed for useful products (i.e. food and shelter by early man and then later for fuel and construction materials). It is only relatively recently (notably since the CBD in 1992) that it has been recognised that woodlands have other, less tangible (e.g. CO_2 reduction, medicinal, biodiversity buffers), assets and that environmental conditions are significant considerations in terms of management. Currently, such tangible and non-tangible assets of the natural environment, including those pertaining to social and culture heritage, are termed ecosystem services and are considered under three main headings:

1. Provision services
2. Regulating services
3. Cultural services (Stoate, 2011).

The UK National Ecosystem Assessment (2011) attempted to put a value on and assess the contribution of these services to the UK's economy and identified woodlands as having high and generally improving importance in delivering aspects to all three types of services listed above. For such services to be continued to be successfully delivered management of the woodlands will be necessary. Wikström and Eriksson (2000) reported that there have been few studies which have looked at optimising stand management subject to environmental considerations. Although Lindenmayer *et al.* (2006. p.434) primarily discussed the importance of sustaining native biota in forests they acknowledged that abiotic factors "*are also fundamental aspects of ecologically sustainable forest management.*"

As Mason (2007. p.50) noted, decisions made today will have a strong bearing on the woodland characteristics of the future. He identified five key areas that are of material consideration for future management of all woodland types, including lowland *Alnus glutinosa*:

1. climate change – conditions of today may be suitable for a particular woodland type but by the time new plantings have matured the climatic conditions may be sub-optimal for a sustainable woodland of that type. Changes in conditions may result in the expansion of the range of pests and disease and consequentially species currently planted beyond the range of such factors may be subjected to attack in future years.

2. timber production – supply has to meet and compete with changes in global prices and demand.
3. impact of stand dynamics – there is a time-lag of growth and development of woodland following decision and implementation of policy and uncertainty that the implications of such decisions will meet aims and objectives of the future.
4. future forests – there is a need for "*better understanding of the links between different forest conditions and desired values*."
5. research – "*more integrated research is needed to provide better insights into the effects of silviculture regimes on different aspects of biodiversity, as well as on the other non-market objectives of managemen.t*"

Before the development of specific management principles and implementation, there must be a clear aim as to the purpose of the management. In this research it is assumed that the overriding aim is to benefit wildlife with emphasis on floristic diversity and interest because *Alnus glutinosa* woodlands are generally of low economic productive value and are a UK Priority BAP habitat. The assumption has been made that floristically diverse habitats are also the most beneficial for the diversity of faunal groups.

Prieditis (1997) noted that changes in water level, siltation and mineralisation are the key factors which cause *Alnus glutinosa* woodlands to change in character over time; it is therefore suggested that in order to maintain the existing character of such woodland these factors should remain more or less constant. Anything, such as drainage, that results in the drying out across *Alnus glutinosa* woodland will initiate succession to a drier and different woodland type, resulting in the loss of a UK Priority BAP habitat (see Section 2.2.3). However, localised alterations or control of water conditions within a site, either increasing or decreasing wetness, can be beneficial in certain situations, e.g. restoration. Therefore when considering management of a site, implications of water movement must be taken into account and if possible any off-site management, especially upstream river works, should also consider the implications for *Alnus glutinosa* woodland in the area. Therefore management principles and strategies pertaining to soil moisture are considered to be critical to wet and, therefore, *Alnus glutinosa* woodlands, although in some instances these may not be under the control of the owner.

Although all may not be appropriate in the UK situation, Prieditis (1997) also identified the following considerations to achieve sustainable management and maintain high biodiversity of *Alnus glutinosa* forests in the Baltic Region:

- appropriate cutting techniques, such as those mimicking natural disturbance to maintain the habitat;
- extend the protected network of *Alnus glutinosa* woodlands in Latvia into the Baltic Region and further afield into the rest of Europe;
- protect woodlands of sufficient size to enable them to be self-regulating.

However, these considerations are reflective of the guiding and stand specific principles and strategies that Lindenmayer *et al.* (2006. p.433) proposed for nature conservation management for woodlands in general:

- guiding principles:
  1. "*the maintenance of connectivity;*
  2. *the maintenance of landscape heterogeneity;*
  3. *the maintenance of stand structure complexity;*
  4. *the maintenance of aquatic ecosystem integrity; and,*
  5. *the use of natural disturbance regimes to guide human disturbance regimes*."

- stand level strategies:
  1. "*the retention of key elements of stand structural complexity;*
  2. *long rotation times (coupled with structural retention at harvest);*
  3. *silvicultural systems alternative to traditional high impact ones; and,*
  4. *appropriate fire management practices and practices for the management of other kinds of disturbance.*"

Woodland can be managed in a variety of ways depending on, for example its location and use, equally there are a number of approaches to determining appropriate management. The following sections (2.5-2.7) consider factors that may influence management decisions.

2.5 Factors that Influence the Management of Wet Woodland for Nature Conservation

Section 2.4 provided an overview of general considerations when managing woodlands for nature conservation and indicated that a number of factors can influence the management decisions. This section considers these factors under the following topics:

1. History and temporal dynamics;
2. Diversity of species and structure;

3. Landscape setting and habitat continuum;
4. Operations;
5. Economics.

2.5.1 History and temporal dynamics

Woodlands are dynamic systems spatially and temporally; both of which have implications to their management, as Neale (1996. p.13) succinctly stated:

> "*…woods are dynamic – they grow and change, and more often than not require some form of management if they are to provide the full range of benefits we expect from them.*"

Referring to river system restoration, Hughes *et al.* (2005 p.3) state that

> "*all biophysical systems are on a constantly changing trajectory through time and are essentially nondeterministic. Frequently, ecological goals are set by reference to some predetermined historic or previous condition… Known relationships between biota and physical parameters can also be used as a reference for refining objectives and the methods adopted to achieve them.*"

This is also of relevance when deciding on appropriate management for a given site. Kirby (2004. p.7) succinctly concludes that while understanding how woodlands have been managed in the past helps in interpreting their current condition, "*it is not always the best guide to their future management*". Therefore, the history of a woodland (i.e. how and what caused it to develop, either naturally or by human intervention) has implications on its future management and character. Although Hughes *et al.* (2005) noted that consideration of site history is important during habitat creation decisions, it will also have implications for habitat management. Historic management may not be appropriate for the existing or future wildlife value of the site. An example where re-introducing historic management operations may be inappropriate is where a coppice stand, which has been neglected for 50 years, has developed into a more stable habitat with associated species more akin to mature forest. Harmer (1995) suggested that older stools are less likely to respond positively to re-coppicing (e.g. stools over 50 years old may fail to produce any new shoots). Introducing coppicing in this situation would result in the loss of the current conditions, such as shade, and associated species, while species associated with the former coppice conditions may not have persisted in the seed-bank.

In conclusion, regardless of the type of management, it is important to acknowledge the dynamic nature of the system and its history.

2.5.2 Diversity of species and structure

Where possible a natural mosaic of habitats, including open areas, should be encouraged as this will help maintain the long-term survival of the wet woodland habitat through provision of regeneration sites. Therefore, management should be aimed at promoting a 3D-structural and localised intra-site variation of the woodland habitat (e.g. deadwood, ponds, glades) so that it can subsequently support a diverse faunal community. Features, such as distorted, moribund and veteran trees provide a variety of localised habitat niches. Encouraging a diverse native understorey increases available habitat niches and localised variation of abiotic conditions. Additionally, an understorey can benefit a timber crop by shading out epicormic and lower branches of the main crop species and suppressing *Rubus fruticosus*.

Native trees (defined here as species naturally occurring within a region/country) are particularly valuable for nature conservation, for example, they:

- generally have a wider range of nature conservation interests and assets than introduced species;
- are less likely to become monocultural or invasive;
- support native faunal communities.

However nativeness/suitability, e.g. local provenance, to a site is also likely to be important. Such species would have adapted over time to suit the environmental conditions of the area although future climate change should be taken into consideration.

In contrast, non-native species can have detrimental impacts on the overall nature conservation value of a site. Non-native invasive species, e.g. *Rhododendron* spp., *Heracleum mantegazzianum*, *Fallopia japonica*, *Symphoricarpos* spp., can be particularly problematic as they can out-compete native species and form dense monocultural stands excluding other species. Non-invasive non-native species are also generally undesirable in a woodland managed for nature conservation and their removal should be encouraged. To avoid sudden changes that could impact upon the current conditions while enhancing naturalness of the woodland, removal of canopy or shrub layer species should be through a gradual thinning and clear-fell processes. However, in some situations it may be beneficial to remove all in one go, e.g. if conditions are created through the partial removal process that then enable the invasive species to increase.

Natural regeneration within woodland promotes structural heterogeneity and since the specimens are from the local provenance pool they are adapted to the specific local conditions. Many species readily regenerate naturally under suitable conditions, e.g. *Betula* spp., *Alnus glutinosa* and *Salix* spp. readily seed into open areas. However, a number of factors will influence the success of natural regeneration:

- grazing/browsing pressure;
- seed predation, e.g. *Columba palumbus*;
- competition by competitive groundflora species;
- thick leaf litter;
- ground scarification/cultivation may promote groundflora/release the seed-bank but can lead to soil damage, such as compaction which may lead to lack of oxygen and loss of structure.

Grazing can be negative or positive; light grazing may reduce competition from groundflora species while heavy grazing will prevent establishment/development. Light grazing can also promote localised intra-site variation. Similarly leaf litter may protect seeds from predation but may inhibit germination of some species. Grazing pressure may originate from wild or stock animals and as such control will vary but may include fencing out stock or culling wild grazers, e.g. *Oryctolagus cuniculus*, deer and *Sciurus carolinenis*.

2.5.3 Landscape setting and habitat continuum

In the spatial context, Hughes *et al.* (2005) stated that restoration of riparian systems should be implemented at a scale to ensure the mobile mosaic of habitats continue to exist; the same approach is applicable to woodland management at both site (e.g. intra-site variation) and landscape scale. They noted that within riparian systems, habitats are modified and created at scales ranging from a single location to an entire landscape. When considered at a landscape scale there is a

> "*mobile mosaic of habitats with many variable lag effects between disturbance processes and the response of both the abiotic and the species of the landscape. Therefore, at any point in space and time, species assemblages are probably unique in terms of precise combinations of species, type, numbers and age structure*" (Hughes *et al.*, 2005. p.6).

The same can be applied to woodland management as it can be implemented on a range of scales, from the whole wood approach down to habitats within the wood and to individual trees, and take place on and off site. The maintenance of a continuum of habitats both spatially and temporally is particularly important for *Alnus glutinosa* woodlands since they are often isolated and of small spatial extant. Such retention/creation of habitat continuum will enable less mobile species to spread and reduces the potential for extinction if part of the habitat is lost, either temporarily or permanently, and naturally, or as a result of rotational management.

2.5.4 Operations

Scottish Native Woods (1996) identified the following issues relating to the management of their riparian habitats including various types of wet woodlands:

- remain in the least accessible places since the floodplains were cleared for agriculture as a result of their high fertility;
- often overlooked in management plans;
- difficult to manage;
- difficult to protect from grazing, e.g. the complex topography or linear nature results in them being expensive and difficult to fence;
- provide bank stabilisation which reduces siltation, increases water clarity and ensures water depth;
- natural diversity and past management accounts for their exceptional conservation value;
- have potential for:
    - firewood and shelter for stock if managed appropriately;
    - small scale timber production;
    - recreation.

The small size is one of the main constraints associated with managing wet woodlands in the UK; Webster (2002) summarised the problems associated with small woodlands in general (less than 10 ha) as:

1. being under-managed;
2. having difficult access;
3. having deficient access.

Another significant constraint to management of wet woodlands is the soft, wet soils which are highly susceptible to damage, e.g. through compaction and subsequent structure degradation and asphyxiation. Studies (e.g. Thompson *et al.*, 2003) have shown that herbicides can damage ecosystems, e.g. remaining in the soil affecting the habitat, for as long as a decade or entering watercourses and subsequently potentially altering the aquatic ecosystem, beyond the extent of the woodland. In the management of woodlands in the UK, herbicides are primarily used in weeding of timber crops and, particularly in sites of nature conservation value, control of the invasive species. However, pan-European guidelines for sustainable forest management discourage the use of herbicides (Forestry Commission, 2011c). Guidance, including application and chemicals, for specific situations, e.g. particular species or close proximity to water, is regularly updated; current best practice is provided by the Environment Agency (2010).

Through a literature review, Wikström and Eriksson (2000) found that ecological considerations can cause constraints on woodland management, for example ecological processes, such as breeding seasons, can influence the:

- time of final harvest;
- number of thinnings;
- thinning form.

The FC (2003a) also identified a number of management complexities and conflicts between sustaining a commercial enterprise and promoting biodiversity in woodlands in general:

- there can be an increased risk of changing the forest structure when undertaking positive management for biodiversity;
- changes in management to promote greater biodiversity may result in the loss of individual species, for example:
    - *Accipiter gentilis* prefer breeding in *Picea* spp. plantation (generally considered as having low biodiversity), therefore if the *Picea* spp. plantation is changed to a more diverse habitat in terms of canopy trees, *Accipiter gentilis* may become locally extinct. However, there is likely to be a net gain in overall biodiversity;
    - *Sciurus vulgaris* (native) versus *Sciurus carolinensis* (introduced): increasing tree species diversity benefits *Sciurus carolinensis* which may then out compete, or have other negative implications for *Sciurus vulgaris*. The end result could be the loss of a native species to an introduced one;

- management for individual species can destabilise the ecosystem's natural balance;
- increasing biodiversity may result in compromised commercial value, e.g. managing for biodiversity can:
    - decrease commercial value;
    - increase labour and harvest costs;
    - possibly decrease planting costs if natural regeneration is successful.

2.5.5 Economics

As well as identifying operational factors that influence the management of small woodlands in general Webster (2002) also noted economic considerations, including low timber quality and the woodlands frequently being isolated from main markets. These factors and those mentioned in Section 2.5.4 can result in low economic return. Planting and management of small woodlands with a variety of constraints can be costly, for example, Jenkins (2003) (reporting on a Welsh Farming scheme which encourages farmers to collaborate and plant up areas of *Alnus glutinosa* and *Betula* spp.), noted that the farmers had to weigh up the benefits, such as shelter and woodchip supply, with the planting costs.

The products obtained from woodland will also influence the management. Examples of products obtained from tree species found in wet woodlands, include: fencing components, basketry, bean sticks and poles, turnery and sculptures, artificial limbs, containers, sports equipment, furniture and joinery and fuel. *Alnus* spp. and *Salix* species are also used in flood reduction, notably bank stabilisation, and phytoremediation.

2.5.6 Summary of factors influencing woodland nature conservation management

It has been shown that extremes, either very intensive or absence, of woodland management, can be detrimental to biodiversity (e.g. Sullivan *et al.*, 2001). However, appropriate management can be beneficial depending upon the objectives of the management for the site.

As a result of the review in Sections 2.4 and 2.5.1 to 2.5.5 it is proposed that some degree of management is necessary to maintain a range of habitats to act as species sources and that, as a result of high density human populations and changes in land uses, habitats associated with natural occurrences are less frequent (e.g. fire, floods; see Niemela, 1997).

Habitat mosaics, and spatial and compositional heterogeneity, generally have greater floristic diversity than structurally and spatially simple habitats. Therefore, in a country where land use conflicts and pressures are increasing, it is necessary to aid nature to create this complexity of habitats. Such complexities can raise a number of dilemmas in terms of woodland management. Should a woodland be managed:

- for a particular species or diversity across the whole woodland ecosystem?
- primarily for commercial gain or nature conservation?
- or can a compromise be achieved?

The current trend, as borne out in European and UK Policy (see Section 1.2.3) is to aim to achieve sustainable management of habitats and ecosystems in terms of both natural processes and economics. While acknowledging the complexities and conflicts, the FC (2003a) realise that the concept of biodiversity is central to achieving sustainable management. Many native species are useful natural products and a balanced ecosystem of native flora and fauna is less likely to suffer from widespread pests and disease than could be experienced in intensive monocultural systems of non-native crop species.

Although it is proposed that management is likely to be necessary in the majority of wet/*Alnus glutinosa* woodlands, the effects and implications of management on the habitat must also be considered.

2.6 Effects and Implications of Management on Woodland Characteristics

Management inherently will affect the woodland character and subsequently the species composition. Section 2.5 discussed how different factors can influence management of a woodland, here the implications of management are considered in relation to the characteristics of woodland, with emphasis on the groundflora. As previously noted there is limited literature pertaining to the current research target habitat, therefore, focus is on small, broadleaved woodlands and applied to nature conservation management of lowland *Alnus glutinosa* woodland.

2.6.1 Management effects and subsequent implications on habitat structure

In the UK, management, more often than not, has the greatest influence on the structure and composition of woodland. Wilson and Carey (2000. p.131) concluded that '*management strategy had a profound impact on community structure*' and Kaila *et al.*

(1997) reported that management alters the natural habitats within woodlands and therefore influences diversity. For example, Corney *et al.* (2006) found that 53.4% of woodland floristic variation was accounted for by management (which included deer grazing, boundary type and spatial variation). Gibson (1986) also found that management influenced the species composition of a site more than the effects of isolation and can result in both additions and extinctions to the flora. In a study of various habitats at Wytham (Oxfordshire, England), Gibson showed that in terms of woodland flora, modern plantation forestry and neglect of traditional management cause more extinctions than would be explained by natural turn-over.

Graae and Heskgær (1997) found that unmanaged Danish deciduous forests, when compared to managed forests of a similar type, were more heterogeneous (e.g. tree species composition, stand structure, light conditions and soil moisture) and had less compacted soils. Although across the whole managed forests (particularly those managed as commercial high forest) can support a range of age classes and, in some cases, species, the individual stands tend to be even aged and usually occur as monocultural discrete blocks. Similarly, well managed coppice systems will create woodland with variable age classes and structure ranging from new growth (just coppiced stools) to mature trees (standards).

Thompson *et al.* (2003) noted that there is reduced niche space and plant species richness where there is low tree species heterogeneity. Wohgemuth *et al.* (2002) provide examples which concur with this. For example, disturbance and/or heterogeneity results in increased diversity of vascular plants, indicating that even-aged, homogeneous stands like those found in high forest management systems will have lower diversity.

It is not just mechanical management operations that can affect the structure and composition of woodlands. It is well documented that grazing, both wild and domestic animals, can have significant affects. For example, it has been shown (Rodwell, 1991; Peterken, 1993) that grazing of wet woodlands can result in grassier groundfloras with more abundant *Holcus lanatus*, *Agrostis canina* or *Agrostis stolonifera* compared to similar, ungrazed woodland types. Different grazing animals and stocking densities have different implications for the floristic composition and structure of woodlands (e.g. Bengtsson *et al.,* 2000; Mayle, 1999). Mayle (1999) noted that both over- and under-grazing can have detrimental affects on woodlands; the former resulting in limited regeneration while the latter results in competitive species out competing less vigorous ones. She also noted that the age, breed and type of grazer all have different effects on the floristic communities. Although, generally grazing results in an increase in the grass component and excessive grazing in the invasion of weed species (e.g. *Rumex obtusifolius*), some species may have specific effects, for example:

- cattle: cause physical damage to the groundflora and result in the degradation of a habitat (Rodwell, 1991); but at appropriate levels can be beneficial to the floristic diversity.
- pigs: can create a diverse vegetation composition on account of their non-discriminate disturbance of species and soils through rooting around (Spencer, 2000);
- deer: can create distinct browse lines which may have implications to light penetration reaching the groundflora.
- domesticated fowl: surface scarification and localised fertilisation.

Different deer species show preferences for plant species, for example *Hyacinthoides non-scripta, Mercurialis perennis, Anemone nemorosa* and *Cardamine pratensis* are favoured by *Muntiacus reevesi* (Gill, 2000). The woody component of woodlands is also influenced by deer as different tree species are more or less susceptible to grazing; Gill (2000, p.1) noted that:

> "*Provided browsing pressures are not high enough to eliminate all seedlings, deer will bring about a change in the species composition of surviving seedlings and saplings. The composition of woodland canopies may then be affected for several decades, or even centuries and this effect is perhaps the most pervasive impact of deer*".

Grazing will also influence the distribution of species within a site, for example Mayle (1999) indicated that where there are high levels of grazing pressure, the more palatable species occur in the less accessible places; such affects are clearly demonstrated in the grazed area of Stonebridge Meadows, Warwickshire (personal observation) where species such as *Rubus fruticosus* are generally confined to the tree bases.

2.6.2 Management effects and subsequent implications on light

One of the most significant effects management can have on a woodland flora is the sudden increase in light penetration following removal of canopy species. Felling, coppicing or the removal of non-native conifers from broadleaf woodland, for example during restoration management, is likely to result in a high and immediate increase in light. In the latter example, although the light levels will decline as the canopy closes again, it may remain higher than previously, depending on the species removed and those that invade the gaps. Sudden increases in light often result in increases and growth of competitors, e.g. *Rubus fruticosus*, to the detriment of other species, although ruderal species may form a significant component of the groundflora immediately following the canopy opening (e.g. Ferris and Simmons, 2000; Radford, 1998).

Increased light levels are not always detrimental; Ferris and Simmons (2000) found that, when compared to unthinned stands, thinned broadleaf-conifer mixtures had more groundflora species. Coomes and Grubb (2000) found that in woodlands on moist, nutrient rich soils (such as found in wet woodlands), light alone limits seedling growth, rather than nutrient and water root competition. Therefore increased light is likely to promote regeneration. The increase in light and ground disturbance can also stimulate germination of species within the seed-bank. The successful establishment and floristic composition resulting from such disturbance will, at least in part, be related to the rate at which the shrub and canopy layers close. For example, if the area is planted rather than allowed to naturally regenerate, the canopy will close more rapidly and create unfavourable conditions for light demanding species in the seed-bank. In broadleaf habitats, as the shrub and canopy layers mature a change towards vernals and less light demanding species are anticipated to dominate the groundflora.

Different management techniques will result in different levels and intensities of light within woodland. For example, selective felling, when compared to clear-fell, is more likely to create dappled light conditions, allowing more shade tolerant species to have the competitive advantage over the high light demanding, often ruderal, species. A well managed coppice wood will have varied light gradients. Peterken (1993) noted an increase from 5% to 100% of light reaching the groundflora in summer. Additionally, in coppice-with-standards systems and long rotations, conditions akin to mature woodland (e.g. heavy shade and deadwood) are created. Harmer (1995) indicated that heavy shade, created by the standards, results in depressed growth of coppice shoots, and suggested that the canopy cover of standards should be reduced to about 30% at the start of each coppice cycle.

Non-intervention is likely to result in fairly shaded conditions until canopy trees naturally fall creating gaps. Some species have a greater affinity to mature woodlands and trees, therefore, since management often prevents, or at least slows, the development of mature woodlands, none/limited management is preferable for such species. Conversely, other species may decline in such habitats as a result of the reduced light levels. Wohlgemuth *et* *al.* (2002) attributed reduced species diversity, following abandonment of management, to lower light levels.

2.6.3 Management effects and subsequent implications on soil chemistry

Management can influence the soil chemistry and therefore, indirectly, alter the flora; for example, Peterken (1993) found that post coppicing and before canopy closure there is an increased rate of organic matter decay, slight increase in acidity and a release of nutrients.

In areas regularly used by grazing stock for resting, or latrines, there can be an increase in competitive species, such as *Urtica dioica*, as a result of increased nitrogen and potassium (Mayle, 1999); this is seen at Stonebridge Meadows (personal observation).

Preiditis (1997) found that, in *Alnus glutinosa* woodlands in the Baltic Region, clear-fell results in increased wetness and, if regeneration, or restock, is restricted, tall herbs may outcompete *Alnus glutinosa* and subsequently a peat bog may develop. However, in the UK such woodlands occur as small entities and therefore these situations, i.e. clear-fell operations, are unlikely to take place.

Management can directly or indirectly influence the woodland flora by altering the soil moisture conditions. A decline in wetness, for example through prevention of inundation, can lead to succession from *Alnus glutinosa* woodland to, drier, *Quercus*-based woodlands. Equally, anything which causes the water table to rise may result in regression of woodland to open bog habitats if conditions are such that they restrict regeneration of woody species, e.g. permanent flood flushes (see Prieditis, 1997). As an example of an indirect affect, post coppicing and before the canopy closes, surface soils dry as a result of evaporation in summer, however the water table rises as a result of reduction of the pumping effect of transpiration (Peterken, 1993; Decocq *et al.*, 2004).

2.6.4 Management effects and subsequent implications on ground disturbance

Intensive management, particularly on a large scale with big machinery, can result in soil compaction which subsequently may inhibit seed germination as a result of altered soil structure. As well as compacting the soils, the use of large machinery can create wheel ruts (which may subsequently fill with water) and general ground disturbance. Such disturbance and exposure of new ground will provide conditions for ruderal species to establish. If the ground is left in a disturbed state, following management operations, a variety of different conditions would remain, such as the water-logged wheel ruts and tree stumps. This is likely to result in species and structural variation in the woodland. Although some species more readily colonise open disturbed ground than others, the proximity of parent plants, or seeds in the seed-bank, is also significant. Rodwell (1991) noted that the *Betula* spp. sub-community of W6 readily and naturally colonises disturbed ground. *Acer pseudoplatanus* also readily colonises *Alnus glutinosa* woodland habitats when the canopy is opened, particularly when associated with drying soils such as created if streams/ditches are cleared allowing water to pass more freely through a site (personal observation). If left unchecked this species can form a monoculture and reduce the species diversity in the woodland.

Ground preparation and use of herbicides, prior to planting, will also influence the subsequent flora. Thompson *et al.* (2003) found that plant species richness can be related to ground preparation, notably that the greatest species richness was found where ground preparation did not occur and the lowest species richness where herbicide was applied; ground that was mechanically prepared showed intermediate species richness. They suggested that effects on the groundflora resulting from intensive management can last for decades compared to natural disturbances.

Disturbance does not necessarily have to be caused by machinery; both domestic and wild grazing animals can disturb the ground and vegetation and cause a change in the flora. In grazed woodlands, there may be extensive areas of bare ground where stock congregate or trample. Although, the trampling action of the grazers can increase the diversity of micro-topographic and micro-climatic conditions, on wet soils it can be particularly damaging causing compaction (Mayle, 1999), which would subsequently result in reduced air pockets and infiltration rates. Such negative impacts on the soils are species dependant, for example cattle and horses are more damaging than sheep. Therefore a balance needs to be achieved, for example although cattle grazing can reduce the dominance of competitive species, too much grazing can cause physical damage to the soils and groundflora.

2.6.5 Management effects and subsequent implications on seed source, seed bank viability and establishment

Woodland flora is, in part, determined by the availability of seed (which may be from outside the woodland or within the seed bank) and appropriate conditions for establishment. Free-ranging grazers, such as deer, can increase the zone of influence from adjacent habitats as they act as seed dispersers across the landscape. Historically, large grazing animals were a more frequent occurrence in woodlands than in the present day and Commoners Rights to use woodland for grazing declined with the onset of agricultural intensification. Tansley (1965) commented that the use of woodlands for cattle pasturing would have led to the decline of woodland groundflora as a result of soil compaction, browsing and the development of grassy vegetation. Such effects of grazing also hinder the establishment of tree seedlings, conversely he also noted that the use of woodlands for pannage may have aided woodland regeneration, through trampling seeds/nuts into the ground and the destruction of small rodents, which are known to have significant impacts on tree seedling establishment.

Compared to commercial, short rotation coppice systems (notably *Salix* spp.), more traditional coppice systems tend to have smaller coupes on longer rotations thus maintaining a regular sequence of open and closed canopy habitats, within close proximity, so allowing migration of species in, or out, as the conditions change during the rotation. Such systems are *"likely to be effective in maintaining the existing groundflora in perpetuity*" (Barkham. 1992. p.167). However, it is suggested that this would be dependent upon the scale and rotation of the coppicing cycle in relation to the size of the entire woodland.

Different species persist in a seed bank for different lengths of time and subsequently management, notably length of felling/coppicing rotation, will affect long-term survival of a woodland flora. For example some seeds may have a relatively short seed-bank life expectancy and are, therefore, less likely to survive a long rotation. At least in mixed broadleaved-conifer ancient woodlands, woodland groundflora is rarely detected in the seed-bank: "*the soil seed-bank cannot be depended upon to restore the majority of ancient woodland plant species to a stand once they are lost from the above ground vegetation"* (Ferris and Simmons, 2000. p.8). Ferris and Simmons (2000) found that *Rubus fruticosus, Juncus effusus, Hypericum* spp. and *Epilobium* spp. were the commonest seed-bank components; all these species are associated with UK lowland *Alnus glutinosa* woodlands.

Different management practices can have different effects on the woodland's floristic composition depending on the conditions required for successful establishment and growth. For *Alnus glutinosa* to successfully regenerate there needs to be sufficient light (e.g. breaks in the canopy or adjacent available land) and moist soils and generally it does not regenerate under its own canopy (McVean, 1954). In addition, given the high fertility of lowland *Alnus glutinosa* woodlands, natural regeneration can be restricted as a result of rapid and competitive growth of *Urtica dioica*, often a significant component of the groundflora. Therefore, it may be necessary to implement other forms of management, such as grazing or groundflora control, to aid natural regeneration. Latham and Blackstock (1998) found that in coppiced *Alnus glutinosa* woodlands there were noticeably more *Alnus glutinosa* seedlings than in similar habitats that were either ungrazed or grazed, and attributed this to the increased light and disturbance resulting from the management. This suggests that the coppicing cycle, which periodically opens up the canopy creates suitable conditions, i.e. light and disturbed soils, may be appropriate to maintain the *Alnus glutinosa* habitat.

2.6.6 Effects and subsequent implications of planting

It is considered unlikely that planting would be appropriate in the course of managing existing wet woodlands, unless a restoration process from inappropriate species is being implemented. In such situations the choice of species will influence the ultimate character and composition of the woodland. For example, Thompson *et al.* (2003) demonstrated that there was greater impact on the woodland when the original canopy species were restocked with fast growing, non-native species, compared to native species. If a variety of appropriate species are planted following a clear-fell operation, the woodland species and structural diversity can be increased, the latter at least partially because of the different growth rates of different species. Equally, appropriate planting will 'fast-track' the establishment of mature woodland.

2.6.7 Effects and subsequent implications of off-site management

To have an effect on the plant composition of a given woodland site, management does not necessarily have to occur on site. For example, Hughes *et al.* (2005. p.9) went so far as to say that "*floodplain forests are dependent on processes higher up in the catchment*" and reported that flood control of a river will reduce the flow variability, sediment deposition and connectivity between the river and the floodplain. As lowland *Alnus glutinosa* woodlands occur in floodplains, river control could potentially have a profound influence on the habitat.

It is suggested that anything that would result in reduced flooding, e.g. river canalisation upstream of the woodland, could instigate the development of wet woodland into mesic, or drier woodland, and subsequently result in a very different flora community.

2.7 MANAGEMENT TECHNIQUES

Management of all woodland types can be considered in four broad categories:

1. intensive;
2. traditional;
3. sensitive to/mimicking natural processes;
4. none/limited.

There are also several other forms of management that are frequently undertaken in woodland that are not directly related to management of the trees, for example, creating drainage ditches and forest infra-structure. Table 2.13 provides a summary of woodland management techniques under the four categories listed above and are discussed further in the subsequent sections in relation to wet woodlands.

2.7.1 Intensive management

Intensely managed woodlands are generally those managed as commercial enterprises and use techniques that are more likely to have significant impacts on the woodland's floristic composition. At the time at which the current research is being undertaken, *Alnus glutinosa*, has low timber value and generally not grown on a commercial scale, principally as a result of the size and location of woodlands and low product market. This view was supported by the results of the questionnaire (Appendix 2) and discussions with woodland managers during the course of this research. Therefore intensive forest management is considered to be of low relevance to the research. However, several operations employed as part of this management technique, e.g. clear-fell, thinning, may be appropriate during restoration of non-native woodlands on sites historically suitable for wet woodlands.

Selective felling is an alternative to high forest and clear-fell management but is still relatively intensive, at least locally. This management technique encourages species and structural heterogeneity by allowing a range of age classes and species to form the canopy; several authors (e.g. Carey and Wilson, 2001; Decocq *et al.*, 2004) found such operations increased diversity. The mosaic of habitats, and habitat continuity, are also likely to be retained as there is no large scale loss of habitat resulting from the management operations.

Management	Brief description
Intensive	
Productive high forest	Evenly aged and spaced mature trees grown for timber. Tree species often planted in blocks of single, or few, species. Usually involves periodic thinning to encourage strong growth of the remaining trees.
Clear-fell and re-stock	Forms part of high forest management: groups of trees felled and then either replanted (re-stock) or allowed to naturally regenerate (regeneration). Artificial re-stock often includes intensive ground preparation such as scarifying and herbicide, pesticide and/or fertiliser application prior to planting.
Selective felling	Forms part of high forest management: selected species or individual trees felled.
Traditional management	
Coppice	Main canopy species cut near to ground level, encourages regrowth and results in multiple stems from one root system. This practice is usually done on a 5-20 year rotation with selected coupes being effectively clear-felled and resulting in even-aged stands.
Coppice with standards	Under storey coppiced on a 5-20 year rotation (see above) with some trees or stems left to form standards creating an uneven-aged upper canopy. The standards are selectively felled on a rotation that is a multiple of the coppice rotation (Harmer, 1995).
Short term rotation coppice	Coppice on a very short cycle. Often used in charcoal or biofuel production.
Sensitive to/mimics natural processes	
Grazed	Stock allowed in to graze the ground cover. If stocking densities are too high this form of management could be perceived as 'intensive'.
Uniform shelterwood system	A gradual transition from one generation to the next without the drastic impact of clear-felling.
Continuous cover	Managing the woodland so that there is no obvious change in the canopy and visual appearance of the woodland within the landscape.
Artificial 'windblow'	An alternative to coppice – allows light in and allowing growth from prostrate stems. Also provides futuristic deadwood. Less systematic and regular than coppicing (see above).
None/Limited	
Non-intervention	No management.
Minimal intervention	Minimal intervention; management may be restricted to health and safety considerations.
Miscellaneous	
Natural regeneration	A component of woodland management following harvesting where the next generation of canopy trees occur through natural invasion/regeneration.
Pollard	Cutting branches of a tree at approximately head height, encourages regrowth out of reach of grazing stock/deer. In the past the crop would have been used as winter fodder and fuel.
Restoration management, e.g. of old wet woodlands	Removal of non-native or inappropriate species, e.g. where a former wet woodland has been planted with conifer species. Filling in drainage ditches on drained sites. Re-introduction of earlier management of neglected sites.
Boundaries	Woodland boundaries can vary from historic wood banks, hedgerows to modern features, such as fencing or infra-structure.

Table 2.13 Woodland management techniques
(based on Miller *et al.*, 2005)

2.7.2 Traditional management

Historically the management of woodlands would have been dictated by geographic location (and therefore climate) and topography, and the demand for end products; the

former would have determined what species could grow and the latter would reflect the local industry in relation to what species grew. Traditional management operations are often less intense than modern forestry and therefore are often perceived as the most appropriate for nature conservation. However, such techniques can be quite intensive at a local scale and have significant implications to the woodland's floristic component. Hansson (2001) found that groundflora species richness was greater in plots where traditional management had been simulated by mowing of small interior grasslands than plots where mechanical clearance or abandonment management regimes were applied. Corney *et al.* (2006) found that groundflora forest specialists were strongly associated with traditional management techniques, such as coppice. However, re-instating traditional management may not be a realistic option: it may be too costly (economic and labour) if there is no longer the market for the end product (Hannson, 2001) or the woodland may be too isolated, or surrounded by residential properties, to extract the products.
Although using a traditional concept, modern day commercial coppicing of *Salix* spp. beds can be very intensive and detrimental to diversity due to the large scale, short rotation, dense planting, herbicide application and hoeing. As an example, short rotation coppice of *Salix* spp. and *Populus* spp. in the UK is recommended at stocking densities of 15,000 whips ha^{-1} and harvesting taking place every 2-4 years (Tubby and Armstrong, 2002).

2.7.3 Management that is sensitive to, or mimics, natural processes

For sensitive sites, such as ancient semi-natural woodland (ASNW) and wet woodlands, the FC (2003a) prefers sensitive and low intensity management, suggesting that intensive management can be detrimental to the natural characteristics of the woodland. Several studies (e.g. Ratcliffe, 1996; Niemela, 1997; Kaila *et al.,* 1997; Simila *et al.,* 2002; Thompson *et al.,* 2003; Wohlgemuth *et al.,* 2002; Bengtsson *et al.,* 2000), support the view that woodland management should be based on, or mimic, natural processes (e.g. windblow and fire) and provide examples where such management has benefited woodland diversity.

Natural disturbances, such as storm damage, can have profound effects on the nature of an ecosystem and may enhance the variation of a site. Natural disturbances experienced by lowland *Alnus glutinosa* woodlands include flooding as well as windblow. Therefore, some forms of management that cause disturbance and open the canopy could increase the natural variation and species composition of a site as a consequence of disturbance. However, natural disturbances are generally infrequent on a human timescale, while management is usually implemented more frequently and, as Graae and Heskgær (1997) noted, can result in unnaturally large disturbances, e.g. felling. If disturbance is too frequent, enough time may not pass to enable the ecosystem to re-establish its balance before the next input/disturbance from management. Therefore management which mimics natural events should be implemented on long-rotations.

Grazing in relation to woodlands is discussed at length in the literature (e.g. Vera, 2000; Jansen and Robertson, 2001; Hansson, 2001; Latham and Blackstock, 1998), including the target habitat of the current research; those most relevant to *Alnus glutinosa* woodlands are discussed here.

Vera (2000) proposed that grazing by large herbivores has a fundamental role in driving woodland dynamics by maintaining a rolling mosaic of forest, shrub and grassland. While such grazing effects are more likely in large scale forests, Parrott and MacKenzie (2000. p.5) noted that grazing, both in the past and the present, is a key contributor to the fragmentation and decline of Scottish native woodlands, at least partially through the hindrance of natural regeneration;

> "*The range for all grazing animals has contracted dramatically with the expansion of afforestation schemes, placing further pressure on unenclosed and vulnerable native woodlands.*"

However, the FC (2003) suggest that light grazing, a natural part of wet woodland ecosystems, helps maintain the open areas and promote natural regeneration; heavier grazing may, however, be detrimental. Mayle (1999) concurred with these generalisations and noted that, whilst high, and no, grazing prevented the regeneration of *Alnus glutinosa*, moderate grazing actually benefitted it. Gill (2000) also noted that *Alnus glutinosa* was less susceptible to deer grazing than other wet woodland species, such as *Salix* spp. and *Fraxinus excelsior*. Peterken and Hughes (1995) also found that wet woodlands along the Beaulieu River, Hampshire, have limited natural regeneration as a result of heavy grazing by horses and deer. Personal observation (2011) of such sites, dominated by *Alnus glutinosa*, also found there to be minimal regeneration and variation among the groundflora; the latter being dominated by grasses and *Ranunculus ficaria*. Therefore personnel observation suggests that grazing would need to be carefully monitored in lowland *Alnus glutinosa* woodland because if the stocking density is too high it can result in woodland devoid of groundflora as well as regeneration.

Armstrong and Bullock (2004) noted that generally cattle are thought to be more beneficial to nature conservation management than sheep; cattle are less selective, remove coarse vegetation and their trampling can break up dense stands of undergrowth species, such as *Pteridium aquilinum,* thereby allowing higher sward diversity by reducing the dominance of strong competitors. Although both cattle and sheep will graze tree and shrub seedlings and saplings potentially reducing regeneration, cattle have the added benefit of creating larger hoof prints, exposing new ground for establishment. Whether impacts of cattle grazing are negative or positive depends on the stocking density, season in which they graze the woodland and local environmental conditions (Armstrong and Bullock, 2004). Sheep may be more beneficial on steeper ground and where the woodland flora is more susceptible to disturbance (Armstrong and Bullock, 2004), but are less appropriate for wet woodlands because sheep are prone to foot-rot.
It has been reported, e.g. McLean *et al.* (undated), that pigs can be beneficial in ground preparation (i.e. clearing undergrowth and scarification) prior to planting. However, this suggests that pigs are likely to have a detrimental effect on natural regeneration and therefore it is not advisable to introduce pigs into an established woodland, particularly small woodlands. However, Mayle (1999) suggested that low stocking densities for short periods of time creates suitable conditions for natural regeneration, although, greater densities are likely to result in soil compaction.

Some reports (e.g. DEFRA, 2004) suggest chickens in woodlands may benefit tree growth, at least in the establishment phase where the foraging chickens act as a weed suppressant around young trees and provide fertiliser. Personal observations suggest that, at least in the short-term and when enclosed and at high densities, chickens (and pheasants) tend to have detrimental effects on the groundflora through increased fertility and direct of loss of plants. However, as a result of the surface scarifying effect, following removal of the fowl, there is the potential for a different and perhaps more varied groundflora which will establish as a result of disturbing the seed-bank and providing a prepared seedbed.

Latham and Blackstock (1998) reported on one of the few studies relating to the grazing of *Alnus glutinosa* woodlands. Prior to closure the woodlands were heavily grazed by sheep and horses but after 20 years of stock exclusion, ungrazed plots showed an increase in tree regeneration and shade tolerant species, a decrease in ruderal and wet pasture species and less surface water and bare soil.

Grazing may also have indirect effects on woodland species composition, for example, Latham and Blackstock (1998), with cross references to other studies, found *Fraxinus excelsior* readily regenerates in *Alnus glutinosa* woodland following stock exclusion and shows rapid growth as soon as the canopy opens, such as following a fallen tree. Once the *Fraxinus excelsior* reaches the canopy it can out-compete the *Alnus glutinosa* for light. This suggests that where *Fraxinus excelsior* is present within lowland *Alnus glutinosa* woodland it should be monitored, and if necessary controlled, if the management objectives are for retaining *Alnus glutinosa* woodland rather than allowing succession to *Fraxinus excelsior* woodland.

The literature indicates that grazing can have both positive and negative influences on the variation of woodlands, but the outcome is dependant upon the grazing intensity and timing, as well as the type of animal and the condition of the woodland prior to grazing. Grazing, therefore, be it by wild or stock animals, will have implications on woodland management. Grazing has more significant effects in small, otherwise non-productive and highly managed woodlands, but needs careful management. Grazing is likely to be a suitable management tool for lowland *Alnus glutinosa* woodlands which occur in pastoral floodplains if stock species and densities are appropriate.

Uniform shelterwood and continuous cover management systems provide habitat continuity with low disturbance. Although there is limited evidence (Mason, 2007), these management techniques also create structural and species diversity and are therefore potentially more resistant to the anticipated implications of climate change. However, there is also potentially greater risk from wind damage (Mason, 2007) and, therefore, aspect and direction of prevailing winds are significant considerations if such silviculture is implemented in small woodlands, such as lowland *Alnus glutinosa*. These systems are likely to be appropriate for lowland *Alnus glutinosa* woodland because of the small spatial extant and fragmented nature of the woodlands.

Windblow can be simulated by pulling over individual trees and allowing them to regenerate from the prostrate stems (FC, 2003a), enabling light to penetrate the canopy and stimulate growth of the understorey and groundflora. Regeneration from prostrate stems also results in more structurally diverse woodland, but is genetically restricted. The uprooting of the root-plate creates localised exposed soil and standing water habitats. This technique may be appropriate for lowland *Alnus glutinosa* woodland as it can provide varied age structure without the need for regeneration from seed.

2.7.4 None/limited management

Within the UK it is generally accepted that there are no 'wildwoods' remaining and that all have, either in the present, or past, been altered/managed by man (Rackham, 1998). Therefore it could be considered that no further intervention would ultimately result in a 'new' equivalent 'wildwood' and benefit nature conservation. Since current characteristics of all woodlands within the UK are a consequence of some form of management it is questioned as to whether none/limited management is appropriate to maintain the current nature conservation interests of the habitats. Although it is acknowledged that in parallel to the regression to 'new wildwood' following lack of intentional intervention a different (and perhaps equally important to nature conservation) woodland ecosystem will evolve. Sullivan *et al.* (2001) found unthinned stands lacked structural diversity and Carey and Wilson (2001) reported that no thinning (i.e. non-intervention) compared to variable thinning (i.e. management) resulted in lower understorey diversity and reduced groundflora cover but there was no decline in species associated with old growth forest. These examples suggest that non-intervention management, at least in planted woodlands, may not be beneficial to overall diversity since structural diversity is poor.

However, regardless of the nature conservation issues, there are several studies, (e.g. Hanssen, 2001 and Barkham, 1992), that have shown that abandonment of management can result in changes of species composition. Hanssen (2001), for instance, found that groundflora species richness declined with abandonment of management, and Barkham (1992) found that the percentage cover of groundflora, ruderal and grassland species declined as a result of the closing canopy.

2.7.5 Miscellaneous forms of management

Natural regeneration is a component of other forms of management following loss of the canopy trees, either through natural processes or harvesting. This results in varied structure and light conditions as a result of the different growth rates of the regenerating canopy species. The technique has the advantage that the individual plants will be adapted to the local conditions, although if climate change occurs at a rate faster than plants can adapt, loss of individuals and habitats is possible because they cannot adapt quickly to the 'new' local conditions.

Pollarding is primarily undertaken on boundary trees to mark the edge of a coppice or landownership, and is associated with pasture-woodland. Historically, however, it was also undertaken on groups of *Ilex aquifolium*, known as hollins, in pastureland. The *Ilex aquifolium* were pollarded at intervals to provide winterfeed (Peterken, 1993). The groundflora of pasture woodland is more typical of grassland and heathland than woodlands (Peterken, 1993). Although individual *Salix* spp. in floodplains are often pollarded, wet, or *Alnus glutinosa,* woodland are generally not associated with wood-pasture or pollarding and as such this form of management is not considered further.

Restoration management often incorporates a range of different techniques depending on the specific conditions on site or the factors that have occurred that require the woodland to be restored. For example, in some instances it may be necessary to undertake clear-fell operations if there are areas of non-native conifers, where historically native broadleaves occurred. In other instances it may be preferable to gradually remove the conifers in order to maintain light conditions, minimise ground disturbance or where it is likely that sudden opening of the canopy will result in the invasion of strong competitors.

Restoration is commonly applied in response to the aim of enhancing the nature conservation value of a woodland and minimal intervention or traditional management systems are often implemented. However, simply re-introducing traditional management is not always appropriate as long periods of neglect can result in a change, or deterioration, of floristic composition that may not recover by reinstating the former management. A neglected coppice may have developed into high forest, with its own distinct associated flora and the original seed-bank depleted.

In order for restoration to be successful, resulting in the establishment of a sustainable community, an understanding of the past history must be achieved. Tipping *et al.* (1999. p.33) concluded that lack of appreciation of a site's palaeoecological record and "*the likely former high taxonomic diversity of woodlands*" may to lead to the creation of low species diversity woodland.

Kellogg and Bridgeham (2002) found that restoring the correct hydrological processes in freshwater marshes was more important than seeding or planting, and resulted in a more variable plant community. Similarly this may also be applicable to *Alnus glutinosa* woodlands that originally established from marshland communities.

Corney *et al.* (2006) found that the type of woodland boundary could influence the groundflora composition, for example:

- stock proof fencing - may restrict larger grazers;
- hedgerows and watercourses - provide dispersal routes (for both flora and fauna) into the wider landscape and connections to other woodlands;
- hedgerows – alter localised climatic conditions by, for example, providing a sheltered situation;
- infra-structure (road, rail) – provide dispersal routes, particularly for plants with windblown dispersal mechanism, and act as a source of pollutants, e.g. car fumes, salt spray.

2.7.6 Determining appropriate management

As has been demonstrated in the preceding sections, there are numerous factors to consider when managing woodlands, for example:

- what the site is managed for, including the provision of ecosystem services
- ever changing policies and guidance, such as the BAP, Lawton Review (Lawton *et al.*, 2011) and The Natural Environment White Paper (HM Government, 2011)
- conflicts, e.g. biodiversity versus economic return.

Therefore mechanisms in aiding making management decision are helpful. Management decisions are never straightforward and superficially "good" management plans can have far reaching negative consequences if all aspects are not fully considered. Wilson (2003. p.51) concisely summarises the current thinking for woodland management as:

> "*Ecologically appropriate forest management requires a holistic understanding of site ecology, considering a wider range of site attributes than those relating to productivity.*"

Recognition of the importance of habitat connectivity for the long-term survival of habitats and species, i.e. the reduction of fragmentation, is reflected in a number of green infra-structure initiatives, such as EMGIN (East Midlands Green Infrastructure Network) and the Northamptonshire Character Assessment (Northamptonshire County Council, 2006) and, more recently, The Lawton Review (Lawton *et al.*, 2010). Although such principles have been acknowledged with the publication of the Natural Environment White Paper (Anon, 2011), such reduction of fragmentation and the implementation of landscape/whole hydrological system approaches are long-term processes and therefore there is a need for site specific management and ecological understanding in order to maintain wet woodland in the interim.

The Forestry Commission *Forestry Practice Guide 8 The Management of Semi-Natural Woodlands: Wet Woodlands* (2003. p.13) provides the current best practice guidelines and reference point for management, providing a baseline from which the Forestry Commission process grant applications. For the management of wet woodland these can be summarised as follows:

1. "*maintain semi-natural woodland types;*
2. *maintain or restore diversity of structure;*
3. *maintain or restore diversity of species, and increase where appropriate;*
4. *maintain a mature habitat, retaining old, dead or dying trees;*
5. *minimise rates of change;*
6. *use low-key establishment techniques*."

The guides have been compiled in liaison with both foresters and ecologists to '*form a distillation of the best advice available'* (Forestry Commission, 2003. p.1).

However, there are a number of other approaches/documents that are used to inform specific elements of the management processes for woodland nature conservation.

National Vegetation Classification (NVC)

Latham (2003) noted that the NVC is used in woodland conservation management and Pilkington (2003. p.25) stated that it "*may allow predictions to be made about future management options*". The NVC itself does not provide guidance on woodland management but provides an understanding of different woodland ecosystems that could then be used to guide management decisions. It can also form the basis of guidance on creating new woodlands, e.g. Rodwell and Patterson (1994), through the identification of appropriate precursor flora and planting mixes to create different native woodland types appropriate for different conditions and situations.

Ecological Site Classification Decision Support System (ESC-DSS)

As discussed in Section 2.3.2 the Ecological Site Classification (ESC) uses the presence of particular plant species to predict soil fertility in conjunction with climate and soil moisture to classify forest sites. The ESC-DSS uses these data and *"allows users to assess the ecological suitability of alternate forest types. ESC is designed to help guide forest managers and planners to select ecologically suited species to sites, instead of selecting a species and trying to modify the site to suit"* (Forestry Commission, 2001).

Using the site specific soil and climatic data, the ESC-DSS identifies tree species suitable for the site conditions through comparing the abiotic conditions with the "*ecological requirements of different species and the ecology of woodland communities defined in the National Vegetation Classification"* (Forestry Commission, 2001). The ESC-DSS also provides an indication of expected yield. Therefore, it is primarily a tool which focuses on two particular elements of woodland management; choice of species and timber production. The ESC-DSS also uses the data to identify the sites likely NVC community (even if a non-native plantation) so giving an indication of its potential floristic diversity, if it were managed as native woodland. While a useful tool to guide restoration of woodlands on formerly wet woodland sites, it is not considered appropriate to guide management decisions for the actual management of lowland *Alnus glutinosa* woodlands for nature conservation. ESC is focused on larger woodland sites with timber establishment and production as the primary objective while nature conservation in lowland *Alnus glutinosa* woodland is likely to require micro-management of existing canopy and shrub layer trees.

Joint Nature Conservation Committee (JNCC) Common Standards Monitoring (CSM)

An essential element to any site management is the identification of management objectives and monitoring to enable an assessment to be made as to whether the management is appropriate for the site and it's associated features. Any observed changes can then be used to guide management decisions. The JNCC note that:

> *"Sound conservation objectives can only be derived by considering the ecology of the habitats and species (at community, ecosystem and landscape scales) on the site and, where appropriate management is known, the range of management options available. Ideally, conservation objectives should be formulated within the context of a management plan which specifies the practical measures needed to achieve favourable conditions for the range of interest features present on the site. This offers a mechanism for resolving any potential conflicts between different interest features"* (JNCC, undated-a).

For protected nature conservation sites (e.g. SSSI) in the UK, the Joint Nature Conservation Committee (JNCC) developed the Common Standards Monitoring (CSM) process. The CSM is designed to be a simple and quick assessment method, supported by limited, more detailed monitoring (JNCC, undated-b). Although not directly a management guidance tool, the CMS includes the requirement to identify *"management measures which may result in improvements to the condition of features or maintain features in favourable condition*" (JNCC, undated). The CMS was principally developed for statutory nature conservation sites (i.e. those considered to be of highest value or representative of UK biodiversity), but the approach can also be applied to other sites.

JNCC provide guidance on identifying conservation targets and subsequent monitoring attributes for different habitat types. For woodlands, five broad attributes are identified:

1. *extent;*
2. *structure and natural processes;*
3. *regeneration potential;*
4. *tree and shrub composition;*
5. *indicators of local distinctiveness* (JNCC, 2004).

The condition assessment process for woodlands is judgemental, rather than statistical, but developed so that consistency can be achieved between assessors/assessments (JNCC, 2004).

2.8 CONCLUSIONS

As discussed in Sections 2.1 - 2.3, although lowland *Alnus glutinosa* woodlands in Great Britain form just a small component of the world's woodland, they are of high significance, particularly as the majority of Britain's floodplain forests (of which lowland *Alnus glutinosa* woodland may be a component), have been lost or are under threat (Peterken and Hughes, 1995). Threats to such habitats are both direct and indirect, for example, atmospheric and waterborne pollution; river management (including flow control and channel re-alignment); drainage; change of landuse, such as agricultural land-take and intensification (e.g. Peterken and Hughes, 1995; Döring-Mederake, 1990). Peterken and Hughes (1995, p.191) noted that "*wherever they occur, floodplain forests are among the richest components of the landscape*" with the richness being created by numerous factors, including flooding. In addition to providing habitat value to a range of wildlife, wooded river corridors also:

- act as dispersal corridors for wildlife across the landscape;
- form a buffer zone between adjacent agricultural land and the river so indirectly influencing the water quality;

- regulate river flow;
- influence the diversity of habitats and species within the river, e.g. through log-dams.

In order to achieve the BAP targets and minimise the conflicts between flora and fauna and management, an understanding of habitat ecology is essential not only for the floristic component of the habitat but also the associated fauna. Despite this recognition at national and international level, literature reviews (Sections 2.1 - 2.7) indicate that there is limited knowledge or information relating specifically to UK wet woodlands and their management and even less concerning lowland *Alnus glutinosa* woodland.

This current research will consider and develop three significant points identified during the literature review in relation to woodland management of lowland *Alnus glutinosa* woodland for nature conservation:

1. Management in relation to environmental conditions as determined by their floristic component, i.e. helping to provide information for a gap, identified by Wilkström and Eriksson (2000), that few studies have considered optimising stand management subject to environmental conditions.
2. The fundamentality of abiotic (as well as biotic) factors in sustainable woodland management in terms of the ecological aspect (Linenmayer *et al.* 2006). This will utilise the interpretation of Ellenberg indicator values and CSR-strategies of the component species.
3. The need for a better understanding of influences that silviculture processes have on different components of biodiversity and non-market management objectives (Mason, 2007). This will focus on the floristic component of the habitat.

3. DEVELOPMENT OF RESEARCH METHODOLOGY AND JUSTIFICATION

Chapter 2 reviewed the literature and identified the following research aim for the current research:

develop a tool that enables appropriate management decisions to be made based on the flora of a site.

In order to achieve this aim, three objectives were identified:

1: identify intra-site variation within lowland *Alnus glutinosa* woodland using and then combining existing tools (CSR & Ellenberg)

2: relate intra-site variation to conditions created through management techniques

3: develop a tool that identifies intra-site variation using groundflora species and subsequently determines which management options are appropriate.

This Chapter develops methods to enable these objectives to be achieved in the subsequent Chapters. As mentioned in Section 1.3, the nature of the research required a series of sequential steps to be followed with feedback loops refining the process. This current Chapter details and discusses the original methods while the following Chapters discuss the refinements in detail.

3.1 DETERMINING SPECIES OCCURRING IN LOWLAND *ALNUS GLUTINOSA* WOODLAND

To identify species associated with *Alnus glutinosa* woodland, specific site visits to known wet woodlands were made (Appendix 4). These sites were primarily identified following the distribution of the questionnaire developed at the very start of this research (see Section 1.1 and Appendix 2). The sites had to ideally meet all, or most, of the following criteria:

- *Alnus glutinosa* dominates the canopy;
- represent different management regimes;
- represent different site histories;
- have distinct variation in the groundflora;
- easily accessible/open access;
- primarily managed for nature conservation;
- allow experimental management to take place.

The last criterion listed above turned out not to be viable, primarily as a result of the size of the woodlands, ownership and public use/perception of the woodlands. The small size of the woodlands would not have allowed for different or repeated management techniques to be implemented at one site. In many cases the woodland owners/mangers were reluctant to cut down trees/manipulate the woodland when current best practice recommended minimal intervention for this Priority BAP habitat as well as having little/no resources to undertake the work. In addition, it would likely to have taken at least a year for the new management to be approved and then implemented. Although, this criterion was not necessary for identifying species associated with the target habitat, it did influence the subsequent direction of research because it would not be possible to manipulate woodlands and assess the changes in flora in relation to different management techniques. A total of 64 sites, each meeting many of the ideal criteria listed above, were identified (Figure 3.1).

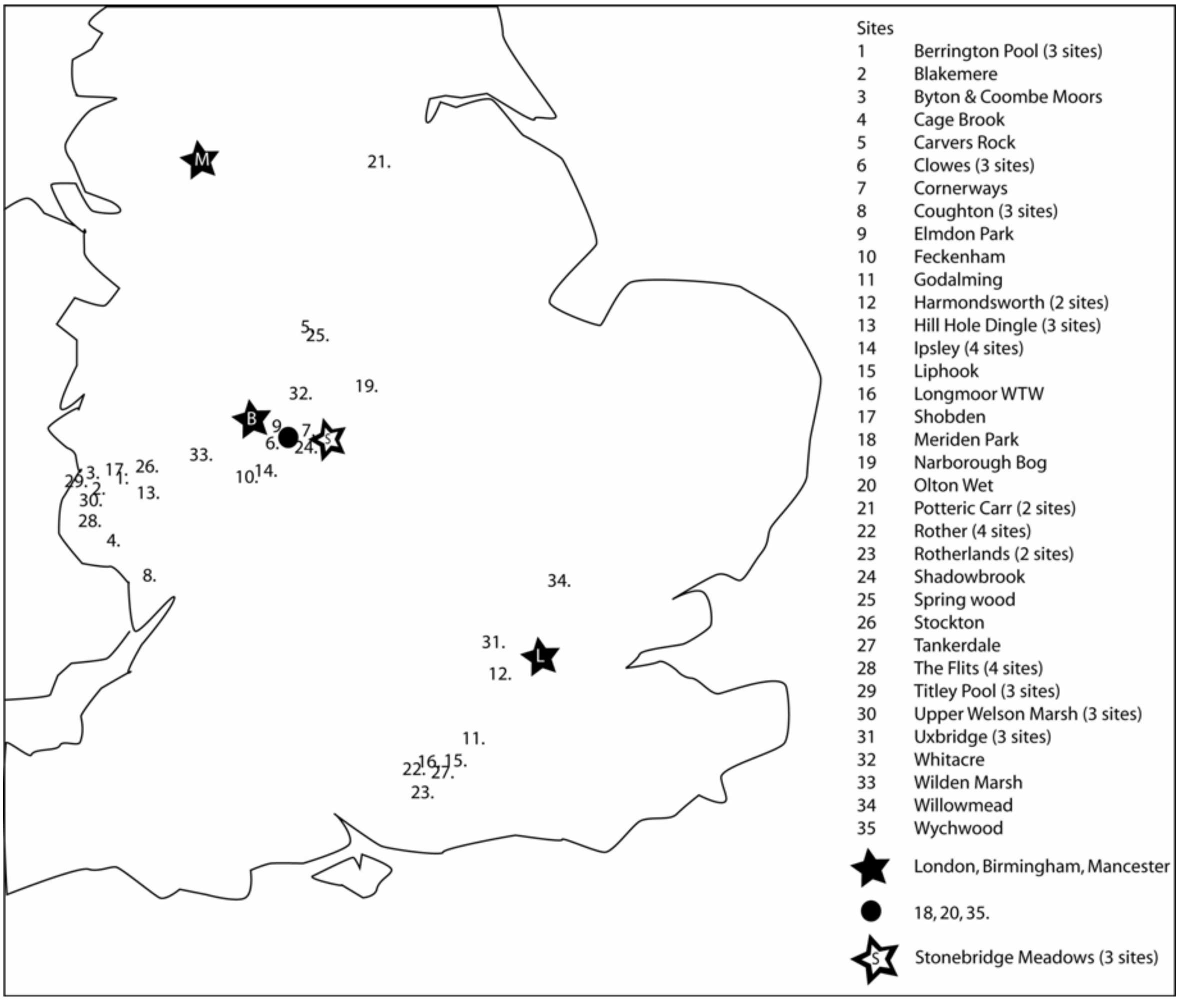

Fig. 3.1 Locations of sites surveyed to determine species associated with lowland *Alnus glutinosa* woodland and the study sites (Stonebridge) used in the detailed analysis (Section 3.5)

The collection of quantitative data was not deemed necessary for determining the species occurring in lowland *Alnus glutinosa* woodlands as the purpose was to identify species that may be found, not their distribution or abundance. Therefore at each site (Figure 3.1), the presence of species was recorded, during surveys systematically across the whole site.

Each site was walked, initially using existing paths and then off the paths (where access was possible and it was safe to do so) to record all readily visible plant species. Given that the target habitat occurs as small spatial extant, this method allowed, in the majority of cases, the floristic composition of the entire woodland to be sampled. Since the aim of the research is to develop a tool to determine the main characteristics of the habitat by non-botanical experts, it was not deemed detrimental to the research if species that are unlikely to be noted by non-specialists were missed. An exception would be where the species is protected by legislation and likely to require specialist management. Species that may have been missed include those that occur as only a few specimens in a woodland. However, to allow comprehensive analyses in the development of the management tool all species, including rarities, were noted. Lower plants were also excluded on account of the specialist knowledge required for their identification. Sites were surveyed at different times of year to record the seasonal plants, such as vernals. A total of 127 surveys were conducted at the sites, shown in Figure 3.1, over a two year period (2004-2005) with additional data used from botanical surveys conducted by the author in August 2002 (four surveys), July 2007 (12 surveys) and June-July 2008 (six surveys).

Although the information gathering questionnaire (Section 1.1) was distributed across the UK, the sites identified as being suitable for further assessment were generally in clusters (Figure 3.1), and as such may not be completely representative of the habitat in the UK. Therefore, the data were supplemented from literature sources to ensure species typical of other geographical regions were also taken into consideration. Literature sources included the National and Local Biodiversity Action Plans, existing UK studies undertaken on the target habitat. Wildlife Trusts were approached for data relating to their Nature Reserves that included *Alnus glutinosa* woodland. The species lists from all sources were combined, with emphasis on the vascular plants, because vascular plant data obtained from literature sources was more readily and consistently available. Table 3.1 summarises the sources of data used in determining species occurring in lowland *Alnus glutinosa* woodlands. The subsequent species list was reviewed and, in order to standardise the list, records meeting any of the following criteria were excluded:

- only genus was recorded;
- species with restricted northern ranges as specified in Stace (2001);
- uncertainty as to whether the species occurred in the *Alnus glutinosa* woodland or adjacent habitats;
- specialists of brackish/coastal environments;
- undetermined species as a result of complex hybridisation;
- species known to have greater affinities to more upland habitats;
- bryophytes and algae.

Species associated with particular topography, or woodlands away from watercourses, such as in Peterken's (Peterken, 1993) spring line and plateau Stand Types, were retained. It is considered feasible that such species (should geographic and source pool conditions be suitable) could occur in lowland *Alnus glutinosa* woodland as a localised variation. For example, plants associated with drier conditions may occur up a bank away from the water table, or species more typical of wetter conditions may occur where there is a seepage/spring in otherwise fairly dry woodland.

The results of the data collection and analysis described above are provided in Chapter 4.

Source	Location of samples	Number of sites	Number of species recorded
McVean (1953)	Norfolk, Stirlingshire, North Wales, Inverness-shire, Dunbartonshire, Shropshire & Berkshire	11	146
Barfield *et al.* (1984)	Herefordshire & Radnorshire	127 grouped into 9 Stand Types	156
UK BAP (anon, 2003)	National, Lancashire, Staffordshire, Worcestershire, Northamptonshire, Devon, Sussex, Oxfordshire, Gloucestershire, Norfolk and Cambridgeshire	10 counties	78
Rodwell (1991)	NVC communities W5, W6 & W7 across Britain	267 grouped into 3 Communities	80
Rackham (2003)	Data primarily from Eastern England	1 list	18
Peterken (1993)	Data from across Britain	79 grouped into 7 Stand Types	127
Tansley (1965)	Data from across Britain	3	103
Original data collected during this research[1]	Derbyshire, Hampshire, Herefordshire, Hertfordshire, Leicestershire, London, South Yorkshire, Surrey, Warwickshire, Worcestershire	64	283

Notes. **1**. see Appendix 4 for details. Data from Herefordshire woodlands were collected in February/early March and therefore are unlikely to be a comprehensive representation of species occurring in the woodlands

Table 3.1 Data sources for determining species associated with *Alnus glutinosa* woodland

3.2 Species Potentially Endemic to Lowland *Alnus glutinosa* Woodland

3.2.1 Determining species potentially endemic to lowland *Alnus glutinosa* woodland

To identify species which can be used to differentiate lowland *Alnus glutinosa* woodland from other habitats the following approach was taken:

1. From the list of species compiled using the approach detailed in Section 3.1 (i.e. species found in lowland *Alnus glutinosa* woodlands) all species that occur in any other habitat as described by the NVC, except those found in W5 – 7 *Alnus glutinosa* woodlands, were removed.
2. To confirm their potential endemic status in lowland *Alnus glutinosa* woodlands, any species remaining on the subsequent list were considered in relation to their specific ecological requirements and geographical distribution as described by their Ellenberg indicator values and details in Stace (2001).

3.2.2 Lowland *Alnus glutinosa* woodland variability and ubiquity of component species

To illustrate the range of habitats in which species associated with lowland *Alnus glutinosa* woodlands also occur, all species identified (see Section 3.1) were considered in relation to their association with the main habitat types described by the NVC:

- Mire
- Heath
- Mesotrophic grassland
- Calcicolous grassland
- Calcifugous grassland
- Aquatic
- Swamp/tall herb
- Salt-marsh
- Shingle, sand dune
- Maritime cliff
- Open habitats
- Wet woodland (excluding W5-7)
- Mesic woodland
- Scrub.

The purpose of analysing the species associated with lowland *Alnus glutinosa* woodland in relation to other habitat types is to illustrate the variability of this habitat and the ubiquity of the constituent species.

The results pertaining to lowland *Alnus glutinosa* woodlands are provided and discussed in Chapter 4.

3.2.3 Review and justification of methods to determine species potentially endemic to lowland *Alnus glutinosa* woodland

Species listed as occurring in habitat types other than lowland *Alnus glutinosa* woodland would not be considered as endemic to the target habitat. However, other sources such as floras, and knowledge of the species ecological requirements, can be used for confirmation of species associations with habitats other than the target habitat. Objective, systematic filtering of data, using recognised data sources, has been used in other studies to remove anomalies/inconsistencies and to identify species specific to particular habitats (e.g. Kirby *et al.*, unpublished; McCollin *et al.*, 2000). For example, to identify woodland species that may colonise/disperse along hedgerows, McCollin *et al.* (2000) applied the following filtering system to a list of all species meeting Peterken's (1974) definition of woodland species:

1. removed canopy species since their presence in woodlands is influenced by management
2. removed species with Ellenberg light values less than 6 to "*objectively select species able to withstand shade*" (p.79)
3. removed species not included in the NVC woodland communities
4. removed species not identified by Stace (1991) as woodland or hedgerow species.

An alternative approach to determining species that are potentially endemic to the habitat include reviewing the habitats that each species is associated with in floras, e.g. Stace (2001), Biological Floras (as published in British Ecological Society Journals) and Ecoflora (Fitter and Peat, 1994). However, this is less robust, inconsistent (e.g. different sources may define habitats differently), less ecologically/habitat based and more generic. In contrast, the NVC (Rodwell, 1991 *et seq.*) is viewed to be the most current and comprehensive, single assessment of British habitats and their species. As Pywell *et al.* (2003, p. 67-68) noted "*The NVC is a systematic phytosociological description of British vegetation based on the description of 860 communities and subcommunities that have* *been derived by the analysis and interpretation of 35 000 sample vegetation stands together with their associated environmental data, such as management and soil type (Rodwell 1991–2000)*". Therefore, it is considered to be a near comprehensive data set which can be used as a baseline to identify species potentially endemic to lowland *Alnus glutinosa* woodlands. The NVC has also been used by other authors in similar situations. For example, Kirby *et al.* (unpublished) used the NVC to create groups of species associated with different habitat types and then compared these lists with lists of species associated with ancient woodland, to determine potential woodland specialists.

The method developed and used (Section 3.2.1) to determine species potentially endemic to lowland *Alnus glutinosa* woodland and illustrating the habitat variability and species ubiquity was loosely based on an approach used by Bunce *et al.* (1999a). Using MG5 grassland as an example, Bunce *et al.* (1999a. p.45) noted that "*many of the species that together typify MG5 grow in abundance in other communities where they exhibit patterns of joint association with other species and may even be used to characterise them.*" To identify species whose joint occurrences characterise MG5 habitats, they listed all species with a constancy of over three from the NVC MG5 floristic table and then removed species that were also common in other habitat types as defined by the Biological Records Centre grades. In the current research, the NVC was used to define species that are common in other habitats, as it was not providing the list of species under assessment.

As the approaches (determining potential endemic species and illustrating the habitat variability and species ubiquity) described in Section 3.2.1 and 3.2.2 are techniques developed for the current research, they were applied to two other habitats; one related, typical mesotrophic woodland NVC W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus,* and one contrasting, calcicolous grassland NVC CG3 *Bromus erectus*. The purpose of this repeat analysis was to ensure that the results of the method when applied to lowland *Alnus glutinosa* woodlands were not unique, but, the method could be applied in different situations. The results of this analysis (Appendix 5) showed that the species considered to be endemic to the habitats are rarely found in other habitats or situations. Their optimal growing conditions also show a strong reflection of the environmental conditions of each habitat. Since the results for W10 and CG3 show that the potentially endemic species for the habitat type have strong associations with the specific habitat, they can be described as endemic. It is, therefore, considered that the approach is valid in determining the potential endemic status of species within lowland *Alnus glutinosa* woodland.

3.3 THEORETICAL ENVIRONMENTAL CHARACTERISTICS OF LOWLAND *ALNUS GLUTINOSA* WOODLAND

This section details three approaches, based on established methods and readily available data, used to determine the environmental characteristics of lowland *Alnus glutinosa* woodland. The methodologies described below were applied to the species associated with lowland *Alnus glutinosa* woodland (see Section 3.1); the results are shown and discussed in Chapter 4. The methods detailed in Sections 3.3.1 and 3.3.2 (and discussed in Section 3.3.4) were also used to describe the detailed study site (see Section 3.5) and are reported and discussed in Chapter 6.

3.3.1 Determining the theoretical environmental characteristics of lowland *Alnus glutinosa* woodland using CSR-strategies of the component species

The life history strategies of the component species, as described by their CSR-strategy (Grime, 2001), are used to assess the environmental conditions of lowland *Alnus glutinosa* woodland in relation to competition, stress and disturbance (see Section 2.3.1). The contributions to each CSR-strategy made by species found in the target habitat were determined and illustrated utilising proportionate circles at the appropriate position within the CSR triangle of each strategy.

The mean CSR-strategy for species found in lowland *Alnus glutinosa* woodland was also calculated using the UCPE Sheffield CSR-Signature Calculator (V1.2) (Hunt, 2007b). The CSR-Signature Calculator determines the net position of the group of species within the CSR-triangle, based on the percentage contribution of CSR-strategies of the component species. Since the total has to add up to 100%, when used to calculate the character of lowland *Alnus glutinosa* woodland, the assumption is made that all species occur at equal cover values.

3.3.2 Determining the theoretical environmental characteristics of lowland *Alnus glutinosa* woodland using Ellenberg light and soil indicator values of the component species

To determine the light and soil conditions of lowland *Alnus glutinosa* woodland, the Ellenberg indicator values for light and soil (moisture, acidity, fertility) of the component species were considered. For each condition the contribution of species in lowland *Alnus glutinosa* woodland to each Ellenberg indicator value (see Table 2.9) was determined. Therefore, by looking at the number of species associated with each indicator value, it is possible to infer the habitat's characteristic environmental conditions.

3.3.3 Determining the theoretical environmental characteristics of lowland *Alnus glutinosa* woodland by considering associations of the component species to other habitats

While CSR-strategies and Ellenberg values indicate individual environmental characteristics, by considering the association species have with particular habitats, all environmental characteristics are reviewed simultaneously. The groundflora species identified as being associated with lowland *Alnus glutinosa* woodlands (see Section 3.1) were divided into two groups:

- Group 1: species that occurred as a 'constant'[1] in at least one NVC sub-community of the specified habitat AND in at least one other NVC habitat type;
- Group 2: species that only occur as a 'constant'[1] in the specified NVC habitat.

3.3.4 Review of methods used to determine the theoretical environmental characteristics of lowland *Alnus glutinosa* woodland

A review of the literature (see Table 3.2) indicated that light and soil conditions (moisture, acidity and fertility) were the most frequently considered environmental conditions when assessing and determining the environmental characteristics of a habitat. Similarly, a number of studies have considered the functional traits of component species, e.g. the CSR-strategy model (see Table 3.3). Therefore, these variables and traits were used to determine the environmental conditions of the current research target habitat.

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[1] Species are identified as 'constants' if they occur in at least 61% of the samples used to determine the given NVC community (Rodwell, 1991 *et seq.*).

Location	Habitat	Variables/approach	Outcome
Netherlands[1]	Roadsides – includes range of habitats from grassland, tall ruderals, hedgerows/ woodland margins, ephemeral and heath	F, N and R correlated with measured soil & vegetation parameters Sample site size: 25 m^2	F correlated well with average lowest moisture content in summer N only weakly correlated with soil parameters N strongly correlated with biomass production Species R values required regional adjustment R & pH were poorly correlated Mean site R values correlated with amount of Ca
Sweden[2]	Park-meadow	L, F, R, N Ordination of quadrat data and the use of Ellenberg indicator values to interpret the axis Use of ordination to estimate indicators values for species where they are unknown	Ellenberg indicator values can be useful when there is limited measured environmental data
Sweden[3]	Deciduous hardwood forests (Boreo-nemoral zone)	L, F, R Weighted averages correlated with field measurements	R values were highly correlated with field measurements, L also significant correlation but F was less well correlated. Weighted abundance and presence/absence data drew similar conclusions
Poland[4]	Woodland (ancient & recent)	L, R, N Compared soil and light conditions with mean indicator values of the species (both as an abundance-weighted mean and on presence/absence) Use of Ellenberg values to characterise environment of ancient & recent woodlands	L, R & N are relatively good predictors of conditions in ancient woodlands but correlations were weaker for recent woodlands. In both woodland types the correlations were significant using both weighted and presence/absence means
Poland[5]	*Alnus glutinosa* woodlands	Review species colonisation rates in ancient and recent *Alnus glutinosa* woodlands and comparison of behaviour of species described as *Alnus* ancient woodland species (AAWS) and other ancient woodland species (OAWS)	"*appeared to be effective in confirming differences in ecological behaviour of species from AAWS and OAWS groups*" p.307
Eastern Scotland & Yorkshire, UK[6]	Woodland	F, R, N Compares soil analysis with mean indicator values of the plants	Abundance weighted means for R and N could be used as substitutes for soil analysis providing sufficient cover of species with Ellenberg values were present within the site Abundance-weighted means for F, although less strong also reflected actual soil measurements

Table 3.2 Summary of studies using Ellenberg indicator values to estimate environmental conditions within a habitat or site (Table continues)

Location	Habitat	Variables/approach	Outcome
Britain[7]	Woodland – semi-natural and plantation	R and N tested against measured soil chemistry Used abundance weighted mean of species Ellenberg values	Mean R & N site values satisfactorily correlate with the measured parameters
Somerset & Cambridgeshire, England[8]	Wetland vegetation	Use of F to characterise the vegetation of grazing marsh, ditches and wet grassland	F values correlate with: ditch water depth (ditches), mean depth of water-table and degree of fluctuation (grasslands) Mean F values can be used to characterise vegetation communities as well as individual quadrats. Mean F value can quantify the impact of changes in water-table
Wales[9]	Wet woodland	Use of Ellenberg values to interpret DCA ordinations of wet woodland sites	12.6% of the variation between sites was explained by pH, nutrients and light (axis 1) and soil wetness, pH, nutrients and temperature (axis 2)
Data sources **1.**Schaffers & Sýkora (2000); **2.**Persson (1981); **3.**Diekmann (1995); **4.**Dzwonko (2001), Dzwonko & Loster (1997); **5.**Orezewska (2010); **6.**Hawkes *et al.* (1997); **7.**Wilson *et al.* (2001); **8.**Mountford & Chapman (1993); **9.**Latham *et al.* (2000)			

Table 3.2 cont. Summary of studies using Ellenberg indicator values to estimate environmental conditions within a habitat or site

Location	Habitat	Use	Outcome
UK[1]	Floodplains – woodland, grassland, swamp	Assessed the contribution of CSR-strategies in different floodplain habitats in areas of pooling and not pooling following flood events, to assess potential implications of nutrient deposits/enrichment.	Results were inconclusive as a result of inconsistent data over an insufficient length of time but there was an indication that the trends emerging were consistent with narrative data from various surveys and reports
UK[2]	Grassland	As a functional trait (along with others, e.g. Ellenberg, NVC) to inform restoration decisions	"*Such indices of performance and a knowledge of the traits associated with successful establishment and persistence in restored vegetation are potentially of great benefit to practitioners and policy makers involved in restoration*" (p.73)
UK[3, 4]	Various	Studied the dominance of strategists in different environments, to detect change, and indicate early warning of long-term trends, in vegetation. Analysed the abundance of CSR-strategies across Britain	C-strategists dominated in productive environments with limited disturbance. R-strategists dominated where disturbance was more frequent. E.g. ruderal (R) strategists predominated in arable habitats while stress-tolerators (S) predominated in mountain habitats Detectable shifts in CSR-strategy abundance over time as a consequence of landuse change

Table 3.3 Summary of studies using CSR-Strategies to describe the places in which a habitat occurs (Table continues)

Location	Habitat	Use	Outcome
UK[5]	Hedgerows	To investigate the species composition of hedgerows and green lanes	"*1. plant species occurring on the central track of green lanes have the lowest value for Competitors and Stress-tolerators, and the highest value for Ruderals, indicating a higher amount of disturbance than the other parts of the lanes* *2. The inside verges of green lanes exhibit a higher Competitor, and Stress tolerators value than all other areas of lanes and matched single hedgerows, whereas they have the lowest Ruderal value – significantly lower than all other lane areas (p<0.05) indicating that the 'inside' species are subject to lower disturbance than elsewhere*" (p.2602)
Northern Ireland[6]	Hay meadows, woodland, heather moorland, wet grassland, limestone grassland, unimproved grassland	Used proportion of species in each strategy to review: a) temporal change within a habitat, b) differences between difference managements of the same habitats c) differences between habitats	Study showed: a) some temporal differences, b) no difference between management, c) differences between habitat types
Poland[7]	*Alnus* woodlands	Review species colonisation rates in ancient and recent *Alnus glutinosa* woodlands and comparison of behaviour of species described as *Alnus* ancient woodland species (AAWS) and other ancient woodland species (OAWS)	AAWS had more C- and S-strategists. OAWS had more CR- and SR-strategists. Both groups had more or less equal species of CSR- and CS-strategists. "*appeared to be effective in confirming differences in ecological behaviour of species from AAWS and OAWS groups*" p.307
Belgium[8]	Oak-beech forest	Used the CSR-strategy to develop a novel approach to detect sites where competition, disturbance or stress dominated.	C-, S- and R-species clustered in certain areas At a scale larger than 50 x 50 m, plants with different strategies were aggregated
Data sources **1.**Miller *et al.* (2008); **2.**Pywell *et al.* (2003); **3.**Firbank *et al.* (2000); **4.**Grime *et al.* (2007); **5.**Walker *et al.* (2006); **6.**McAdam (1999); **7.**Orczewska (2010); **8.**Massant *et al.* (2009)			

Table 3.3 cont. Summary of studies using CSR-Strategies to describe the places in which a habitat occurs

To determine the characteristics of, and indications of variation in, lowland *Alnus glutinosa* woodlands, the groundflora is considered to be the most significant variable. This is also reflected in the woodland NVC accounts (Rodwell, 1991) in that, generally, the groundflora characteristics are used as the second tier diagnostic features of communities and sub-communities, following the larger, woody species. Rackham (2003. p.23) commented on the fact that the canopy layer was tolerant of a wider range of environmental conditions than the groundflora and "*vegetation boundaries are often determined by slight and subtle influences – a slope of less than one degree, or a small* *change in the depth of topsoil ...*" He also noted that the occurrence of a tree in a given location is not so much related to the conditions being suitable for its survival, but rather whether it had the opportunity and conditions for establishment; this may be natural or artificial, e.g. planted.

However, to review the potential implications of larger woody species (i.e. canopy and shrub layers) skewing the results, on account of their wider tolerance of environmental conditions compared to the groundflora, the analysis detailed in Section 3.3.1 and 3.3.2 was conducted on each layer (groundflora, shrub and canopy) separately as well as together. The assessments were completed using the species list defined by the methodology described in Section 3.1, i.e. the species found to be associated with lowland *Alnus glutinosa* woodland.

As noted by Pywell *et al.* (2003, p.67), the CSR-strategy model, Ellenberg indicator values and the plant associations in the NVC are three "*widely available generic classifications of plant ecological characteristics*" and the data are generally readily available in the literature. They commented that "*this facilitates the use of these common traits in other studies and also introduces a degree of independence to the analyses in that the traits were not measured in the same experimental restorations that provided performance data.*"
A review of the literature and work undertaken on floodplain habitats by the author (Miller *et al.,* 2008; 2008a), has shown that environmental conditions of a habitat can be determined by analysis of the CSR-strategies and optimal light and soil conditions (as indicted by Ellenberg indicator values) of the component species. These two approaches (CSR-strategies and Ellenberg) are discussed further.

Life history strategies

The validity of plant strategies, such as CSR (Grime *et al.,* 2007), to describe the places in which a habitat occurs has been demonstrated in other studies, see Table 3.3 for examples. The examples in Table 3.3 indicate that the CSR-strategies within a community are reflective of environmental conditions and that trends in environmental conditions can be identified at both a countrywide and site scale through analysis of the physiology of the component species. Therefore, by determining the proportion of species associated with each CSR-strategy, the general conditions of a habitat, or site, can be identified (e.g. Hunt, undated).

Although there are an infinite number of CSR-strategies, only the 19 readily recognised ones (Grime, 2001 (1979)) are considered during this analysis. Other authors, such as Bunce *et al.* (1999), have illustrated the percentage of species in each CSR-strategy within a habitat with numeric figures depicted at each location within the CSR triangle or as pie-charts. However, Miller *et al.* (2008) considered that the relative contribution from each strategy can be illustrated more clearly, and allow better visual comparison, utilising proportionate circles at the position (within the CSR triangle) of each strategy.

Light and soil conditions

Although developed using Central European species, Ellenberg indicator values have been found to be relevant to a number of other geographical areas, Persson (1981). However, in some instances, including Britain, the values have been recalibrated to better reflect the conditions in which the species grow in the specific geographic regions. The Ellenberg values used in this research are those recalibrated by Hill *et al.* (2004).

Ellenberg indicator values, as estimates of environmental conditions within a habitat, have been successfully used in other studies, for example Latham *et al.* (2000) and Wheeler *et al.* (2001); see Table 3.2 for a summary of some sample examples. Several of the studies detailed in Table 3.2, e.g. Hawkes *et al.* (1997), found that weighted means generally produced better correlations with the measured environmental variables. In some instances (e.g. Schaffers and Sýkora, 2000) there was no apparent difference in the correlation of site and average indicator value when a weighted mean was used, based on abundance compared to presence/absence data. It is generally accepted (e.g. Persson, 1981) that the indicator values of a group of species, rather than individual species, provides a better indication of environmental conditions. Dzwonko (2001) suggests that the accuracy of using species and associated indicator values, such as Ellenberg, to predict environmental conditions may relate to the age and stability of the habitat under assessment. For example, they found that Ellenberg indicator values better predicted conditions in ancient woodlands than recent secondary woodlands, and suggested that there is a time-lag for species to fully reflect local situations, given that many tolerate a spectrum of conditions. However, commentary by Rackham (2003), suggests that species from a preceding habitat, such as grassland, can persist, in some cases, for many years after woodland has established.

Ewald (2003) assessed the success of using Ellenberg indicator values to predict environmental conditions, when a complete set of species data was not available. It was found that even when the low abundance species were excluded, the correlation with the environmental variable was similar to when all species were included in the calculations.

Miller *et al.* (2008) used Ellenberg indicator values to determine environmental conditions within floodplains, using theoretical communities (i.e. NVC floristic tables) and actual communities (species composition) of various woodland types and other habitats. The results showed that for both theoretical communities and for actual species compositions, the conditions matched those described by the NVC for the given habitat and conditions recorded on site. Additionally, similar environmental characteristics of wet woodlands have been described using different approaches; Rodwell (1991) utilised collected data, ecological observation and interpretation, and Wheeler *et al.* (2001) utilised the WETSPEC database. The mean Ellenberg indicator values of the constituent species of vegetation communities have successfully been used to determine the requirements of the given community (e.g. Firbank *et al.,* 2000).

Although these examples (and those in Table 3.2) confirm that the approach using floristic data is valid for describing and identifying the environmental conditions at a site, an element of precaution in interpreting the results is necessary. Mountford *et al.* (2005) noted in relation to soil moisture, that it is not solely the optimal level of water in the soil that determines the presence of species, but also the temporal aspect: e.g. some plants have the same optimal overall wetness but require particular levels of wetness at different stages of their life cycle. Mountford *et al.* (2005), however, did acknowledge that the mean Ellenberg value for a site was a valuable tool to investigate the site's characteristics. It is also noted that as a result of the interdependent nature of the Ellenberg indicators values for each species, caution needs to be applied when interpreting the results (Firbank *et al.*, 2000). In addition, care is needed as a result of the fact that plants can tolerate and grow in a range of conditions outside their optimal (i.e. Ellenberg indicator value). The degree of tolerance may also vary with the environmental condition under consideration. For example, a species may have a wide tolerance of light conditions, but have a very specific requirement for soil moisture. In another situation, species growing in their optimal soil moisture condition may tolerate a soil fertility outside its optimal, while if it is outside its optimal soil moisture it may have low tolerance of fertility beyond its optimal. Prieditis (1997) found that mean Ellenberg light values for *Alnus glutinosa* woodlands across the

Baltic Region showed little variation despite the wide geographic range and differences of floristic components of the woodlands. This suggests that light is less likely to be significant in determining the variation in floristic composition between lowland *Alnus glutinosa* woodlands.

<u>Habitat associations</u>

Whereas the CSR-strategy and Ellenberg indicator value approaches to determine the environmental characteristics of a habitat consider one characteristic at a time, the use of species associated with a habitat are more likely to take account of the interaction of single variables and provide a more encompassing description of environmental conditions. Different habitats have different environmental conditions and, therefore, the species composition reflects the specific conditions of the habitat. For example, Wulf (2003) reported that woodland species, in their strictest sense, are those that are shade tolerant and occur in the centre of the woodland. However, when considered in a wider sense woodland plants include light demanding species associated with glades, edges and non-woodland habitats and the latter notably, also occur in meadows and pasture. Therefore, by considering the 'faithfulness' and proportion of species to different habitats, the environmental conditions can be inferred. Here, 'faithfulness' is 'measured' by the NVC constancy values of species in relation to the communities. Species are identified as 'constants' if they occur in at least 61% of the samples used to determine the given NVC community. It was assumed that if a species occurred as a 'constant' within a given community, it had strong affiliations with the environmental conditions of that community. Where species occurred as 'constants' across a range of different communities of differing environmental conditions, the species are more likely to be generalists or that there is a similarity of conditions between the communities.

The approach detailed in Section 3.3.3 makes the following assumptions:

1. Species included in Group 1 are likely to have strong associations with the conditions of such habitats, but will also occur in other habitats.
2. Species included in Group 2 are likely to be more specialist species with a narrower tolerance of different conditions and therefore have stronger associations with the conditions of the given habitat.

In support of these assumptions, Pywell *et al.* (2003, p.69) noted that "*Habitat specialists (H4) were indicated by …presence in a low number of NVC communities and a low NVC* *constancy score*." They also found that generalist species occurred in a large number of different communities.

The NVC has been used by a number of other authors as a baseline by which to compare species groups. For example, Kirby *et al.* (unpublished), compared ancient woodland indicator species lists against species occurring in woodland and 'non-woodland' habitats as derived from the NVC floristic tables. They produced the 'woodland' and 'non-woodland' lists from plants occurring in nine of the broad habitat types (i.e. swamps, mires, mesotrophic grassland, upland and acidic grassland, calcareous grassland, heath, sand dunes, maritime cliffs and woodland). Pywell *et al.* (2003, p.67) used the NVC to "*calculate measures of habitat specificity and dominance for each species*". The former used the number of NVC communities that the species occurred in while the latter used the constancy of species. Bunce *et al.* (1999a) used the NVC to assess botanical quality and change over time while McCollin *et al.* (2000) used the number of NVC woodland communities that species occurred in as an autecological indicator of within habitat amplitude when considering the use of hedgerows by woodland species. The latter found that plants frequent in hedgerows generally were associated with fewer NVC woodland types compared to plants that were more frequent in woodland.

3.3.5 Alternative approaches to describe the environmental character of a habitat

Other approaches, as outlined in Chapter 2, could have been used to determine the environmental characteristics of lowland *Alnus glutinosa* woodlands. The data gathered by Grime *et al.* (2007) were considered to be too restrictive, in that data were not available for a comprehensive number of species and that characteristics of species were determined from a small area of the UK, i.e. Sheffield region.

An alternative to using the CSR-strategy (Grime, 2001) to assess the effects of competition, floristic composition and environment conditions is Tilman's Resource Theory (Tilman, 1982) based on US data. However, a review of the literature found Grime to be both more ecologically-based (as opposed to mathematical) and more influential in European studies than Tilman, and consequently has been used in this current research. For example, considering Tilman and Grime, Cerabolini *et al.* (2010, p.254) found the CSR-strategy to be "*consistent with contemporary biology at a range of scales* [and] *can be applied* <u>in situ</u> *rather than an abstract mathematical model, to predict, quantify and compare community structure…and ecosystem processes*". They also found numerous references where Tilman's theory repeatedly failed, although acknowledge the uncertainty of application of CSR beyond Britain. Although there has been much debate (e.g. Grace, 1991) over the last 30 years or so about the approaches Grime and Tilman, and their respective advocates, followed in relation to competition, for the current research Grime's CSR-model was chosen having reviewed its use in the literature, some of which is summarised in Table 3.2. The validity of Grimes' CSR-model has also been shown to have been successfully applied in a range of different situations (see Section 3.3.4 and discussion above on life-histories). Of particular relevance to the current use of the CSR-model is the study by Massant *et al.* (2009), who used the model to detect sites where competition, disturbance or stress dominated.

3.4 THEORETICAL NICHES OF A HABITAT (NOAHS)

Variation in floristic composition of woodlands can be considered at two main levels: between sites and within sites. This research considers variation within a site and is referred to as intra-site variation or Niches of a Habitat (NoaH). Intra-site variation is taken as reflecting small scale influences on the vegetation composition within a given site, for example localised standing water, a glade or raised ground, giving rise to small scale heterogeneity within a habitat (e.g. see Douda, 2008).

Various studies in the literature (e.g. Rodwell, 1991; Douda, 2008; Prieditis, 1997) indicate that intra-site variation can occur in response to a number of abiotic factors. For example, in W5a (*Phragmites australis* sub-community) woodlands, Rodwell (1991) found that *P. australis* is only frequent where the canopy remains open, suggesting that light levels are a factor in dictating its distribution and abundance within a woodland. Prieditis (1997) found that the more diverse *Alnus glutinosa* woodlands were those where underground water flow created areas of standing water and surface run-off in close proximity to drier areas of raised hummocks. Subsequently species associated with drier conditions, stagnant water and submersed/floating species all co-existed. In several of the *Alnus glutinosa* woodlands described by the NVC, Rodwell identified examples of groundflora species that showed preferences for drier or wetter conditions. Examples are provided in Table 3.4 which, for reference, also shows the corresponding Ellenberg indicator values for each species.

NVC community	Species with preference for drier conditions (Ellenberg F value)	Species with preference for wetter conditions (Ellenberg F value)
W6a	*Arrhenatherum elatius* (5)	bulky monocotyledons (N/A)
	Heracleum sphondylium (5)	
W6b	*Dryopteris dilatata* (6)	*Iris pseudacorus* (9)
	Poa trivialis (6)	*Galium palustre* (9)
	Ranunculus repens (7)	
W7a	*Allium ursinum* (6)	**Shallow free flowing surface water**
		Chrysosplenium oppositifolium (9)
		Areas of stagnant waters
		Chrysosplenium alternifolium (8)
		Caltha palustris (9)
		Cardamine amara (9)

Table 3.4 Examples of species preferences for contrasting soil conditions within the same sub-community (as discussed in Rodwell, 1991) and the species corresponding Ellenberg indictor values

Wilson *et al.* (2001. p.114) concluded that:

> "*the relative abundance of a small number of common species in the ground vegetation on a site offers a convenient qualitative method of predicting the soil nutrient regime without recourse to soil sampling and chemical analysis.*"

They also noted that Ellenberg indicator values, or similar, are appropriate substitutes for soil analysis, while Hawkes *et al.* (1997) observed that plants (and soil humus) provide a better understanding of the ecological and biodiversity value of a site than soil quality alone.

Corney *et al.* (2006) found that soil pH, areas of wetness, large glades and slope accounted for the majority of the variation within woodlands, in general, in Britain. The first three of these factors can readily be substituted by using Ellenberg indicators values, (i.e. soil acidity, soil moisture and light). However, as a result of their small size and location in floodplains, large glades and slope will be of low relevance to lowland *Alnus glutinosa* woodlands.

Environmental variation of different conditions does not occur in isolation, but rather as a complex interaction and as such species composition varies accordingly. For example, Rodwell (1991) found that in W7a (*Urtica dioica* sub-community) woodland *Mercurialis perennis, Geum urbanum, Geranium robertianum* and *Circaea lutetiana* occur in drier locations with some base-enrichment, and that *Brachypodium sylvaticum* may occur in similar conditions in W7c (*Deschampsia caespitosa* sub-community) woodland. However, the two sub-communities are differentiated by the degree of waterlogging and the nature and supply of water: W7a is typically associated with eutrophic, free-draining brown alluvial soils with a high water table, while W7c is usually associated with brown earths, sometimes with gleying, or soils kept moist as a result of impeded drainage. Also in W7c, *Anthoxanthum odoratum* and *Agrostis capillaris* may occur in drier areas (Rodwell, 1991), but are likely to occur in greater abundances where there is disturbance, such as that caused by grazing animals.

These examples suggest that local variation in conditions, such as light and water, create corresponding localised changes in floristic composition.

Although riparian zones are known to be species-rich and communities are typically productive and dynamic, little is known about how influencing factors interact (Xiong *et al.*, 2003). However, while acknowledging that floodplain forests are species-rich habitats, Peterken and Hughes (1995) reported that individual stands may be less rich and dominated by a single species, e.g. *Urtica dioica*, with a few others. As discussed in Section 2.3 floristic composition is influenced by a number of different factors and Chapter 4 demonstrates that lowland *Alnus glutinosa* woodlands are diverse and variable habitats.

As previously discussed (Section 3.3.4) groups of species with similar Ellenberg indicator values and CSR-strategies reflect the conditions in which the plants grow. For example, if there is a high proportion of species associated with open water (F values 10-12), it suggests that a pond is present within the site or, as recognised by Grime, C-strategists indicate greater fertility, while R-strategists indicate localised disturbance. Massant *et al.* (2009) tested the expectation that plants with similar strategies (e.g. CSR) will occur together in ecological space where conditions are similar. To do this they posed two questions:

1. Do Grime life strategies form patterns at a meso-scale (larger than 50 m x 50 m) or are they just randomly distributed?
2. Does forest management control these patterns?

This research investigates whether CSR-strategies can also be used to describe groups/associations of species at a more detailed scale than that used by Massent *et al.* (2009), i.e. intra-site variation, less than 50 x 50 m.

In Section 3.3.4 it was noted that the canopy, shrub and the groundflora composition do not necessarily vary simultaneously (i.e. a change in one is not necessarily reflected in the other) and that the groundflora generally provides a better indication and understanding of the natural conditions. Groundflora composition often indicates changes in the soil nutrient regime, e.g. Wilson *et al.* (2001), and is likely to be more sensitive and responsive to minor variation in conditions compared to shrub and canopy species. In a detailed study of Bradfield Woods (UK), to provide some understanding of the complexities of vegetation communities within the wood, Rackham (2003) applied separate ordination analysis on the groundflora and underwood (shrub layer), making the assumption that the variation in trees and herbs is not dependent on one another. The relationships between sample plots were interpreted in terms of actual species assemblages and, wherever possible, the ordination axes were correlated with measurable environmental factors:

> "*Bradfield* [Woods] *analysis bears out the general conclusion that factors influencing tree distribution are more subtle than those affecting ground vegetation and are not so easily accessible to measurement, at least from the soil surface. Herbs are of more value as indicators of pH, drainage, and other surface factors*" (Rackham, 2003. p.32).

As previously inferred, the groundflora is most likely to show specific, local variation in relation to subtle changes in environmental conditions within a site. The canopy and shrub layer are more likely to tolerate a wider range of environmental condition, at least in part, as a result of their larger size and longer lifespan. The analysis described in the following sections does not take location in relation to sites into account as it was not the intention to classify the sites, more to predict which species could theoretically occur in similar conditions.

The majority of the studies discussed in Section 3.3.4 considered the environmental conditions of the whole site, rather than the variation within the site. However, Mountford and Chapman (1993) showed that the calculated mean soil moisture (Ellenberg F value) can be used at both site community level and for individual quadrats. Kirby *et al.* (unpublished) showed that the range and mean Ellenberg indicator values differed between three groups of species found within woodlands:

1. Ancient woodland (woodland specialists)
2. Other woodland (strong association with woodlands)
3. Non-woodland (weaker association with woodlands).

They demonstrated that Ellenberg indicator values can be used to differentiate between habitat types, even those that may be considered broadly similar, i.e. ancient and secondary woodland.

These two studies (Mountford and Chapman, 1993; Kirby *et al.,* unpublished) suggest that the use of Ellenberg indicator values may be sensitive enough, and appropriate for, determining localised heterogeneity within a community, i.e. intra-site variation. The approach used in the current research is described below in Sections 3.4.1 and 3.4.2.

3.4.1 Identifying potential NoaHs in lowland *Alnus glutinosa* woodlands, based on CSR-strategies and Ellenberg indicator values of the component species

Initially, individual CSR-strategies and Ellenberg indicator values of the component species were examined to identify potential Niches of a Habitat (NoaHs) of lowland *Alnus glutinosa* woodland. For the purposes of this research NoaHs are taken to be specific locations in a habitat described by a given set of environmental characteristics, defined by the preferred growing conditions and strategies of the habitat's component plants. The results of the methods described in this section are detailed and discussed in Chapter 5.

The first step to identifying potential NoaHs was to group (list) species associated with the target habitat according to their CSR-strategies and Ellenberg indicator values (see Section 2.3.1). Taking the various environmental variables in isolation (competition, stress and disturbance, and, light and soil moisture, acidity and fertility) 58 potential groups can be defined:

- CSR – 19 groups (see Section 2.3.1)
- Light – 9 groups (Ellenberg L1-9)
- Soil moisture – 12 groups (Ellenberg F1-12)
- Soil acidity – 9 groups (Ellenberg R1-9)
- Soil fertility – 9 groups (Ellenberg N1-9).

However, it is considered that the 19 readily recognised CSR-strategies plus the 39 Ellenberg indicator values provide too fine a detail for the ultimate aim of this research (implementing appropriate management at site level). In addition, there is little potential difference between managing for different conditions, e.g. highly acidic and for moderately acidic soils. Therefore, the groups were reviewed based on the following to determine a more appropriate level of differentiation:

- hierarchy of CSR strategies (see Section 2.3.1);
- CSR groupings commonly used by other authors (e.g. Kirby *et al.*, unpublished);
- available CSR data for species (Hunt, 2007b);
- number of species associated with different optimal growing conditions (Ellenberg indicator values).

To avoid confusion between these reduced groups and the original CSR-strategies and Ellenberg indicator values, they have been termed Characteristics of a Habitat; CoaH.

The method in Section 3.3.4 considered the average condition across all species associated with lowland *Alnus glutinosa* woodland (as determined by approach detailed in Section 3.1). Here the range and distribution of conditions are considered for groundflora species alone. The range and distribution of CSR-strategies and Ellenberg indicator values (and therefore CoaHs) within the groundflora species are considered to be a reflection of different conditions within the woodlands. Lists were produced comprising species with the same CoaH. A CSR-triangle was produced to illustrate the contribution of species to each CSR-CoaH and, as in Section 3.3.1, the contributions of species to each CSR-strategy are illustrated by proportional circles rather than numerical values. The contributions of species to each Ellenberg-CoaH (i.e. light, moisture, acidity, fertility) are illustrated in pie charts for ease of visual comparison.

3.4.2 Identifying potential NoaHs in lowland *Alnus glutinosa* woodlands, by combining the CSR-strategies and Ellenberg indicator values of the component species

As previously discussed at the start of Section 3.4 the floristic distribution and composition is determined by a number of interacting factors. Therefore, this section details a more encompassing approach that accounts for various conditions simultaneously in order to determine potential NoaHs in lowland *Alnus glutinosa* woodland (Section 3.4.1 considered the conditions independently from one another).

The approach described below simultaneously considers life-history strategies and environmental conditions by combining CSR-strategies (Grime, 2001) with Ellenberg indicator values (Hill *et al.*, 2004) using multivariate analytical techniques. The approach follows that of Shreeve *et al.* (2001). See Section 2.3.1 for discussion on CSR-strategies and Ellenberg values.

Having grouped the species according to their CSR-strategy and Ellenberg indicators separately (Section 3.4.1), the strategies and values were then combined. With 46 variables, this gives 61,236[2] possible combinations, although it is anticipated that not all combinations will occur in lowland *Alnus glutinosa* woodlands, as it is unlikely that there will be representative species from each individual Ellenberg value or CSR-strategy. For example a woodland is not going to have species represented by Ellenberg light value 9, i.e. full light, mostly in full sun (Hill *et al.*, 2004), or wet woodland (e.g. *Alnus glutinosa*) will not be extremely dry with soils often drying out for some time, i.e. Ellenberg soil moisture value 1 (Hill *et al.*, 2004). Therefore, an approach was needed to identify a more manageable and realistic set of intra-site variation in conditions. It was expected that following the determination of the contributions of species to each Ellenberg value and CSR-strategy and the subsequent ranges of variables, it might be feasible to group some together and therefore reduce the number of potential combinations.

The species associated with lowland *Alnus glutinosa* woodland were classified (i.e. grouped into discontinuous categories) using Two Way Indicator SPecies ANalysis (TWINSPAN; Windows Version 2.3, Hill and Šmilauer, (2005)) according to their CSR-strategies and Ellenberg indicator values. The input data used in the TWINSPAN analysis consisted of a species x character (Ellenberg value and CSR-strategy) matrix. This matrix comprised binary data following an approach described by Shreeve *et al.* (2001), i.e. for each environmental condition/life history strategy (CSR-strategies and Ellenberg indicator values) each species was given either a ‘1’ or ‘0’. If a species was described as, for example, C/CSR, both C and CSR were indicated by a ‘1’, all other CSR-strategies were indicated by a ‘0’. Therefore, each species was described by a series of 37 ones and zeros (see Appendix 6). Species were coded for all variables and all variables were given equal weighting to remove any bias to particular conditions. Only CSR-strategies and Ellenberg indicator values occurring in the data set were used, i.e. none of the species had Ellenberg light indicator 1 or 2 and, therefore, these were not used in the binary state. This resulted in the following ranges;

- light: 3- 8;

[2] 7 CSR x 9 Light x 12 Moisture x 9 Acidity x 9 Fertility

- soil moisture: 4 - 12;
- soil acidity: 2 - 8;
- soil fertility: 2 - 9;
- CSR-strategy: C, CR, CSR, R, S, SC, SR and no value.

The input data were analysed using the standard parameters of the TWINSPAN statistical package (Hill and Šmilauer, 2005). The significance of the differences between the output groups, based on the mean Ellenberg and CSR-values of the constituent species, was assessed in Excel (Microsoft, 2003) using an ANOVA function. The groups were considered to be significantly different when the F value (i.e. between sample variance/within sample variance) exceeded the F-critical value at a confidence level (P) of at least 0.01. The F-critical and P values were automatically calculated by Excel during the analysis.

The output species groups were then used to identify groups of species following ordination by Detrended Correspondence Analysis (DCA) using Canoco 4.5 (Ter Braak and Šmilauer, 1997). Ordination by DCA places the input species relative to continuous scales (axes) which can then be defined through interpretation and understanding of the species autoecology. The input data were the same as that used for the TWINSPAN classification, i.e. species x character matrix. This matrix was analysed using the standard parameters of Canoco 4.5 (Ter Braak and Šmilauer, 1997). For clarity of data interpretation through reducing the influence of rare species and minimising skewed effects of the data, species were down weighted and log transformed. The axes Eigenvalues of the output provided a measure of the importance of the ordination axes so were, therefore, reviewed to determine which axes explained the greatest amount of variance. The axes explaining the greatest variance (i.e. Eigenvalues >0.3, Shaw (2003)) were subsequently investigated further in the output graphs and were interpreted using the following aids:

- Colour coding the species in accordance with their associated Ellenberg and CSR values;
- plotting an *xy* scatter graph of the species scores of the ordination axis (scatter graph *y* axis) against the species Ellenberg or CSR value (scatter graph *x* axis). The significance of the correlations with various variables and the ordination axes were assessed using the product moment correlation coefficient (r) (Equation 3.1, Fowler

et al., 1992), where *y* is the variable value (e.g. Ellenberg value or CSR-numerical value (Hunt, 2007a)) and *x* is the ordination axes value:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \qquad \text{(Eqn. 3.1)}$$

The statistical significance of the correlations was determined through consulting a probability table for r at number of pairs less two degrees of freedom (Fowler *et al.*, 1998). The strength of the correlations between ordination axes value and environmental/life history strategy variables is described as detailed in Table 3.5.

Value of r (either positive or negative)	**Description of correlation strength**
0.00 – 0.19	Very weak
0.20 – 0.39	Weak
0.40 – 0.69	Modest
0.70 – 0.89	Strong
0.90 – 1.00	Very strong

Table 3.5 Strength of product moment correlation coefficient
(as described by Fowler *et al.*, 1998)

It is suggested that points in ordination space which are greater than four standard deviation (s.d.) units (ordination axes units) apart are most dissimilar (Jongman *et al.*, 1995). The species groups determined following TWINSPAN classification and DCA ordination were further investigated by considering the number of species associated with the main CSR-strategies and Ellenberg values described in 3.3.1 and 3.3.2.

Potential NoaHs were, therefore, initially determined using statistical methods: TWINSPAN classification and subsequently reviewed using DCA ordination. Since ecology is not a pure mathematical subject and, although generalisations can be made, plant communities respond to many more factors, and combinations of factors, than can be considered by statistics alone. Therefore, these groups of species were then individually assessed and reviewed using autecological knowledge (from both the literature and experience) of the component species to refine the groups and determine their practical differences, in terms of management, in environmental conditions that the species describe.

3.4.3 Review of approaches used to identify NoaHs

Although, as shown at the start of Section 3.4, CSR-strategies have been used to show differences between habitats and locations, there is little evidence in the literature that CSR-strategies have been used to identify variation within the groundflora and how it may relate to potential future management. Therefore, the approach developed and used here is considered to be a pilot and it is recommended that it is tested further.

As discussed in Section 3.3.4, both Ellenberg indicator values and CSR-strategies have been used in a number of studies, both separately and in parallel (e.g. Pywell, 2003; Willi *et al.*, 2005) to describe variations within the flora. Although a few species can be used as indicators of a condition, the condition is less likely to be of sufficient area to implement specific management if it is only represented by a low number of species. An exception would be when the component plants have the ability, or tendency, to form extensive near monocultural stands, e.g. *Phragmites australis*. For practicality of management the level of detail of variation could not be too specific. The groups of species indicating different conditions could also not be so small so that sufficient plants are not encountered, for example although 269 species were found to be associated with lowland *Alnus glutinosa* woodland (see Section 4.3), the number of species occurring in one site may range from four (1.5%) to 82 (30%) species with an average of about 30 (11%) (data based on the 64 sites surveyed during the current research; see Section 3.1). Since CSR-strategies and Ellenberg values indicate the optimal, rather than tolerance range, of species it was considered viable to merge similar conditions together. The merging of conditions was based on the composition of species associated with each Ellenberg value and CSR-strategy and the species' autoecology; this is discussed further in Chapters 5 and 7.

Therefore, the first step in determining NoaHs (Section 3.4.1) was to reduce the number of CSR-strategies and Ellenberg indicator values to describe intra-site variation at a level appropriate for the management of woodlands. CSR-strategies are regularly reduced to the seven main and intermediate strategies (see Tables 2.10 and 3.3). Similarly simplifications of Ellenberg values have been used in other studies. For example, Critchley *et al.* (2010. p.15) divided the species into high and low fertility (values 6-9 high; 1-5 low), light (values 7-8 high; 1-6 low) and acidity (values 7-9 high; 1-6 low) groups with "*cut-off levels being specified after examination of the frequency distributions of the values across all species to ensure that approximate equal numbers of species were in each category.*"

Although CSR-strategies and Ellenberg indicator values do not appear to have been combined, studies have shown, e.g. Walker *et al.* (2006), that the two sets of plant traits are significantly correlated. Therefore, it is suggested and explored in this current research that, by combining the two sets of plant traits, e.g. through multivariate analysis (Section 3.4.2), a more comprehensive review of plant associations could be investigated. However, problems in data analysis of multivariate attributes can occur where values cover very different scales or do not have a numerical value. Different approaches to resolve this problem have been applied by different authors. For example, with reference to other examples, Shreeve *et al.* (2001) successfully used a binary system, to develop an ecological classification of British butterflies based on their ecological attributes and biotope occupancy. This approach enabled them to take non-numerical variables into consideration. Massant *et al.* (2009) converted the CSR strategies into numerical values using linear interpolation in three dimensions.

As previously mentioned, the multivariate analysis described in Section 3.4.2, is based on the approach used by Shreeve *et al.* (2001), who transposed a series of ecological attributes into a binary state which was subsequently used in PCA and Factor analysis. In the current study the CSR-strategies and Ellenberg indicator values are analogous to the ecological attributes and the plant species to butterfly species. Shreeve *et al.* also noted that such use of binary data has successfully been employed in other studies using these two multivariate analyses. The main advantage of this approach for the current study, is that it brings data with vastly different ranges into the same order of magnitude: Ellenberg values range from 1 to 11, while CSR numeric values (i.e. their position within the CSR-triangle) range from 0 to 1. It also reduces the likelihood of any particular variable having more influence on the outcome, as all are considered as either ‘positive’ or ‘negative’.

TWINSPAN classification and DCA ordination can be used in tandem with the output species groupings of one method helping to refine the output groups of the other and *vice versa*. However, the resultant groupings still require a certain level of subjective judgmental decisions to be made based on ecological knowledge of individual species and associations. Using both classification and ordination in combination with ecological interpretation allows a more robust and ecologically meaningful set of species groups to be identified to describe NoaHs within the target habitat.

3.4.4 Discussion on the interpretation of ordination outputs

Eigenvalues provide a measure of the importance of the ordination axes and range between 0 and 1 (Jongman *et al.*, 1995). Different authors (e.g. Jongman *et al.*, 1995 and Shaw, 2003) suggest different thresholds for Eigenvalues worthy of further investigation; Jongman *et al.* suggest values over 0.5 denote a good separation of species/sites along the axis, while Shaw suggests 0.3. Shaw also noted that there is no formal guidance on the interpretation of Eigenvalues, or the percentage variation that they explain. However, Jongman *et al.* (1995. p.132) stated that ordination diagrams are "*typically interpreted with the help of external knowledge on sites and species*", and noted that correlation coefficients are "*often adequate summaries of scatter plots of environmental variation against ordination axes*", given that it can be expected there are "*straight line …relations between ordination axes and quantitative environmental variables that influence species.*" However, they identified a number of methods to help interpret the ordination output plots, including:

1. "*writing the values of an environmental variable in the order of the site scores of an ordination axis below the arranged species data table*
2. *writing the values of an environmental variable near the site points in the ordination diagram*
3. *plotting the site scores of an ordination axis against the values of an environmental variable*
4. *calculating (rank) correlation coefficients between each of the quantitative environmental variables and each of the ordination axes*
5. *calculating mean values and standard deviations of ordination scores for each class of a nominal environmental variable … and plotting these in the ordination diagram.*"

The methods employed in the current study to interpret the axes (Sections 3.4.2) were based on points 2 and 3 above, and Eigenvalues of at least 0.3 were used as the threshold for further investigation of the axes.

3.4.5 An alternative approach considering several factors simultaneously

A second approach (to that of combining CSR-strategies with Ellenberg indicator values) was investigated that considered factors that define a habitat by reviewing the 'constant' species occurring in NVC habitat types. However, this approach failed to provide conclusive results and as such is not reported in the main thesis. In brief, it considered the presumption that species that are constant in a particular habitat type are likely to have strong associations with, or be more specialist with respect to, the environmental conditions of that specific habitat. Section 3.2 described and discussed a method using the NVC to identify species potentially endemic to lowland *Alnus glutinosa* woodland based on the species association with other habitat types. The idea of species association was considered further, using the NVC 'constant' species, to determine the environmental characteristics of the target habitat. The approach considered all species that are 'constant' in at least one community/sub-community, rather than those 'faithful' to a particular habitat, to allow for the fact that although species may be more likely to occur in conditions associated with a given habitat, they will also occur in other habitats if conditions are suitable. This approach, therefore, allowed for the fact that species occur outside their optimal conditions described by the Ellenberg indicator values. If a species is not a 'constant' in any habitat, it is assumed to be a generalist without a strong association to the conditions of the habitats in which it occurs. 'Constant' species are likely to be specialists and occupy specific conditions, and as such could reflect localised intra-site variation in environmental conditions within lowland *Alnus glutinosa* woodland.

Species that occur as 'constants' in each of the habitat types described by the NVC (Rodwell, 1991 *et seq.*) and are also found in lowland *Alnus glutinosa* woodland were reviewed in relation to the environmental conditions that they represent. The analysis and review concluded that species constant in a given habitat type could represent intra-site variation within lowland *Alnus glutinosa* woodland. For example, if a species found in lowland *Alnus glutinosa* woodland constantly occurs in open water habitats, then there is likely to be some open water in the woodland. However, not all the groundflora species found in lowland *Alnus glutinosa* woodlands can be attributed to an NVC constant species: only 148 of the 267. Therefore, there is only a 55% chance that a species will be an NVC constant species and subsequently indicate a potential intra-site variation condition. If a woodland supports 30 species (the average number of species in a woodland based on the 64 sites surveyed during the current research) there is a 20% chance that a species will also be an NVC constant species and subsequently indicate a potential intra-site variation condition but a 25% chance it will not be an NVC constant species. Therefore, there is a higher probability that any given species will not indicate intra-site variation to aid in management decisions. Therefore, the use of NVC 'constant' species, to identify potential intra-site variation within any given woodland is not considered viable to help make decisions on appropriate management and are not considered further in this thesis.

3.5 DETAILED VEGETATION STUDY

In order to determine if the potential NoaHs, identified through the methods described in Section 3.4, actually occur it is necessary to apply and review the outcomes in relation to actual woodlands. Therefore, this section details the approach used to identify appropriate sites and the necessary data collection to determine actual occurrences of NoaHs in lowland *Alnus glutinosa* woodland.

3.5.1 Determining optimal survey period

In order to determine the most appropriate time of year to assess the flora of lowland *Alnus glutinosa* woodlands, 17 of the 64 sites (identified in Section 3.1), were visited at different times of year (see Appendix 4) and plant species were identified and listed. The sites were selected on the following basis:

- representative of different site characteristics (e.g. management, history);
- have distinct variation in the groundflora;
- easily accessible/open access;
- within a commutable distance.

A total of 88 surveys were conducted across the 17 sites over a two year period (2004-2005). Each site was surveyed with plants being identified and listed at least three times during different seasons.

The optimal survey period was determined by the month that had the maximum average number of species recorded. In order to ensure vernals were accounted for, the month with the maximum average of species recorded in spring was also determined.

3.5.2 Choice of sites for detailed vegetation study

In addition to the criteria detailed in Section 3.5.1 the ideal study sites to develop guidance on management decisions had also to meet the following criteria:

- be representative of different site characteristics (e.g. management, history) within a small spatial area so as to minimise other variables, such as climate, geology, that may influence the vegetation
- be primarily managed for nature conservation
- allow experimental management to take place.

3.5.3 Quantitative data collection

In order to detect transitions and localised conditions, the study sites were sampled using transects, located at 10 m intervals, orientated at approximately 90^{O} to the river flow and the length of the woodland. Each transect comprised consecutive 2 x 2 m quadrats. The following data were collected:

- Transect:
  - GPS reference of start and end point
  - Direction relative to north
  - Fixed point photography of start and end points
- Quadrat:
  - List of all plants
  - Percentage cover, assessed by eye, of all vascular plants.

Data were collected over the shortest period of time possible and over consecutive days.

3.5.4 Review and justification of approaches taken to collect quantitative data to test the theoretical NoaHs determined by methods described in Section 3.4

Determining optimal survey period

To identify sites for further more comprehensive surveys in order to determine the optimal survey period, one of the criteria had to be that sites were within commutable distance, as a result of timing and work commitments. Therefore, the sites were not reflective of different parts of the country, and as such the optimal survey period would be biased towards the Midlands and South England.

It is generally accepted that spring/early summer is the best time to undertaken botanical surveys in woodlands. Surveys documented in the literature have variously been carried out in April-June, e.g. ancient woodland surveys in the UK by Willi *et al.* (2005) and *Alnus glutinosa* woodland surveys in Poland by Orczewska (2009a). The study conducted between 2004 and 2005 concurred with such suppositions and indicated that the majority of species would be encountered if surveys were conducted in April and June. However, a degree of flexibility was also applied when the final detailed surveys were conducted to account for annual variations of seasons and weather conditions. A period of expected dry weather was chosen as personal experience shows continual rain/wetness results in less vigorous/comprehensive data collection in the field.

Choice of sites for detailed vegetation study

While the majority of the ideal criteria (Section 3.5.2) for choice of study sites could be achieved, manipulation through management was not feasible, primarily because of the small size of woodlands that met other criteria. In addition, following further discussions with woodland managers, it was deemed that significant changes would not be visible over the duration of a PhD research period. Therefore, it was deemed more important to find several sites within a small spatial area that were subjected to different management techniques, either through current or historic practices. However, the initial investigations, notably through responses of the questionnaire devised at the start of this research, indicated that wet woodlands are rarely managed and as such it was difficult to identify sites with a recorded management history.

Quantitative data collection

In an ideal situation the entire woodland would be surveyed, however, this is impractical and therefore samples had to be taken. Random quadrat sampling was considered inappropriate as it would not enable transitions of conditions to be detected, and therefore sampling along transects was adopted.

Although transect/quadrat methods are variously used in woodland surveys, although most notably when assessing edge and migration effects, there does not appear to be a consistent quadrat or sample size and distribution. For example, Willi *et al.* (2005) positioned transects of 19-536 m in length perpendicular to the woodland boundary/ride with 1 m^2 quadrats placed at logarithmically increasing intervals towards the centre of the woodland; all species and percentage cover were recorded. Orczweska (2009a) also positioned quadrats perpendicular to the site boundary but located the quadrats (16 m^2) at 4 m intervals with all species and percentage cover again recorded.

In the current study, quadrats of 2 x 2 m were chosen as this is the generally accepted size appropriate for sampling ground cover. Although Rodwell (1991. p.6) notes 2 x 2 is suited to "*most short, herbaceous vegetation…4 x 4 for taller or open herb communities, sub-shrub heaths and low woodland field layers,*" it was considered that 2 x 2 m was appropriate given the generally closed groundcover and limited bare ground during the survey periods.

3.6 VERIFYING THE OCCURRENCE OF NICHES OF A HABITAT – LOWLAND *ALNUS GLUTINOSA* WOODLAND

To determine if the species in each potential C/NoaH (identified by the methods detailed in Section 3.4) occur together on the ground, quadrat data collected at Stonebridge (see Section 3.5) were utilised. Two quantitative approaches were taken:

1. Multivariate analysis using TWINSPAN classification and Detrended Correspondence Analysis (see Section 3.4.2) of the species data to determine the association of species based on their occurrence together in a quadrat. Species that are classified together by TWINSPAN, or in DCA ordination space, are likely to occur in the same geographical space, i.e. quadrats.
2. Consideration of occurrence of species in quadrats along the transects.

In addition, the validity of using qualitative data was also reviewed. The approaches are described below and the results presented and discussed in Chapter 7.

3.6.1 Multivariate analysis of percentage cover of species in quadrats at Stonebridge

The abundance data collected at Stonebridge were arranged in a species x quadrat (percentage cover) matrix and classified using TWINSPAN. The same data were also analysed using DCA ordination to order species along a continuous gradient. The use of TWINSPAN to identify groups and the interpretation of the axes in the DCA output graphs was as described in Section 3.4.2. The Ellenberg and CSR-strategies of the indicator species[3] and preferential species[4] of the TWINSPAN quadrat output groups were considered in relation to their position along the ordination axes.

The species in the ordination output of the Stonebridge data were colour coded according to their CoaHs and NoaHs (as determined in Sections 3.4.1 and 3.4.2) in order to illustrate whether species in the same groups were clustered in ordination space and, therefore, likely to occur together on the ground.

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[3] Species which occur exclusively within a group of quadrats (Kent and Coker, 1992)

[4] Species which are more than twice as likely to occur within a group of quadrats compared to the second group of quadrats in the same dichotomy (Kent and Coker, 1992)

3.6.2 Occurrence of species in quadrats along the transects at Stonebridge

To illustrate the spatial distribution of potential CoaHs and NoaHs across a site a grid was drawn up where the columns represented quadrats along the transect and rows represented species. If a species was recorded in a quadrat the appropriate grid square (cell) was coloured, e.g. if species A was represented by row 1 and occurred in quadrats 2, 5, 7-10, then the cells positioned in columns 2, 5, 7-10 in row 1, would be coloured, see Figure 3.2. Different colours were used to represent different C/NoaHs.

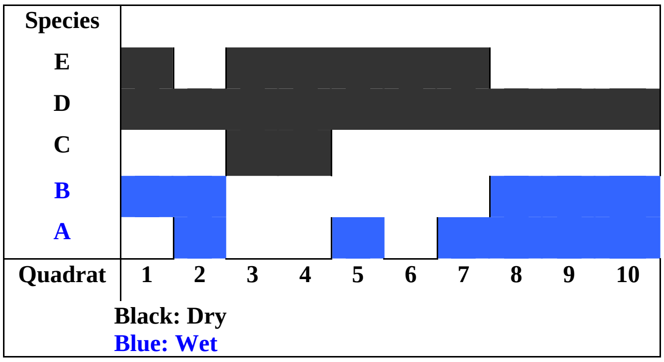


Fig. 3.2 Hypothetical example of the graphical representation of species occurrence in quadrats along a transect

Using the method described above to illustrate species distribution across a site, the following patterns illustrate six potentially different situations regarding the spatial distribution of species:

1. more or less continuous row of points along a single row: species occurs ubiquitously across the site;
2. discontinuous but clustered row of points along a single row: species occurs in discrete localised areas within the site;
3. discontinuous row of individual points along a single row: species occurs sporadically across the site;
4. column comprises a variety of different coloured points: quadrat includes species from a number of different conditions within the CoaH type or species from a number of NoaHs, i.e. the quadrat does not describe a particular condition;
5. column is dominated by the same colour points: quadrat primarily comprised species from the same C/NoaH, i.e. the quadrat represents a localised condition;
6. a number of columns, either consecutive or nearly so, show the same pattern of colours: quadrats adjacent, or in close proximity, represent the same localised conditions and as such may represent a distinct area of intra-site variation.

3.6.3 Qualitative data: Four sites along the River Rother, Hampshire

To validate the use of qualitative data to identify NoaHs, presence/absence data from four sites, identified and surveyed to identify species associated with lowland *Alnus glutinosa* woodland, were considered. The sites, four in close proximity along the River Rother at Liss, Hampshire, are described and reviewed in relation to predicted C/NoaHs in Section 7.6.2. The qualitative data were collected using the walk-over survey as detailed in Section 3.1; eight survey visits were conducted between 2004 and 2007 at different times of year (see Table A4.1, Appendix 4). The approach used to predict the C/NoaHs is the same as that used to define the characteristics of lowland *Alnus glutinosa* woodland (Section 3.3.3) but uses the C/NoaHs (as defined by the methods described in Section 3.4) rather than Ellenberg values and CSR-strategies.

3.7 Developing a Management Decision Tool

In order to develop a management decision tool for the management of lowland *Alnus glutinosa* woodlands the following steps were taken:

1. identify guiding principles and a suite of potential management aims and objectives for:
    a. general nature conservation of the target habitat,
    b. site specific situations;
2. identify suitable management options appropriate for the nature conservation of the habitat;
3. review the likely conditions created by the management options identified in Step 2;
4. identify ground conditions and character of the site requiring management;
5. determine the compatibility of potential management options with the conditions and character (C/NoaHs) of the woodland.

Steps 1 and 2 will build from and develop ideas in the literature for small native woodlands using knowledge gained during the course of this research. Step 4 will utilise the approaches described in Sections 3.3 and 3.4 to identify the environmental conditions, based on the presence of species, of the site. As well as environmental conditions, the physical conditions, e.g. relative size and age of the woodland/stand, and the possible constraints such as access and adjacent landuses, will need to be identified before management can be determined. Steps 3 and 5 will review the literature and use the author's knowledge of woodlands and their management to assess the compatibility of management techniques with the various conditions that may occur in a lowland *Alnus glutinosa* woodland. For example, clear-fell operations would result in high light conditions, so would not be suitable for a woodland with a high proportion of plants with preferences for shaded conditions, unless the management aim for the wood was to increase the number of species associated with high light conditions.

Subsequent to the steps detailed above a process/tool is described that enables the characteristics (C/NoaHs) of a site to be defined from a list of groundflora species occurring at the site. The outcome of which can then be used in a table to identify suitable management options. These options can then be further refined by consideration of specific situations, or constraints, associated with the woodland concerned.

The results obtained from employing the methods detailed in this Chapter are provided and discussed in Chapters 4 to 8, starting with Chapter 4 which details the species composition and characteristics of lowland *Alnus glutinosa* woodlands.

4. DEFINING CHARACTERISTICS OF LOWLAND *ALNUS GLUTINOSA* WOODLAND

4.1 Introduction and Aims of Chapter

The literature review in Chapter 2 identified *Alnus glutinosa* woodland as the target habitat for the current research. The use of an existing classification (e.g. Rodwell, 1991 *et seq.*, Peterken, 1993) and its species list was considered too restrictive to capture the variability within lowland *Alnus glutinosa* woodlands, which may be encountered when deciding on appropriate management for a site. Therefore, it was considered necessary to pool data from a variety of sources and consequently define the type of habitat considered in this research. Using the methods detailed in Sections 3.1 to 3.3, this chapter's aim is to:

Define the characteristics of lowland *Alnus glutinosa* woodland to be used in the current research in terms of the following:

- geographic and spatial location
- component species
- potential endemic species
- environmental conditions as inferred by the Ellenberg indicator values and CSR-strategies of the component species.

4.2 Geographic and Spatial Location

As discussed in Chapter 2 and by Peterken (1993) and Rackham (2003) the location, both geographically and within a landscape, will have significant influences as to what species occur within any given woodland. In this study into management implications of the floristic composition of *Alnus glutinosa* woodlands, the focus is on sites occurring in lowland Britain and adjacent to, or in close proximity to, a watercourse: i.e. part of the riparian ecosystem. The riparian zone is typically unpredictable and variable temporally, physically and biologically with the variability of the physical factors being reflected in the variability of the biotic features over time, i.e. biotic factors respond to abiotic factors (Hughes *et al.*, 2005).

4.3 Species Occurring in *Alnus glutinosa* Woodland

In total 332 species were identified from the data sources detailed in Section 3.1 (which totalled 560 sites), as occurring in lowland *Alnus glutinosa* woodland. Of these, 269 are considered as groundflora, 30 as the shrub layer and 33 as the canopy layer. For the purpose of this study the following definitions have been used:

- Groundflora: herbs and small, low growth, low spread shrubs, such as *Rubus ideas* and ground cover species such as *Hedera helix*. It is noted that *H. helix* is also a climber, occurring in the canopy.
- Shrubs: second tier canopy and shrub layer, including small trees such as *Ulmus* spp. (it is noted that *Ulmus* spp. can establish into large mature trees, however in *Alnus glutinosa* woodland situations and in the current effects of Dutch elm disease, these species rarely grow beyond the shrub layer) and aggressive shrubs such as *Rubus fruticosus.*
- Canopy: upper most layer within a woodland, for example *Alnus glutinosa.*

The 332 species identified as occurring in lowland *Alnus glutinosa* woodland are provided in Appendix 7.

4.4 Species Potentially Endemic to *Alnus glutinosa* Woodland

Using the methods described in Section 3.2, it was found that only about 12% (41 species) of the 332 species occurring in lowland *Alnus glutinosa* woodland (Section 4.3) could potentially be endemic to the target habitat. These species are listed in Table 4.1 and their potential endemic status considered in relation to their native status in the UK, distribution and other habitats in which they occur.

Therefore, about 88% (291 species) of lowland *Alnus glutinosa* woodland species occur in at least one other semi-natural habitat type as described by the NVC. This indicates that lowland *Alnus glutinosa* woodlands provide conditions for a variety of species with different requirements, and therefore are likely to be diverse either between or within sites. Additionally the remaining 12% (41 species - listed in Table 4.1), are also associated with other habitats, suggesting that all species associated with lowland *Alnus glutinosa* woodland also occur in at least one other habitat type, either semi-natural or not (such as gardens).

Scientific name	Notes on native status and distribution (from Stace, 2001, unless otherwise stated)	Other habitats in which the species occurs (from Stace, 2001)
Groundflora		
Aconitum napellus	Native. Very local, probably restricted to SW England and S Wales. Cultivated forms naturalised sparsely across Britain. Nationally scarce[2]	Shady places by streams, gardens, waste land.
Allium vineale	Native. Common in S England, frequent to scattered across rest of Britain.	Grassy places, rough ground, banks and waysides.
Bromopsis ramosa	Native. Frequent throughout most of lowland Britain. Identification errors possible[1]	Woods, wood margins and hedgerows.
Ceratocapnos claviculata	Native. Scattered distribution across most of Britain.	Woods and other shady places, often on rocks.
Dryopteris affinis	Native. Frequent to common across Britain. Numerous sub-species; therefore possible misidentification or grouping[1]	Woods, hedge banks, ditches, mountains, in open or shade.
Epilobium roseum	Native. Scattered throughout most of Britain; locally frequently, apparently decreasing. Hybridises and some crosses recognised; therefore possible misidentification or grouping[1]	Shady places, damp ground, cultivated and waste land.
Epilobium tetragonum	Native. Common central Britain. Readily hybridises and several crosses recognised; therefore possible misidentification or grouping[1]	Hedgerows, open woods, by water, cultivated and waste ground.
Equisetum hyemale	Native. Scattered throughout most of Britain, decreasing. Hybridises and some crosses recognised; therefore possible misidentification or grouping[1]	Ditches and on river and stream banks.
Eranthis hyemalis	Introduced, becoming naturalised. Scattered in Britain.	Woods, parks and roadsides.
Geranium endressii	Introduced, frequently naturalised. Scattered across most of Britain.	Gardens, grassy places and waste ground.
Helleborus viridis	Native. Very local in England and Wales. Also grown in gardens and naturalised in places. Associated with alkaline conditions[1]	Woods and scrub on calcareous soils and gardens.
Hyacinthoides hispanica	Introduced, naturalised. Scattered across most of Britain. Over recorded for *H. hispanica* x *H. non-scripta*.	Woods, copses, shady banks and field borders and gardens.
Hypericum androsaemum	Native. Locally frequent across most of Britain, especially in the W. Also cultivated and sometimes naturalised.	Damp woods and shady hedgerow banks.
Lathraea clandestina	Introduced, naturalised on *Populus* spp. and *Salix* spp. scattered in England and N Wales.	Damp places.
Oreopteris limbosperma	Native. Common in W & N Britain, frequent in SE and SW England.	Damp shady places in woods on acidic soils.
Paris quadrifolia	Native. Rather local, absent from most of Wales & SW England. Associated with alkaline conditions[1]	Moist woods on calcareous soils.
Persicaria bistorta	Native. Throughout most of Britain but common only in NW England. Also introduced in much of S Britain.	Grassy places.
Pulmonaria longifolia	Native. Extremely local in Dorset, S Hants and Isle of Wight perhaps are escapes elsewhere. Nationally scarce[2]	Woods and scrub.
Vicia sylvatica	Native. Scattered throughout most of Britain but local.	Open woods and wood borders, scree, scrub, maritime cliffs and shingle.
Vinca major	Introduced, naturalised. Across most of Britain, frequent in the south.	Woods, hedge banks and other shady places.
Wahlenbergia hederacea	Native. Common only in Wales and SW England, naturalised else where in wet lawns.	Damp acid places on heaths and moors, in woods, by streams.
Carex elongata	Native. Scattered throughout most of Britain north to Dunbarton.	Damp places – meadows, wet woods, ditches, streams
Equisetum sylvaticum	Native. Throughout Britain, common in north and west, rare in most of central and east England.	Lowlands - damp woods, hedgerows, stream banks. Uplands – moorland.
Impatiens glandulifera	Introduced. Locally common throughout most of Britain.	River & canal banks, damp places and waste ground. Ubiquitous along river banks[1]
Petasites hybridus	Native. Frequent throughout most of Britain.	Near rivers, ditches, damp fields and waysides, often in the shade.
Ribes nigrum	Probably introduced. Throughout most of Britain.	Woods, hedges and shady streams. Much grown and often relict or escape.

Table 4.1 Lowland *Alnus glutinosa* woodland species that are not recorded at any frequency in any NVC community in relation to their native status in the UK, distribution and other habitats in which they occur (Table continues)

Scientific name	Notes on native status and distribution (from Stace, 2001, unless otherwise stated)	Other habitats in which the species occurs (from Stace, 2001)
Canopy		
Acer platanoides	Introduced, planted & self-sown. Throughout lowland Britain.	Rough grassland, scrub, hedges and woodland.
Alnus incana	Introduced, planted, suckers and occasional self-sown. Throughout Britain.	Planted for shelter and ornamental especially on poor wet soils.
Populus alba	Introduced, planted and naturalised. Scattered across Britain, especially central and south.	Much planted and coastal dunes.
Populus nigra 'Italica'	Introduced, much planted but not naturalised. Throughout much of Britain.	Parks.
Salix alba	Native. Common across most of lowland Britain. Identification errors possible[1]	Marshes, wet hollows and by streams and ponds
Salix triandra	Native. Frequent in south and central England, less so in Wales, north England, Scotland. Identification errors possible[1]	Damp places.
Populus canescens	Possibly native, much planted but rarely naturalised. Scattered throughout Britain.	Damp woodlands and by streams, usually alone or in groups with native taxa.
Populus nigra	Native. Scattered throughout most of England and Wales.	Fields by streams and ponds, especially in floodplains. Also planted.
Shrub layer		
Mahonia aquifolium	Introduced, naturalised. Throughout Britain north to central Scotland. Often planted, e.g. for game cover.	Scrub, woodland and hedges.
Prunus cerasifera	Introduced. Across Britain north to central Scotland.	Hedges, street tree, planted for hedging and ornamental
Prunus laurocerasus	Introduced, sometimes naturalised. Throughout most of Britain. Abundantly planted.	Woods and shrubberies.
Prunus lusitanica	Introduced, sometimes naturalised. Scattered across Britain north to central Scotland. Commonly planted.	Woods, shrubberies and waste land.
Prunus padus	Native. Britain from central England and south Wales to north Scotland. Planted and naturalised in south and central England.	Woods and scrub.
Symphoricarpos albus	Introduced, naturalised. Frequent throughout Britain.	Woods, scrub and rough ground.
Symphoricarpos orbiculatus	Introduced, naturalised. Scattered throughout Britain north to central Scotland. Rarer than *S. albus.*	Open scrub.
Notes **1.** General observations about the species; **2.** As defined by JNCC (2009) Conservation designation of taxa		

Table 4.1 cont. Lowland *Alnus glutinosa* woodland species that are not recorded at any frequency in any NVC community in relation to their native status in the UK, distribution and other habitats in which they occur

Figure 4.1 illustrates the proportions of the 332 species associated with lowland *Alnus glutinosa* woodland (Section 4.3) that occur (at any frequency as defined by Rodwell, 1991 *et seq*) in other habitat types described in the NVC (excluding W5-7). This Figure shows that the majority of these plants are also found in other woodland types, open habitats, mire and swamp/tall herb habitats.

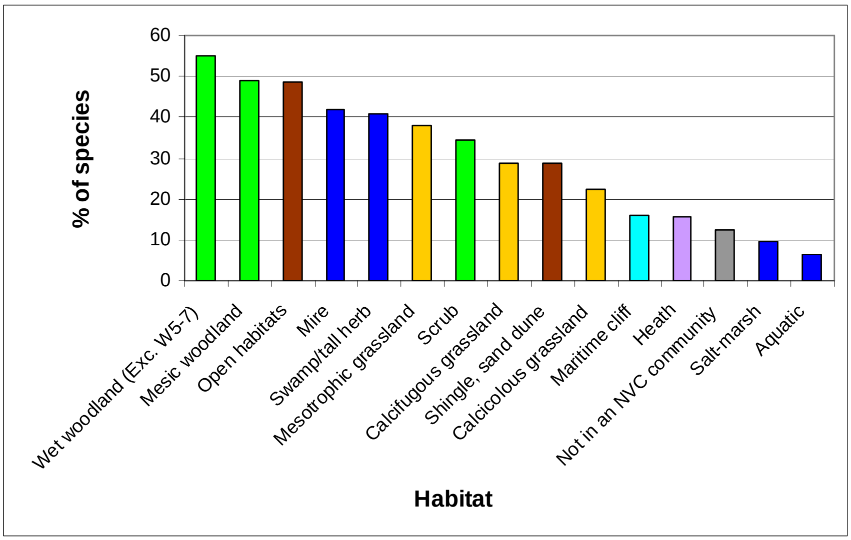


Fig. 4.1 Percentage of species associated with lowland *Alnus glutinosa* woodland that occur in other habitat types described in the NVC

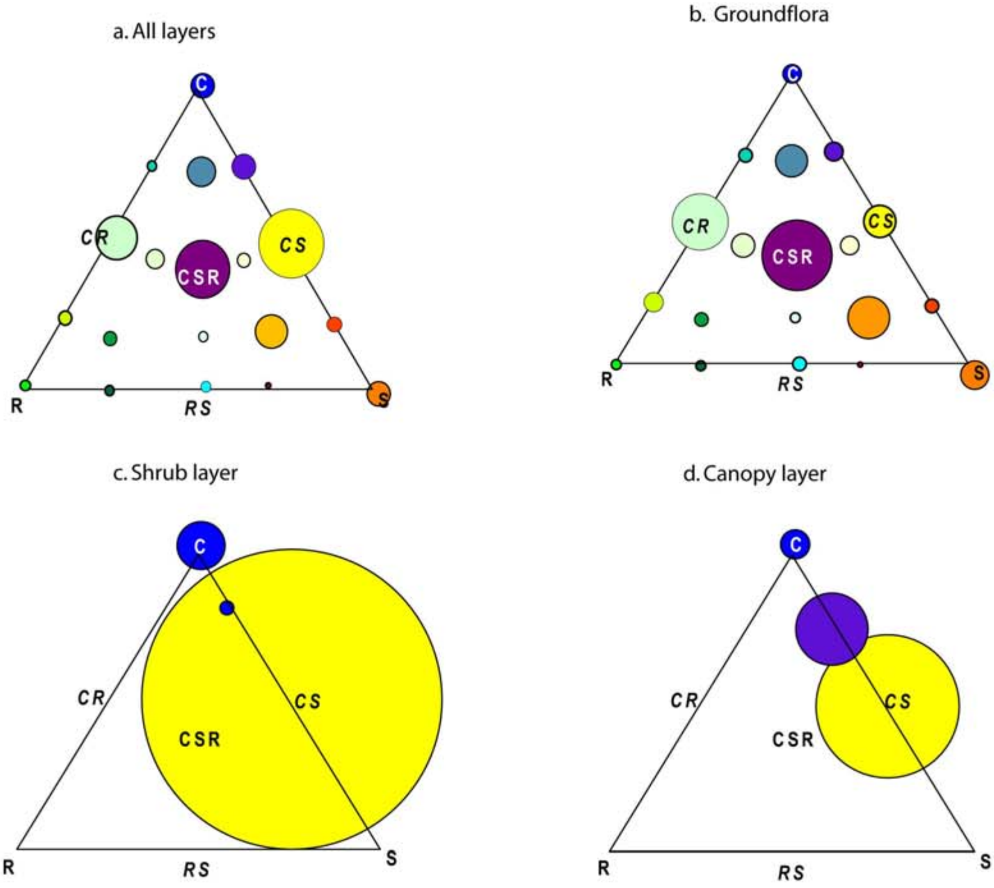
4.5 Theoretical Environmental Characteristics of *Alnus glutinosa* Woodland

This section provides the results of the various methodologies detailed in Section 3.3 to describe the environmental characteristics of the target habitat, inferred by the life-history strategies and Ellenberg indicator values of the component species (determined in Section 4.3).

4.5.1 Life-history strategies of species in lowland *Alnus glutinosa* woodlands

The CSR Triangles depicted in Figure 4.2 represent the range and distribution of lowland *Alnus glutinosa* woodland species in relation to their CSR-strategies. Figure 4.2a shows that species representative of nearly all strategies exist within lowland *Alnus glutinosa* woodlands. Although there is a fairly even-spread of species across each of the main categories, there is a slightly greater proportion of competitor-based strategists (62% - C, CS, CR & CSR *cf.* ruderal-based strategists with 39% - R, CR, RS & CSR).

When considering the groundflora alone (Figure 4.2b) there is a slight bias towards stress tolerators (19% of species) and competitors (18% of species). Both the shrub (Figure 4.2c) and canopy layer (Figure 4.2d) show a strong bias towards the stress-tolerant competitors; 63% and 32% percent of species respectively. However, a high proportion of species (23% shrub; 47% canopy) were not included in the look-up table (Hunt, 2007a) used in this research.



Strategy	All layers No. spp.	All layers %	Groundflora No. spp.	Groundflora %	Shrub layer No. spp.	Shrub layer %	Canopy layer No. spp.	Canopy layer %
A. Competitors	**60**	**18.0**	**49**	**18.2**	**4**	**13.3**	**7**	**20.6**
C	16	4.8	11	4.1	3	10.0	2	5.9
C/CR	7	2.1	7	2.6	0	0.0	0	0.0
C/CSR	20	6.0	20	7.4	0	0.0	0	0.0
C/SC	17	5.1	11	4.1	1	3.3	5	14.7
B. Stress-tolerators	**51**	**15.3**	**51**	**19.0**	**0**	**0.0**	**0**	**0.0**
S	17	5.1	17	6.3	0	0.0	0	0.0
S/CSR	23	6.9	23	8.6	0	0.0	0	0.0
S/SC	9	2.7	9	3.3	0	0.0	0	0.0
S/SR	2	0.6	2	0.7	0	0.0	0	0.0
C. Ruderals	**30**	**9.0**	**30**	**11.2**	**0**	**0.0**	**0**	**0.0**
R	5	1.5	5	1.9	0	0.0	0	0.0
R/CR	11	3.3	11	4.1	0	0.0	0	0.0
R/CSR	9	2.7	9	3.3	0	0.0	0	0.0
R/SR	5	1.5	5	1.9	0	0.0	0	0.0
D. Competitive ruderals	**45**	**13.5**	**45**	**16.7**	**0**	**0.0**	**0**	**0.0**
CR	31	9.3	31	11.5	0	0.0	0	0.0
CR/CSR	14	4.2	14	5.2	0	0.0	0	0.0
E. Stress tolerant-competitors	**59**	**17.7**	**29**	**10.8**	**19**	**63.3**	**11**	**32.4**
SC	48	14.4	18	6.7	19	63.3	11	32.4
SC/CSR	11	3.3	11	4.1	0	0.0	0	0.0
F. Stress tolerant ruderals	**14**	**4.2**	**14**	**5.2**	**0**	**0.0**	**0**	**0.0**
SR	8	2.4	8	3.0	0	0.0	0	0.0
SR/CSR	6	1.8	6	2.2	0	0.0	0	0.0
G. Competitive, stress tolerant ruderals	**40**	**12.0**	**40**	**14.9**	**0**	**0.0**	**0**	**0.0**
No strategy data	34	10.2	11	4.1	7	23.3	16	47.1

Fig. 4.2 Relative proportions and distribution of lowland *Alnus glutinosa* woodland species (see Section 4.3) across the CSR-triangle (Circles are proportionate to number of different species in each group)

4.5.2 Light and soil conditions in lowland *Alnus glutinosa* woodlands

Using the 332 species found to be associated with lowland *Alnus glutinosa* woodland (Section 4.3 and Appendix 7), Figures 4.3 and 4.4 and Table 4.2 show the range and mean light, soil moisture, acidity and fertility conditions (as described by Ellenberg indicator values) in each layer (groundflora, shrub and canopy) of lowland *Alnus glutinosa* woodland. They also show the conditions taking all three layers together.

	L	F	R	N
All layers				
range	3 - 8	3 - 11	2 - 8	2 - 9
mean	6.2	6.6	6.0	5.3
Ground flora				
range	3 - 8	4 - 11	2 - 8	2 - 9
mean	6.3	6.8	6.0	5.2
Shrub				
range	4 - 7	4 - 8	3 - 8	3 - 7
mean	5.5	5.2	6.4	5.7
Canopy				
range	3 - 8	3 - 9	2 - 8	2 - 8
mean	5.9	6.3	5.7	5.2

Table 4.2 Range and mean of Ellenberg indicator values in lowland *Alnus glutinosa* woodland. L-light, soil conditions: F-moisture, R-acidity, N-fertility. (see Table 2.6 for interpretation of indicator values: 1-low, 11-high except acidity where 1-acidic, 8-base-rich)

Based on the contributions of all species to each optimal environmental condition, over 60% of the species fall within the following ranges of Ellenberg values:

- semi-shade to well lit (light values 5-7);
- moist to wet soils (moisture values 5-9);
- more or less neutral soils (reaction values 6-7);
- intermediate to richly fertile (nitrogen values 4-7).

Therefore overall it can be said that lowland *Alnus glutinosa* woodlands are likely to have the above environmental attributes.

When the three layers are considered individually, the groundflora shows the greatest variability across the optimal environmental conditions, while the canopy layer shows the least variability.

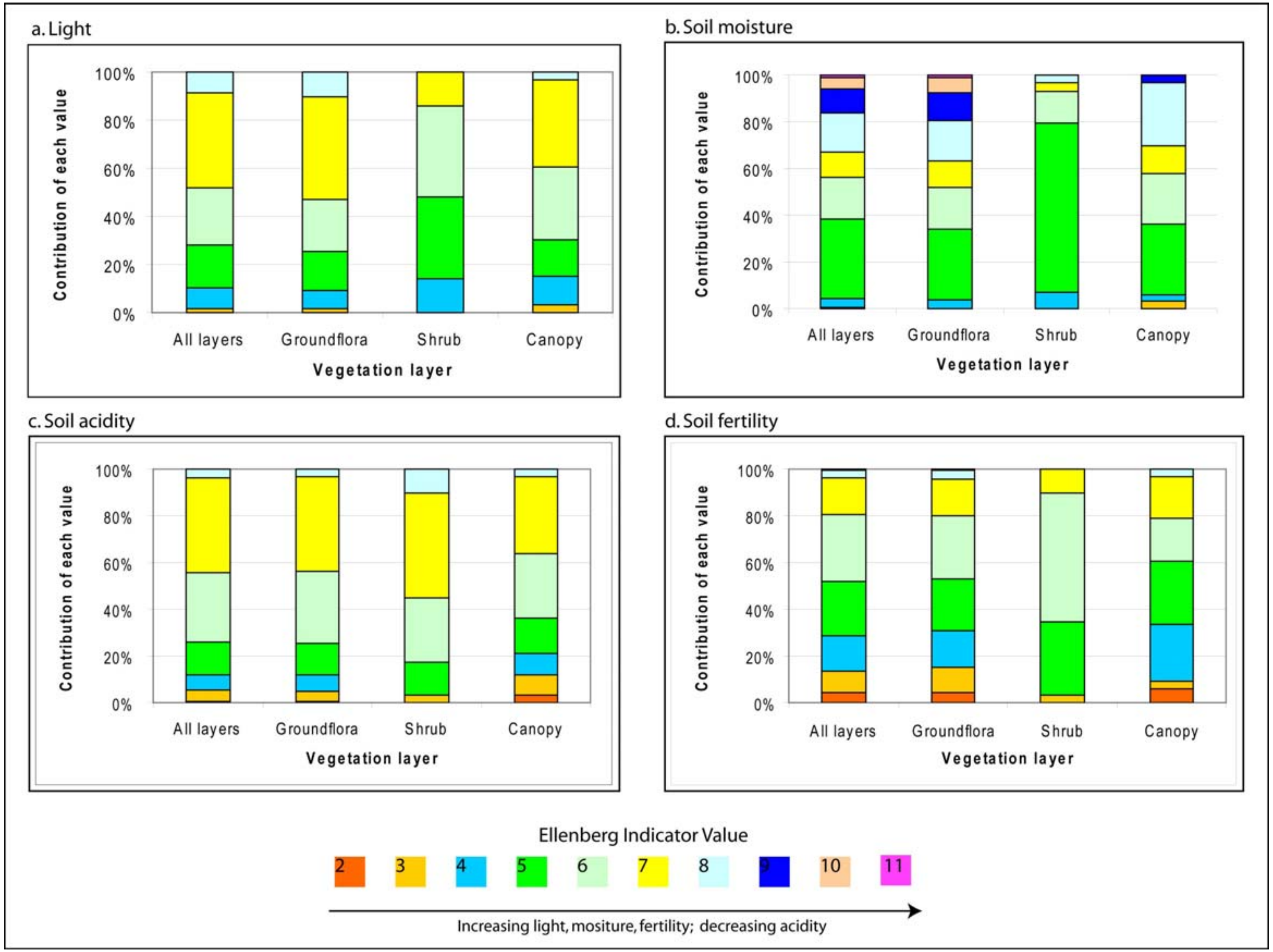


Fig. 4.3 Percentage of each Ellenberg indicator value (light, soil moisture, acidity and fertility) in lowland *Alnus glutinosa* woodland by vegetation layer (see Table 2.6 for interpretation of indicator values)

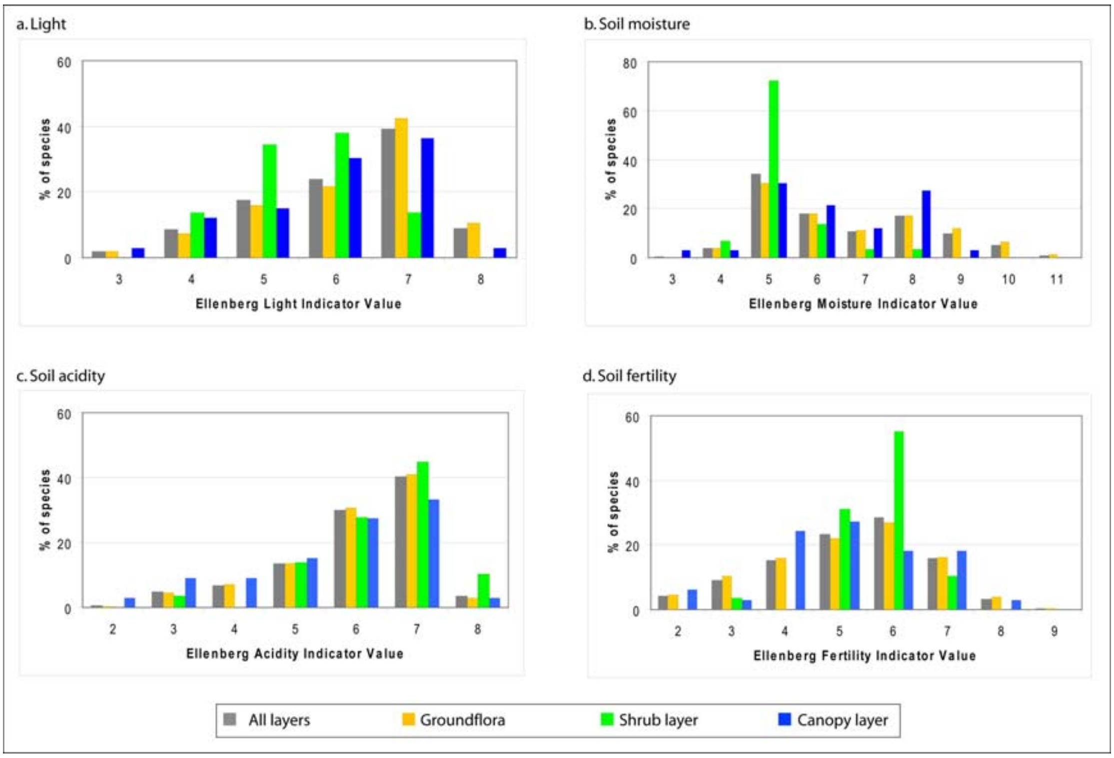


Fig. 4.4 Distribution of species contributions in lowland *Alnus glutinosa* woodlands along the Ellenberg Environmental gradients (see Table 2.6 for interpretation of indicator values: 1-low, 11-high except acidity where 1-acidic, 8-base-rich)

The graphs of Figures 4.3 and 4.4 show that the greatest numbers of species occur in average conditions, for light soil acidity and fertility, along the Ellenberg value scales, i.e. values of 5-7 rather than extreme ends of the scales. The species show two main groups when considered in relation to soil moisture; one at value 5 and a second at value 8.

The distribution of groundflora species closely follows that of all species when taken together. The light and acidity distributions show a significant peak at value 7 (well lit, and neutral) and there is a gradual increase of species between low values and 7, followed by a sharp decline. The distribution of soil fertility values is similar except the peak is at value 6. The soil moisture values show two distinct peaks, one at 5 (moist) and the other at 8 (wet).

The distribution of shrub-layer species are similar to those described by the groundflora except that the light values peak at 6, and the fertility peak at 6 is more pronounced and is followed by a sharper decline. The moisture values have a pronounced peak at 5 followed by a gradual decline.

The distribution of the canopy-layer species in relation to light and soil acidity and fertility conditions are again similar to those described by the groundflora. The soil moisture distribution is also similar to those previously described although the second peak at value 8 is more pronounced.

As mentioned above, the groundflora shows the greatest variability in terms of optimal environmental conditions, these are discussed in more detail below.

Light

The groundflora is dominated by species (*c*. 40%) with a preference for well-lit conditions (but also occur in partial shade) (Ellenberg light value 7), and semi-shade to well lit (light values 5 & 6) (*c*. 40%). There are also species at the two extremes:

- shade plants (Ellenberg light values 3 & 4) with a preference for relative illumination mostly less than 5% and no greater than 30% (*c*. 10% of species); and,
- light-loving plants (Ellenberg light value 8) with a preference for relative summer illumination of more than 40% (*c*. 10% of species).

Soil moisture

Groundflora species show a preference for at least moist soil conditions with approximately 60% of the species having Ellenberg soil moisture values 5-7, i.e. moist to constantly moist soils. Approximately 30% are associated with constantly moist to wet soils, which often have surface water and are badly aerated (Ellenberg soil moisture values 8 & 9). About 7% occur in shallow water (Ellenberg soil moisture values 10 & 11) and 4% on drier ground (Ellenberg soil moisture value 4).

Soil acidity

Three-quarters of the groundflora species have Ellenberg reaction values 6-8 indicting preference for more or less neutral soil acidity. However, there is a slight bias towards acidic soil conditions with approximately 25% of the species being associated with acidic to moderately acidic soils (Ellenberg reaction values 3-5).

Soil fertility

The majority (*c*. 80%) of groundflora species found in lowland *Alnus glutinosa* woodlands show preferences for intermediate to richly fertile soils (Ellenberg fertility values 4 to 7).

Approximately 15% are associated with more or less infertile soils (Ellenberg fertility values 2-3) and 5% with near extremely fertile soils (Ellenberg fertility value 8).

4.5.3 Habitat associations of component species of lowland *Alnus glutinosa* woodland

Fifty-two percent of the groundflora species found in lowland *Alnus glutinosa* woodland are constant in at least one sub-community, or throughout a community of the habitats, described by the NVC (Rodwell, 1991 *et seq*.). Figure 4.5 illustrates how species found in lowland *Alnus glutinosa* woodlands are distributed across other habitats.

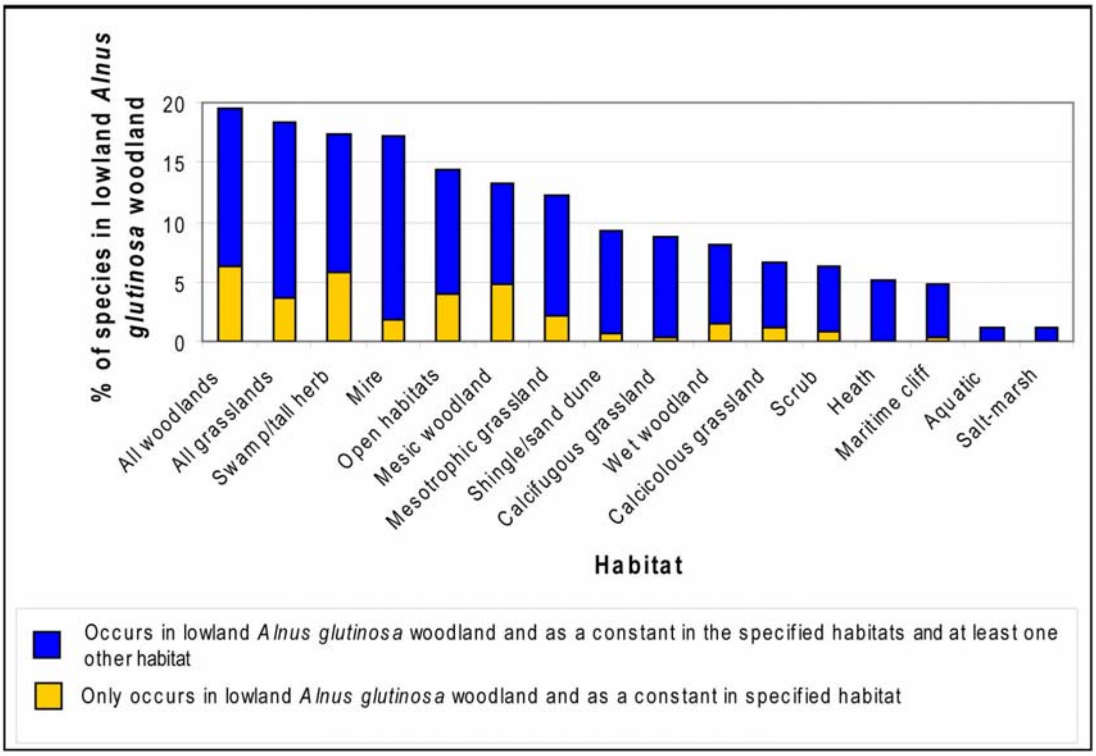


Fig. 4.5 Association of species found in lowland *Alnus glutinosa* (see Section 4.3) with other habitats described by the NVC

Table 4.3 summarises the generic environmental characteristics for the different types of habitat (as described by the NVC) within which lowland *Alnus glutinosa* woodland species are found.

Habitat	Environmental conditions
Mire	Essentially habitats of permanently or periodically waterlogged soils as a result of high atmospheric humidity, high water or lateral flow (Rodwell, 1998a)
Heath	"*vegetation types in which sub-shrubs play the most important structural role...*" (Rodwell, 1998a. p.348). Usually acidic habitat.
Grassland	Open habitats which may have a calcareous, acidic or neutral character. Grasses dominate the floristic components. Mesotrophic grasslands: "*drought-free, mesotrophic to nutrient-rich mineral soils with a pH of 4.5-6.5 throughout those parts of the British lowlands with a fairly moist and mild climate with a long growing season.*" (Rodwell, 1998. p.21). Calcareous grassland: free-draining, calcareous and oligotrophic soils. Acidic grasslands: base-poor, often leached soils; drought-free.
Aquatic	Communities of open water, both standing and running, of various degrees of nutrient status.
Swamp/tall herb	Includes habitats associated with "*open-water transitions with permanently or seasonally submerged substrates*", topogenous mires although "*not restricted to open-water transitions and floodplain systems, nor are they confined to organic substrates*" and wet ground. (Rodwell, 2000. p.109)
Salt-marsh	Mainly occur within the inter-tidal zone. Flora has two distinct components: halophytes and glycophytes (Rodwell, 2001).
Shingle, sand and dune	Primarily coastal in distribution.
Maritime cliff	Communities occurring in sea-cliff crevices, maritime grasslands and bird colonies (Rodwell, 2001). Usually experience at least some sea-spray.
Open habitats	Communities of open, disturbed/colonising habitats, including river banks, pool edges, ephemeral ponds, spoil, wall & rock crevices, arable margins (Rodwell, 2001). Occur on a range of different soils but usually in an open situation.
Woodland	Habitats dominated by tree and shrub species in a range of soil and climatic conditions.
Scrub	Generally habitats of more open situations and include hedgerows, woodland margins as well as isolated scrub patches such as in grassland. Occur on a range of different soils.

Table 4.3 Summary of environmental characteristics of the various habitats, as defined in the NVC, within which lowland *Alnus glutinosa* woodland species (see Section 4.3) are found

Based on the generic conditions outlined in Table 4.3 and the proportions of species associated with the various habitats in Figure 4.5, it could be inferred that lowland *Alnus glutinosa* woodlands have the following characteristics:

- damp – wet: indicated by the species associated with mire and swamp/tall herb;
- disturbed/colonising open ground: indicated by the species associated with open habitats;
- shaded but with open areas: indicated by the more or less equal contributions of species associated with woodland (shaded) and grassland and mire habitats (open);
- localised areas (inferred by being represented by fewer numbers of species) of:

- open water: indicated by aquatic species;
- open/shade interface: indicated by scrub species.

4.6 Discussion on Defining the Characteristics of Lowland *Alnus glutinosa* Woodland

It was not the intention to classify or develop a classification system for the woodlands used in the current research, but rather to describe them and provide an explanation of their composition and variation in terms of the floristic component. Therefore, classification techniques, such as two-way indicator analysis or ordination, have not been used in this chapter. The approach, refined as part of the current research, considered the known/reported association of species with pre-described habitats or conditions. In order to describe the abiotic conditions associated with lowland *Alnus glutinosa* woodland, the generic preferences of the component species in relation to light and soil characteristics (moisture, acidity and fertility) were reviewed as well as the species life-history strategies as described by Grime (2001), i.e. competitors, ruderals or stress-tolerators. The species were also reviewed in relation to their association with other habitats as described by the NVC. However, to provide context to classification systems, the habitat is reviewed (in Appendix 3) in relation to the classifications described in Section 2.3.2.

4.6.1 Species occurring in *Alnus glutinosa* woodland

Habitats comprise a number of different plant species and, of particular relevance to woodland, they occur in different layers: groundflora, shrub and canopy. In addition, notably in wet woodland situations, "*many species are present which depend on the diversity of habitats and/or a range of aquatic and semi-aquatic habitats*" (Peterken and Hughes, 1995. p.193). As such, a single species is not usually reflective of a habitat (or community); it is the association of several species that describe a given habitat. This supposition is clearly shown in studies of ancient woodland indicators, i.e. a single indicator species does not categorically indicate that a woodland is ancient, more that a group of species (and often associated physical features) is required for certainty (Kirby *et al.*, unpublished). For example *Urtica dioica* is commonly found in a wide variety of habitats ranging from ephemeral wasteland to established woodland (e.g. see Taylor, 2009). Corney *et al.* (2006) found that of 352 species recorded from 103 woodland sites within the UK, only 29% were considered to be forest specialists, i.e. those adapted to below canopy conditions and a stable environment. In considering the riparian habitats along watercourses in Wales and adjacent English counties, Mason *et al.* (1984) found that the woody species component was dominated by *Alnus glutinosa* but was distinctly different to woodland communities described by Peterken (1993); the species composition was reflective of past and current management within the riparian zone.

Therefore, since the same species may be typical of more than one habitat, it is the specific association of species that indicate the presence of a particular habitat. However, some, albeit very few, can be endemic to particular habitats, for example *Potamogetum coloratus* only occurs in ponds and pools, while the majority of other *Potamogetum* spp. are found in both flowing and standing waters (as described by Stace, 2001).

Although, as discussed in Section 3.1, the sites surveyed to identify species associated with lowland *Alnus glutinosa* woodland were clustered, rather than evenly distributed across the UK, the number of species (283) identified from 64 sites is comparable with other studies undertaken on similar habitats, see Table 4.4. As the surveys (totalling 149) were completed at different times of the year principally over a 2 year period (2004-2005 with additional data collected in July 2007, June-July 2008 and August 2002), with repeat visits to 17 sites it is considered that a representative list was compiled. These data were then supplemented with data from other parts of the country through a desk-based exercise, which resulted in an additional 49 species.

No. Sites	No. Species	Habitat type	Reference
64 (560)[1]	283 (332)[1]	Lowland *Alnus glutinosa* woodland, UK	Current research
33	313	Ancient and recent *Alnus glutinosa* woodlands, Poland	Orczewska (2010)
103	352	Woodland sites (various types), UK	Corney *et al.* (2006)
107	98	W5 *Alnus glutinosa-Carex paniculata* woodland, UK	Rodwell (1991)
58	82	W6 *Alnus glutinosa-Urtica dioica* woodland, UK	Rodwell (1991)
102	106	W7 *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland, UK	Rodwell (1991)

Notes
1. Number in brackets includes data from the desk exercise

Table 4.4 Number of species found in sites for other woodland studies compared to the current research

4.6.2 Species endemic to lowland *Alnus glutinosa* woodland

Of the species that could potentially be considered as endemic to lowland *Alnus glutinosa* woodlands (Table 4.1), many are either introduced, garden escapes, rarities or have local distributions, and therefore, less likely to have been encountered during the NVC surveys.

There were few existing data pertaining to woodlands that could be utilised when developing the NVC and the surveys sampled represented woodlands from across the UK (excluding Northern Ireland), collecting floristic data using quadrats from homogeneous stands (Rodwell, 1991). Other species, such as *Salix* spp., often hybridise and hence identification errors are more likely. This indicates that none of the species found to occur in lowland *Alnus glutinosa* woodland are endemic to the habitat, but a reflection of the location of the woodland or the data sources (Section 3.2) used to identify species occurring in this habitat. Sites used to compile the list of 332 species associated with lowland *Alnus glutinosa* woodland included those that were:

- open green space - easy and open access, often adjacent to residential buildings;
- nature reserves;
- ancient semi-natural woodland.

The sites which are in close proximity to residential buildings would have a high probability of garden escapes, while nature reserves and ancient semi-natural woodland are more likely to contain rarer species. Despite the apparent lack of endemic status to lowland *Alnus glutinosa* woodland, the species, listed in Table 4.1, have optimal growing conditions (as determined by the Ellenberg indicator values as calibrated by Hill *et al.*, 2004) typical of wet woodland habitats (2 species did not have data):

- light: 5-6 (73% of species), i.e. plants of semi-shade to well lit situations;
- moisture: 5-7 (66%), i.e. moist to constantly damp, but not wet, soils;
- acidity: 6-7 (80%), i.e. moderately acidic to weakly basic soils;
- fertility: 5-6 (63%), i.e. intermediate to richly fertile soils.

The high number of species associated with lowland *Alnus glutinosa* woodland that also occur in other woodlands, open habitats, mire and swamp/tall herb habitats as listed in the NVC (Figure 4.1) is to be expected as lowland *Alnus glutinosa* woodlands are woodland habitats with a strong wet soil element. Also, as noted by Rodwell (1991), wet woodlands often develop from precursory mire and swamp habitats and a number of species occurring in the former habitats remain in the groundflora of the establishing woodland. The similarly high proportion of mesotrophic grassland species, would be reflective of glades and woodland edge within the *Alnus glutinosa* woodland.

The occurrence of non-woodland species may also be a reflection of the age of the site as well as variation of conditions, for example, Orczewska (2010) noted that the number of woodland species in recent *Alnus glutinosa* woodlands in Poland was dependant on the woodland's age, i.e. younger woodlands had less species than more established, older woodlands.

Although the species listed in Table 4.1 were shown not to be endemic to lowland *Alnus glutinosa* woodland, these species could be considered to be characteristic of the habitat since they are reflective of the environmental conditions and locality in the landscape in which the woodlands occur. These results concur with other studies of *Alnus glutinosa* woodlands, for example, Douda (2008) found that similar woodlands in the Czech Republic comprised a number of transient species with no diagnostic species.

In support of the low endemic status and ubiquity of species associated with lowland *Alnus glutinosa* woodland a brief investigation was carried out at Stonebridge (see Chapter 6) towards the end of the current research, details of which are given in Appendix 8. The data from this investigation have not been included in the main thesis because the work was carried out only at Stonebridge and is not supported by data from other sites nor has it been subjected to robust statistical analysis. It does however indicate that, at least in Stonebridge, the species within the woodland are found in the adjacent grassland and likewise the grassland species are found within the woodland. Orczewska and Glista (2005) found similar relationships between adjacent *Alnus glutinosa* woodland and meadows habitats in Poland. The Stonebridge study revealed that of species occurring in the woodland, 69% also occurred within the first 24 m of the adjacent habitats (in this case grassland and scrub). In addition 80% of the species recorded in the adjacent habitats also occurred at least 24 m into the woodland habitats. This investigation could be taken further to determine the influence and importance of adjacent habitats as sources of species occurring in lowland *Alnus glutinosa* woodlands.

4.6.3 Environmental characteristics of lowland *Alnus glutinosa* woodlands based on the component species

Life-history strategies of species in lowland *Alnus glutinosa* woodlands

The range and distribution of species across the entire CSR-Triangle (Figure 4.2) suggests that there is a high diversity of conditions within *Alnus glutinosa* woodlands. The slightly greater proportion of competitor-based strategists (62% - C, CS, CR & CSR, e.g. *cf.* ruderal-based strategists with 39% - R, CR, RS & CSR) suggests that lowland *Alnus glutinosa* woodlands are relatively stable with no extremes in terms of stress or disturbance, restricting or destroying growth respectively. The bias towards competitors is reflected in the two triangles depicting the shrub layer (Figure 4.2c) and canopy (Figure 4.2d) species. This is to be expected as trees and shrubs usually occupy this area of the CSR Triangle, while herbs tend to concentrate in the centre (Grime *et al.*, 2007). The concentrations of CS-strategists in the canopy and shrub layers, compared to the distribution across all strategies in the groundflora, suggest that the diversity and variability within lowland *Alnus glutinosa* woodland occurs in the groundflora. This is not unexpected as species typically associated with the groundflora occur in a range of habitats and therefore, as indicated in Figure 4.2, the component species have a range of strategies.

When considering the groundflora alone, the slight bias towards stress tolerators, competitors and competitive ruderals indicates that generally (at least in terms of groundflora) lowland *Alnus glutinosa* woodlands have relatively high productivity, yet experience some degree of stress and disturbance. Alternatively there is a co-existence of species which can escape or tolerate the competitive pressure created by the dominant species. This may be achieved by having a different life strategy, for example vernals, or morphology which allows them to avoid competition, e.g. deep roots.

The CSR Triangles (Figure 4.2) indicate the degree of disturbance and stress experienced by species associated with lowland *Alnus glutinosa* woodlands. Further analysis, e.g. use of Ellenberg indicator values, can provide an indication of the drivers dictating the distribution of species across the CSR Triangle.

<u>Light and soil conditions in lowland *Alnus glutinosa* woodlands</u>

Figures 4.3 and 4.4 show that when the three vegetation layers are considered individually, the groundflora shows the greatest variability across the optimal environmental conditions while the canopy layer shows the least variability. The greatest variation occurring in the groundflora and the least in the canopy layer can, in part, be attributed to the larger resource space required by trees and shrubs compared to herbs, and suggests that the herbs occupy different localised variations of environmental conditions. Another reason for the groundflora showing the greater variation reflects the number of species contributing to each layer, i.e. groundflora 269, shrub 30 and canopy 33. These variations in the groundflora are considered in further detail in Chapter 5.

Although, soil moisture shows two distinct peaks (values 5 and 8), the graphs of Figure 4.3 show the greatest number of species occur in average conditions (i.e. Ellenberg indicator values 5-7) with fewer at the two extreme ends of the scales (values 1-4 and 8-9 (8-12 for moisture)). Wheeler *et al.* (2001, p.26) drew similar conclusions for wet woodlands in Wales: "*the greatest number of woody species in wetland vegetation is loosely associated with the middle (WETSPEC-estimated) water table range … and with intermediate soil fertility*". This distribution of species along the Ellenberg environmental gradients is more clearly shown in Figure 4.4. The sudden peak at soil moisture value 5 in the shrub layer suggests that the shrub species are less able to tolerate a wide range of moisture conditions. Lowland *Alnus glutinosa* woodland can be coarsely divided into those that are relatively dry with seasonal wetness and those that are consistently wet throughout the year. It is suggested that it is this difference in specific site characteristics that is reflected in the two peaks in species associated with relatively drier (value 5) and wetter (value 8) soils (Figure 4.4).

The general wider range of conditions shown by the groundflora is also reflected in greater detail by the species distribution characteristics at a given site, in that certain species have a localised distribution, while others are more uniformly distributed. Rodwell (1991) noted that in sub-community W6d (*Sambucus nigra* sub-community), where there was a slight base-enrichment along streams within the woodland, plants such *Geum urbanum, Circaea lutetiana* and *Mercurialis perennis* were more frequent, suggesting a localised distribution relating to increased wetness and reduced soil acidity. In the canopy and groundflora, light also becomes more variable (Figure 4.3). In the shrub layer, species show a strong preference for semi-shaded conditions while in the canopy and groundflora, the majority of species have a preference for well lit/partial shade although a number show preferences for either lighter or more shaded conditions (Figure 4.3).

The dominance of plants with a preference for well-lit places is unexpected in a woodland situation where canopy trees can cast deep shade. Therefore the same approach used to determine the light conditions in lowland *Alnus glutinosa* woodland (Section 3.3.2) was applied to a variety of contrasting woodland and non-woodland habitats described by the NVC (Appendix 9). In addition the method was applied to the three NVC *Alnus glutinosa* communities. A similar distribution of light values was found for other *Alnus glutinosa* woodlands using data from the NVC communities (W5, W6 and W7), while *Quercus* spp. and *Fagus sylvatica* woodlands showed a greater proportion of plants associated with more shaded conditions (see Appendix 9, Figure A9.1). In contrast habitats typical of open conditions (i.e. grassland, aquatic, swamp and strandline) had noticeably higher proportions of species with preferences for light conditions: Ellenberg values 7 and above.

This preference of lighter conditions by species associated with *Alnus glutinosa* (both the NVC and sites used in the current research) can be attributed to the fact that *Alnus glutinosa* generally forms a light canopy of dappled shade. Alternatively that there is significant edge effect, since many *Alnus glutinosa* woodlands tend to be fairly small or linear in nature resulting in a high perimeter-area ratio. Woodland occurring along a lowland watercourse also has a higher probability of having a well-lit edge compared to woodlands, for example, in a gully. The presence of glades will also add to the high proportion of light-demanding species as well as increasing the edge effect, although the latter would be relevant to all woodland types, not just *Alnus glutinosa.* The management and spacing of trees will have implications on the light characteristics of woodland, for example, densely planted high forests will have heavier shade than woodland managed on a coppice-with-standards rotation. These factors, however, are more likely to be wood-specific rather than related to woodland type. In conclusion it is considered that the results obtained for lowland *Alnus glutinosa* woodland are appropriate and valid.

Section 4.5 has shown that the canopy and shrub components of the *Alnus glutinosa* habitat generally span a narrower range of CSR-strategies and Ellenberg indicator value when compared to the groundflora. Therefore, only the groundflora (as identified in Section 4.3) will be considered when identifying potential characteristics and niches of a habitat (C/NoaHs) in the target habitat (Chapter 5).

<u>Habitat associations of component species of lowland *Alnus glutinosa* woodland</u>
Species that occur as a constant in at least one sub-community, or throughout a community of a particular habitat (as described by the NVC, Rodwell, 1991 *et seq*.), are likely to have a strong preference for the environmental conditions associated with these specific habitats. However, such species are only likely to be present in lowland *Alnus glutinosa* woodland if suitable conditions occur within the site and/or seed sources are in close proximity, such as adjacent habitats. The range of different habitats in which lowland *Alnus glutinosa* woodland species are found (Figure 4.5) suggests that these woodlands are potentially very variable and diverse but also that the species are generalists rather than specialists. Although Figure 4.5 shows that a few species associated with salt-marsh occur

within lowland *Alnus glutinosa* woodland, such species are likely to be glycophytes, which commonly occur inland in non-saline conditions. Similarly, common and widespread species also occur in the shingle, sand dune and maritime cliff communities. Therefore the conditions that are generally associated with such habitats (Table 4.3) are less likely to occur within lowland *Alnus glutinosa* woodland.

4.7 Concluding Characteristics of Lowland *Alnus glutinosa* Woodland

Based upon CSR analysis, the primary factor determining growth and composition of lowland *Alnus glutinosa* woodland is competition; secondary factors include disturbance, such as flood events or management, and stress, such as water logging. The data analysis of the Ellenberg indicator values of species occurring in lowland *Alnus glutinosa* woodland indicates that the woodlands have the potential to support a range of environmental conditions, and that they are theoretically diverse habitats. The analysis further suggests that soil moisture and fertility are key factors determining the plant composition within lowland *Alnus glutinosa* woodlands. These conclusions, at a habitat scale, partially support what Rodwell (1991. p.30) identified as the causes of floristic variation at a broad habitat scale across the seven types of wet woodland in the NVC:

> "*For the most part, floristic variation among these* [W1 to W7] *communities can be understood in terms of interactions between the amount of soil moisture, the degree of base-richness of the soils and waters and the trophic state of the system.*"

Based upon a variety of sources, notably UK Local BAPs, classification systems (e.g. Rodwell (1991) and Peterken (1993); see Section 2.3.2) and the results of the questionnaire (Appendix 2), the following could be considered to be determining features of wet woodlands (which include lowland *Alnus glutinosa* woodlands) within the UK:

1. occur in the UK;
2. are concentrated in the lowlands, but also occur in the uplands;
3. occur as fragments, scattered and localised habitats;
4. are small in spatial extent (< 4 ha);
5. are often concentrated along watercourses and in the riparian zones; usually being associated with river valleys, springs/flushes, bogs/mires, hydroseres, streams/rivers. However, they also occur occasionally as plateau woodland or in peaty hollows;
6. form a mosaic with other semi-natural habitats, notably wetlands and woodlands, where anthropogenic constraints allow (e.g. intense agricultural, urbanisation);

7. are at least damp underfoot for the majority of the year, i.e. at least seasonally wet, but can be waterlogged and may include drier raised areas;
8. occur on a range of soil types, although often poorly drained, organic and fertile; soil pH is variable, e.g. 3.3 – 7.3, but rarely calcareous;
9. can be of either secondary or ancient origin.

Starting from the above general characteristics of UK wet woodlands, further refinement through the analysis completed in Sections 4.2 to 4.5 enabled the following features of lowland *Alnus glutinosa* woodland to be identified by this research:

1. Spatial characteristics
    a. generally small, less than 4 ha;
    b. comprise young to mature stands; 20-100 years although may have a longer history;
    c. located in the lowlands of Britain, mainly adjacent to, or in close proximity to watercourses.
2. Species composition
    a. at least 332 species are associated with this habitat, of which 269 are groundflora, 30 shrub layer and 33 canopy species;
    b. there are no species considered to be endemic to this habitat; all species occur in at least one other habitat type as described by the NVC, or are rare or garden escapes;
    c. the species composition is likely to have a strong association with adjacent habitats and/or the history of the site. For example, a site adjacent to residential dwellings may have a number of non-native or naturalised species, while a site that has been, or is within, a woodland that has been used for game is more likely to have species such as *Rhododendron ponticum* or *Prunus laurocerasus*. Equally, woodlands that established relatively recently on grassland may have a high proportion of species more typically associated with grassland, if the flora has not yet adjusted to the new woodland conditions or if there is no seed source of woodland species within the seed dispersal range;
3. Environmental conditions
    a. this habitat is variable and likely to include a number of different environmental conditions, such as open water and dry banks, either within a

single site or in different sites. However, the following characteristics are likely to prevail:

- relatively stable environment with no extremes of stress or disturbance;
- semi-shaded to well lit;
- moist to wet soils;
- more or less neutral soils;
- intermediate to richly fertile soils creating a high productive habitat.

The characteristics listed above are used as the defining features of lowland *Alnus glutinosa* woodland studied in this research project. As a result of data being pooled from a number of sources, including existing classification systems, lowland *Alnus glutinosa* woodland can also be described by at least one of the classifications discussed in Section 2.3.2. A summary of each *Alnus glutinosa* woodland type described by the classifications in relation to lowland *Alnus glutinosa* woodland is provided in Appendix 3.

Having defined the research habitat in this chapter, Chapter 5 uses the data here to identify potential theoretical Characteristics and Niches of a Habitat (C/NoaHs) within lowland *Alnus glutinosa* woodlands.

5. IDENTIFYING THEORETICAL NICHES OF A HABITAT – LOWLAND *ALNUS GLUTINOSA* WOODLAND

5.1 INTRODUCTION AND AIMS OF CHAPTER

Chapter 4 described the research habitat in terms of its environmental conditions based on the optimal growth conditions (Ellenberg indicator values) and life strategies (CSR-strategies) of the constituent species associated with the habitat. The current chapter utilises these data to identify and describe potential Niches of a Habitat (NoaH) in lowland *Alnus glutinosa* woodlands. The Aim of Chapter 5 is therefore to identify groups of species, associated with lowland *Alnus glutinosa* woodland, with similar specific habitat requirements that could theoretically represent intra-site variation, i.e. NoaHs.

5.2 IDENTIFYING CHARACTERISTICS OF A HABITAT (COAHS) IN LOWLAND *ALNUS GLUTINOSA* WOODLANDS TO AID DETERMINATION OF THE NICHES OF A HABITAT (NOAHS)

This section, using the methods described in Section 3.4, considers the 269 groundflora species identified in Section 4.3 as being associated with lowland *Alnus glutinosa* woodland to identify potential Characteristics of a Habitat (CoaHs) within the habitat to aid the determination of Niches of a Habitat (NoaH). It uses qualitative data (i.e. presence/absence) and elaborates on the results of Chapter 4 that used Ellenberg indicator values and CSR-strategies to describe the overall habitat characteristics. Here, the species Ellenberg values and CSR-strategies are considered in more detail and the degree of variation of the variables, rather than the average or most dominant, are analysed to determine potential for intra-site variation.

5.2.1 Defining Characteristics of a Habitat (CoaHs)

As discussed in Section 3.4.1, the commonly recognised 19 CSR-strategies and Ellenberg indicator values are considered to provide too fine a detail for the implementation of management within a site. Following the process described in Section 3.4.1, the 19 CSR-strategies used in Chapter 4 were condensed into the seven main and intermediate strategies (these are summarised in Table 5.1 and constituent species listed in Appendix 10).

CoaH ref.	Condition	Characteristics	Component CSR-strategies
A	Competitors	High productivity and fertility, low disturbance and stress	C, C/CR, C/CSR, C/SC
B	Stress tolerators	Low productivity and fertility, high stress	S, S/CSR, S/SC, S/RS
C	Ruderals	High disturbance, >50% bare soil, disturbed open vegetation	R, R/CR, R/CSR, R/RS
D	Competitive ruderals	Productive and high fertility, occasional disturbance, >50% bare soil	CR, CR/CSR
E	Stress tolerant competitors	Productive, undisturbed	SC, SC/CSR
F	Stress tolerant ruderals	Moderate disturbance and stress	RS, RS/CSR
G	Non-extreme	Average conditions or species with a wide ecological amplitude	CSR

Table 5.1 Characteristics of each potential CSR-CoaH (Characteristic of a Habitat) ascertained from consideration of each CSR-strategy in isolation

The Ellenberg values for each environmental condition have been condensed into two to four groups each (CoaHs) based on the contribution and growth habits of species associated with different optimal growing conditions. These CoaHs are detailed in Table 5.2 and constituent species listed in Appendix 10.

CoaH ref.	Condition	Characteristics	Component Ellenberg indicator value
H	Shade	Shade condition	L3 - 4
I	Semi-shade	Dappled canopy or edge habitat	L5 - 6
J	Well lit	Glade or edge habitat	L7
K	Very well lit	Large glade or edge not obstructed by topographic features/adjacent vegetation	L8
L	Drier/moist	Low water table, discontinuous supply of water	F4 - 5
M	Constantly moist/damp	Water table near soil surface	F6 - 7
N	Wet	Marginal vegetation, damp hollows, mire habitats	F8 - 9
O	Very/permanently wet	Surface water, swamp habitats	F10 -11
P	Acidic	Acidic soils	R2 - 5
Q	Moderately acidic/more or less neutral	Near neutral soils with slight acidic bias	R6 - 8
R	More or less infertile	Away from areas where silt is deposited during flood events; sandy/free draining soils	N2 - 4
S	Intermediate fertility	Intermediate conditions	N5 - 6
T	Richly fertile	Localities where silt during flood events can collect, e.g. nearer river banks, in hollows	N7 - 9

Table 5.2 Characteristics of each potential CoaH ascertained from consideration of each Ellenberg indictor in isolation

On review of the species associated with lowland *Alnus glutinosa* woodland in relation to their Ellenberg indicator values, it was found that some Ellenberg values were only represented by a few species. In such situations the individual species were considered in relation to their ability, or tendency, to form extensive stands. For example, although CoaH-O only contains 7% of species (20) (Ellenberg moisture values 10 and 11, Figure 4.3b), the plants are generally adapted to standing water conditions and have the potential to represent a large spatial area within a woodland, assuming conditions occur, as several are also gregarious and stand forming. For example, *Caltha palustris*, *Carex acutiformis* and *Rorippa nasturtium-aquaticum* all have preferences for very wet conditions and can potentially form extensive, near monocultural, stands in spring and, therefore, such conditions have the potential to be significant on site. Personal observation in Site B at Stonebridge (see Chapter 6) shows this to be the case as there is a swath of these three species through the site, see Figures 5.1 and 5.2.

Fig. 5.1 Swath of species (*Caltha palustris*, *Carex acutiformis* and *Rorippa nasturtium-aquaticum*) associated with very wet conditions in *Alnus glutinosa* woodland Site B at Stonebridge (H S Miller, 22/04/08)

Fig. 5.2 Close up of species associated with very wet conditions in *Alnus glutinosa* woodland Site B at Stonebridge forming an extensive swath (H S Miller, 10/05/08)

The definitions of soil acidity used by Hill *et al*. (2004) indicate that species with Ellenberg soil acidity values 2 to 5 show some degree of tolerance to both acidic and moderately acidic conditions. Species of higher and lower Ellenberg soil acidity values are less tolerant of the counter condition. Therefore, it is considered that there is little potential difference between managing for highly acidic and for moderately acidic soils, so, Ellenberg acidity values 2 to 5 have been grouped in CoaH-P. Only eight species (3%) among the 269 groundflora species found in lowland *Alnus glutinosa* woodland are associated with more basic soil conditions (Ellenberg acidity value 8; Figure 4.3c). None of these eight species are considered to be strong calcicoles (Grime *et al.,* 2007 and Stace, 2001), but generally occur on soils less than pH5. Therefore, they can potentially occur on near neutral soils (Ellenberg values 6-7). Additionally, these species do not have gregarious/monocultural stand forming habits so are unlikely to represent a distinct intra-site variation condition. Several of these species also have a restricted geographic range or have a rare distribution. It is, therefore, suggested that, for lowland *Alnus glutinosa* woodland species, separation of species with preferences for basic (Ellenberg 8) and near neutral (Ellenberg 6-7) soils is inappropriate.

The CoaHs summarised in Tables 5.1 and 5.2 are considered further in Sections 5.2.2 to 5.2.4.

5.2.2 CSR-CoaHs of species found in lowland *Alnus glutinosa* woodlands

Figure 5.3 details the number and percentages of groundflora species, found in lowland *Alnus glutinosa* woodland, occurring in each CSR-CoaH. The Figure shows that most species represent CoaH-B, stress-tolerators, (19%) and CoaH-A, competitors, (18%). CoaH-F, stress-tolerant ruderal strategy, is least represented.

CoaH/CSR-stratgey	No. species	%
A. Competitors *(C)*	49	18.2
B. Stress-tolerators *(S)*	51	19.0
C. Ruderals *(R)*	30	11.2
D. Competitive ruderals *(CR)*	45	16.7
E. Stress tolerant-competitors *(SC)*	29	10.8
F. Stress tolerant ruderals *(RS)*	14	5.2
G. Competitive, stress tolerant ruderals *(CSR)*	40	14.9
No strategy data	11	4.1

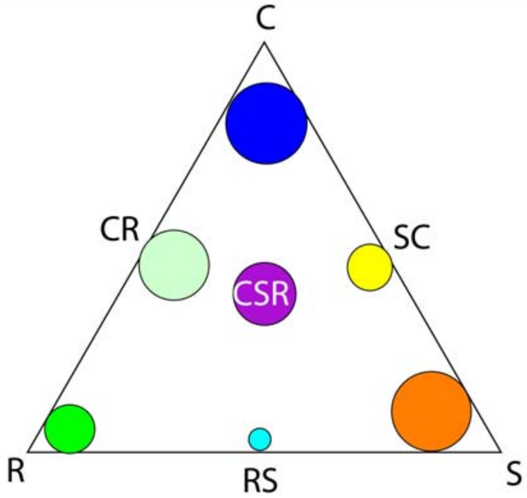


Fig. 5.3 Summary of species found in the groundflora of lowland *Alnus glutinosa* woodlands (see Section 4.3) in each main CSR-CoaH group
(Circles are proportional to the number of species in each group)

5.2.3 Light-CoaHs of species found in lowland *Alnus glutinosa* woodland

Section 5.2.1 concluded that the six Ellenberg light values (3-8) represented by species found in lowland *Alnus glutinosa* woodland can be condensed into four conditions that could be influenced by woodland management operations. These four conditions are illustrated in Figure 5.4 which shows that the majority of species are associated with 'well lit' (42%) and 'semi-shade' (38%) conditions. The remaining species are evenly divided between 'very well lit' and 'shaded' conditions. The species occurring in each of these four light conditions are listed in Appendix 10.

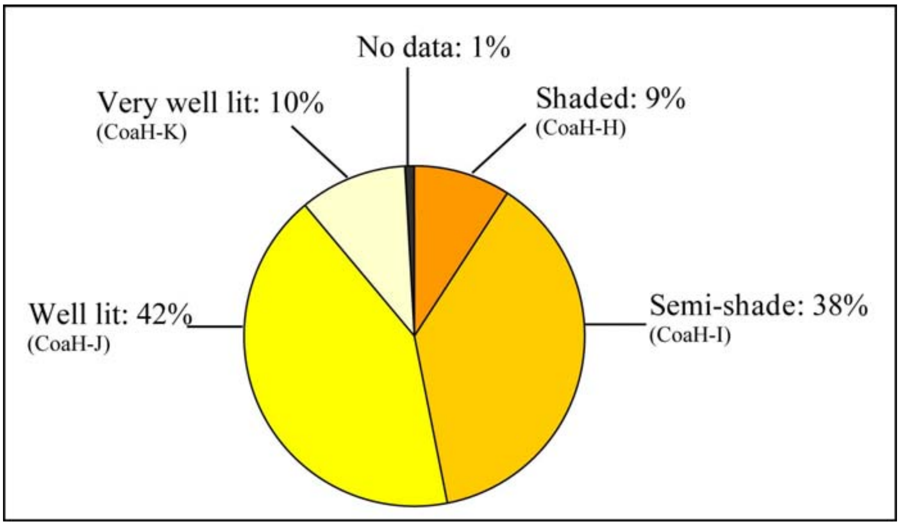


Fig. 5.4 Light Characteristics of a Habitat (Light-CoaH) that could occur in lowland *Alnus glutinosa* woodland based on Ellenberg indicator values (Hill *et al.*, 2004) of the groundflora species found in the habitat

5.2.4 Soil CoaHs of species found in lowland *Alnus glutinosa* woodland

Soil moisture

The four distinct soil moisture conditions identified in Section 5.2.1 after condensing the Ellenberg indicator values into conditions that may be influenced by management are presented in Figure 5.5. The Figure shows that the majority of species found in lowland *Alnus glutinosa* woodland are more or less evenly divided between drier/moist (34%), constantly moist (29%) and very wet (29%) soil conditions. The least number of species are associated with very wet (7%) conditions. The species occurring in each of these conditions are listed in Appendix 10.

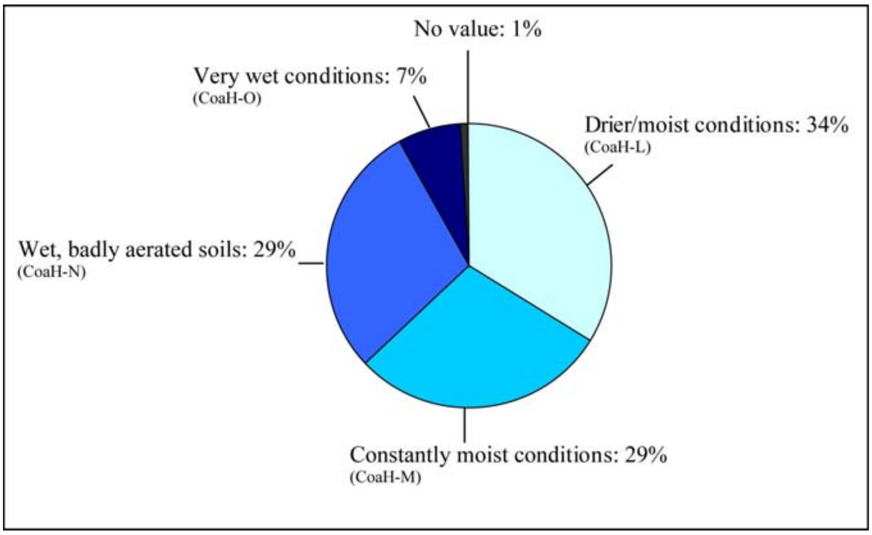


Fig. 5.5 Soil moisture Characteristics of a Habitat (Moisture-CoaH) that could occur in lowland *Alnus glutinosa* woodland based on Ellenberg indicator values (Hill *et al.*, 2004) of the groundflora species found in the habitat

Soil acidity

Section 5.2.1 concluded that species associated with lowland *Alnus glutinosa* woodland fall into one of two soil acidity conditions (acidic and moderately acidic/near neutral) that could dominate a woodland. The proportion of species that show optimal growth in each of these conditions is illustrated in Figure 5.6 and the species listed in Appendix 10. The Figure shows that most species (74%) have preferences for moderately acidic/near neutral conditions, with about 25% in acidic soils.

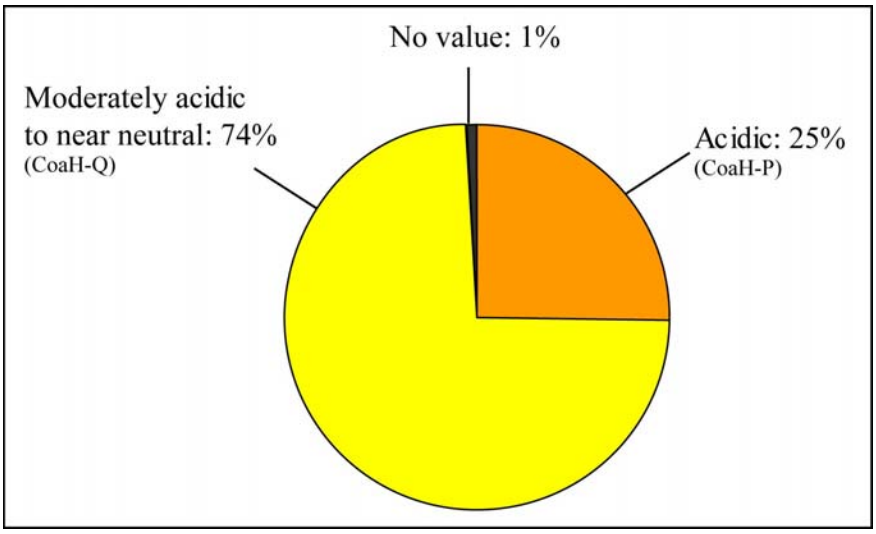


Fig. 5.6 Soil acidity Characteristics of a Habitat (Acidity-CoaH) that could occur in lowland *Alnus glutinosa* woodland based on Ellenberg indicator values (Hill *et al.*, 2004) of the groundflora species found in the habitat

Soil fertility

The proportion of species associated with the three soil fertility conditions derived from Ellenberg indicator values in Section 5.2.1, are illustrated in Figure 5.7. The Figure shows that although there is a slight bias towards intermediate fertility (49% of species), the three conditions are fairly evenly represented by species found in lowland *Alnus glutinosa* woodland. The species occurring in each of these groups are listed in Appendix 10.

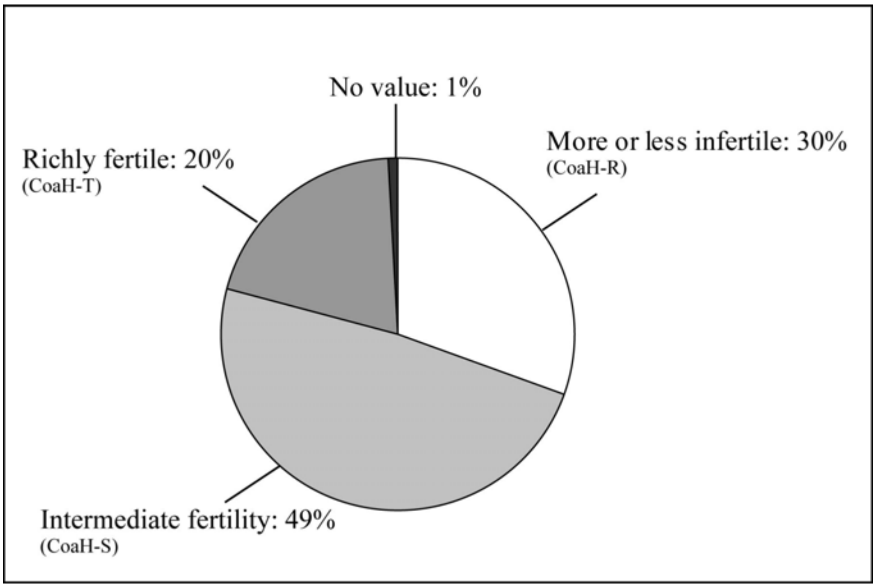


Fig. 5.7 Soil fertility Characteristics of a Habitat (Fertility-CoaH) that could occur in lowland *Alnus glutinosa* woodland based on Ellenberg indicator values (Hill *et al.*, 2004) of the groundflora species found in the habitat

Association between CSR-strategies and soil fertility

The association between soil fertility and CSR-strategies is demonstrated in Figure 5.8, in that species with preferences for highly fertile conditions (21%, 54 species) are primarily C- (30%) and CR- (31%) strategists. The species associated with intermediate fertility conditions (51%, 131 species) are fairly evenly distributed across the CSR Triangle, while those associated with low fertility (32%, 82 species) show a bias towards S-strategies (40%). If the component species of the CSR-strategies are considered in relation to their Ellenberg values, 89% of the C-strategists (Figure 5.3) prefer intermediate to richly fertile soils (Ellenberg values 5-8). The results, depicted in Figure 5.8 and interpreted from Figure 5.3, strongly support the definitions of CSR-strategists discussed in Section 2.3.1, i.e. C-strategists are associated with fertile conditions with low stress and disturbance. The results also justify the use of the CSR-strategy theory in assessing environmental conditions within a site.

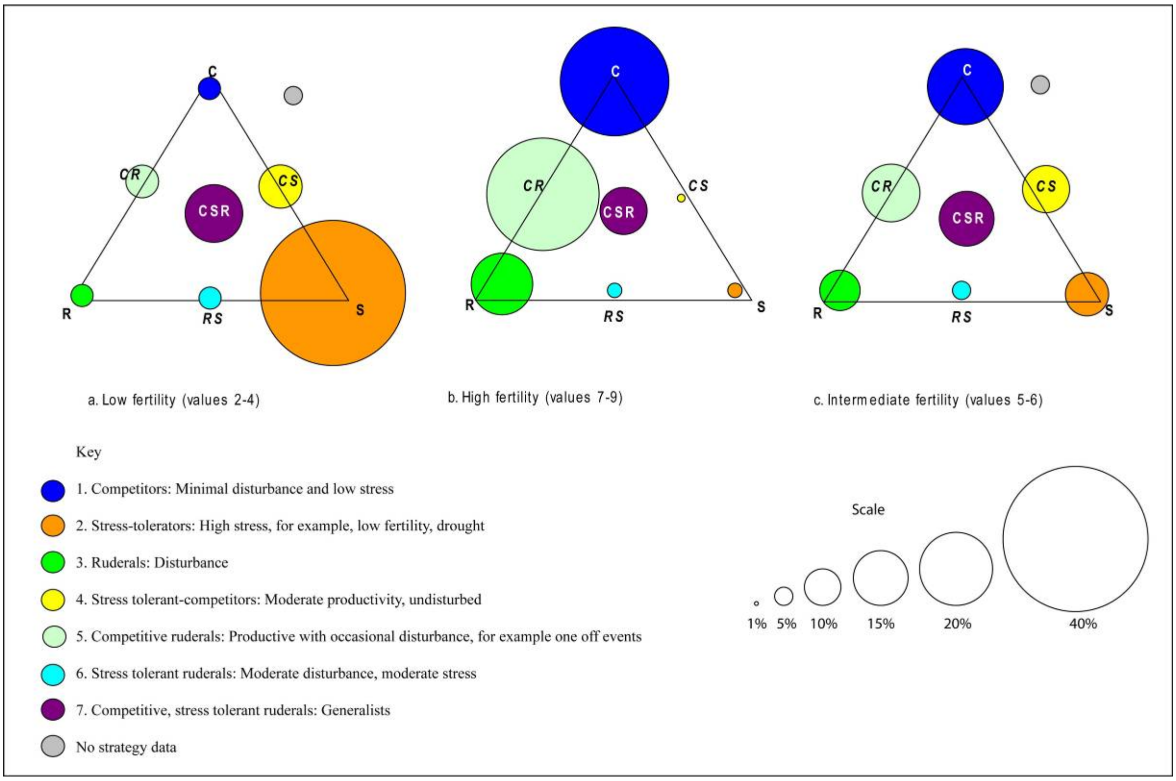


Fig. 5.8 Relative proportion and distribution of lowland *Alnus glutinosa* woodland groundflora species associated with different soil fertility conditions across the CSR-triangle; illustrating the different strategy biases depending on the soil fertility preferences of species
a) low fertility - 82 sp., b) high fertility - 54 sp. c) intermediate fertility - 131 sp.

5.3 LIFE-HISTORY STRATEGIES COMBINED WITH LIGHT AND SOIL CONDITIONS OF SPECIES IN LOWLAND *ALNUS GLUTINOSA* WOODLANDS

As discussed in Section 3.4.1 the complete range of CSR-strategies and Ellenberg indicator values are considered to be too fine a scale for implementing management and were therefore reduced into characteristic groups (CoaH – Characteristics of a Habitat); see Section 5.2. These 20 CoaHs (reduced from 139 possible variables and illustrated above in Section 5.2), give rise to 672[1] potential combinations, i.e. NoaHs. However, not all combinations occur within the 269 groundflora species associated with lowland *Alnus glutinosa* woodland. A review of groundflora species found within lowland *Alnus glutinosa* woodland identified 129 unique combinations of CoaHs (Appendix 11, Section A11.1). Of these CoaH groups, the majority (*c.* 94 groups; 71%) comprised one to two species. The maximum number of species within a group was 10 and this only occurred in

[1] If there are 20 CoaHs in 5 groups (7 CoaH-CSR; 4 CoaH-light; 4 CoaH-moisture; 2 CoaH-acidity and 3 CoaH-fertility) and only one CoaH from each group can occur at once (i.e. each combination contains one CoaH from each group) this gives 7 x 4 x 4 x 2 x 3 combinations, i.e. 672.

one group. As discussed in Section 3.4.3, such small groups are considered inappropriate for implementation of management within a site.

An alternative mechanism for taking account of each Ellenberg indicator and CSR-strategy to determine NoaHs is to use multivariate analysis as described in Section 3.4.2. A species x character matrix, comprising species found in lowland *Alnus glutinosa* woodlands and their preferred growing conditions (Ellenberg values) and life history strategies (CSR), was analysed separately using both TWINSPAN classification and DCA ordination multivariate techniques (see Section 3.4.2). The outputs of each where then considered together to refine the final NoaHs and their constituent species. The results of these analyses are provided below.

5.3.1 Use of TWINSPAN to assess CSR-strategy and Ellenberg indicator values simultaneously

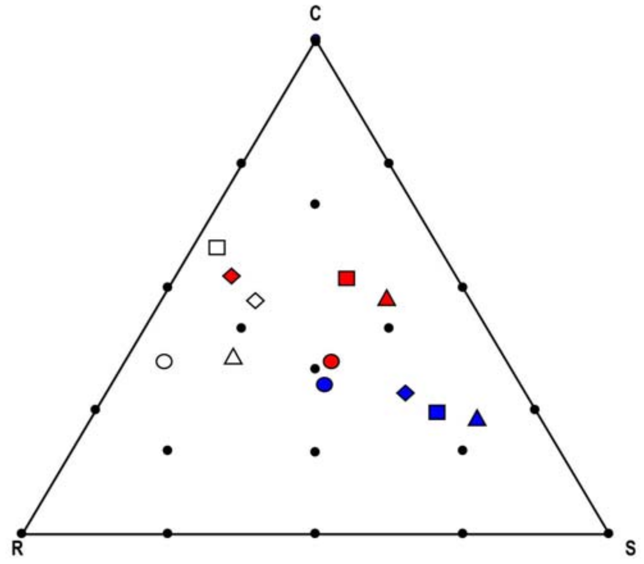
The species groups of the first two divisions of the TWINSPAN analysis (0, 1 and 11, 01, 10, 11) were diverse in terms of the Ellenberg values and CSR-strategies of the component species. However, there were some slight biases towards different characteristics:

- Level 1: species comprising positive group (1) had a bias towards preferences for low-intermediate fertility and acidic soils
- Level 2 (negative): species comprising group 00 had slight preferences towards well lit and very wet, high fertility soils compared to group 01
- Level 2 (positive): species comprising group 10 were more stress-tolerant with preferences for neutral and intermediate fertility soils compared to group 11 species with preferences towards acidic and low soil fertility.

At division levels 3 and 4 the component species of the groups became more consistent in terms of Ellenberg values and CSR-strategies. However, even at these levels of division the component species included a range of conditions within each Ellenberg type (e.g. light, soil moisture etc) and CSR-strategy (e.g. C, CSR etc), suggesting that some species may be better placed in a different TWINSPAN group. Table 5.3 details the number of species, mean and range of Ellenberg values, while Figure 5.9 shows the CSR-strategies of the 12 TWINSPAN output species groups; the species occurring in each group are listed in Appendix 11 (Section A11.2). Despite the clear overlap in terms of range of conditions, ANOVA (Table 5.3) indicates that these 12 groups are statistically different in at least one Ellenberg type/CSR-strategy based on the means of the component species. The 12 groups could, therefore, be considered to be potential NoaHs within lowland *Alnus glutinosa* woodland and were subsequently reviewed and refined using DCA ordination.

TWINSPAN species group	Light		Moisture		Acidity		Fertility		No. species
	range	mean	range	mean	range	mean	range	mean	
0000	4-7	6.82	5-10	5.88	6-7	6.47	6-9	6.53	17
	Well lit		Drier		Near neutral		Intermediate		
0001	7	7.00	5-11	9.33	6-7	6.92	6-8	6.83	12
	Well lit		Very wet		Near neutral		High		
001	3-8	6.30	5-10	6.37	6-7	6.59	4-8	6.20	46
	Well lit		Constantly moist		Near neutral		Intermediate		
0100	3-8	6.89	4-9	6.67	5-8	6.39	3-6	4.83	18
	Well lit		Wet		Near neutral		Intermediate		
0101	4-8	5.85	5-11	6.10	5-8	6.10	4-7	5.35	20
	Semi-shade		Wet		Near neutral		Intermediate		
0110	3-7	5.61	4-9	6.78	7	7.00	4-8	6.22	18
	Semi-shade		Wet		Near neutral		Intermediate		
0111	6-8	6.75	6-9	8.00	6-7	6.88	5-7	6.38	8
	Well lit-shade bias		Wet		Near neutral		Intermediate		
100	3-7	5.46	5-10	6.46	6-8	7.00	5-8	5.92	24
	Semi-shade		Constantly moist		Near neutral		Intermediate		
101	5-8	6.50	4-10	7.06	3-7	5.53	2-6	4.34	33
	Semi-shade-light bias		Wet		Moderate acidic - near neutral		Low		
110	4-8	5.68	4-9	6.12	4-7	5.21	2-6	4.44	52
	Semi-shade		Constantly moist		Moderate acidic		Low		
1110	6-8	7.29	4-10	7.71	3-8	5.14	2-8	3.21	14
	Very well lit		Wet		Moderate acidic		Low		
1111	6-8	7.67	8-9	8.33	3-8	4.17	2-4	2.50	7
	Very well lit		Wet		Moderate acidic		Low		
F	7.175		5.720		20.333		28.372		
P-value	1^{-10}		3^{-8}		4^{-29}		2^{-38}		
F critical	1.828								
Significant?	✓		✓		✓		✓		

Table 5.3 Summary of the characteristics (light, soil: moisture, acidity, fertility), based on the constituent species, of each output group following TWINSPAN classification of the groundflora species found to be associated with lowland *Alnus glutinosa* woodland (Section 4.3). Results of ANOVA statistics also shown.



TWINSPAN Group		C	S	R	CSR Value
Grp 0000	○	0.348	0.069	0.583	CR
Grp 0001	□	0.583	0.042	0.375	CR
Grp 001	◇	0.476	0.161	0.363	CR/CSR
Grp 0100	△	0.361	0.181	0.458	CR/CSR
Grp 0101	● (red)	0.346	0.358	0.296	CSR
Grp 0110	■ (red)	0.519	0.297	0.184	SC/CSR
Grp 0111	◆ (red)	0.524	0.095	0.381	CR/CSR
Grp 100	▲ (red)	0.482	0.384	0.134	SC/CSR
Grp 101	● (blue)	0.299	0.371	0.330	CSR
Grp 110	■ (blue)	0.241	0.593	0.166	S/CSR
Grp 1110	◆ (blue)	0.285	0.514	0.201	SC/CSR
Grp 1111	▲ (blue)	0.233	0.683	0.084	S/CSR
ANOVA Statistics					
F		4.853	15.131	8.250	
P-value		9^{-7}	2^{-22}	3^{-12}	
F Crit		1.828			
Significant?		✓	✓	✓	

Fig. 5.9 Mean CSR-strategies (as calculated using UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)) for each TWINSPAN output group of the binary species x environmental variable matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Results of ANOVA statistics also shown.

5.3.2 Use of DCA ordination to review the TWINSPAN output groups

To help determine if certain species would be better placed in different TWINSPAN groups, the same input matrix was analysed using DCA ordination. The output of the DCA ordination analysis (axes 1 and 2) is shown in Figure 5.10. The constituent species of the TWINSPAN groups are considered in relation to their preferred environmental conditions and CSR-strategies in Figure 5.11 to 5.15.

Figure 5.10 shows that the majority of species are densely clustered in the centre of the ordination with more scattered groups with lower axes 2 scores, lower axes 1 scores and higher axes 1 scores. The results of linear regression and product moment correlation coefficients (R) (see Section 3.4.2 and Table 3.5) are shown in Table 5.4. These results show that the distribution of species along the first axis is best described by soil acidity and fertility and degree of stress, while axis two is best described by light and soil moisture. From the correlations between the ordination axes scores and the Ellenberg indicator values and CSR-strategies detailed in Table 5.4, it can be expected that species with the following preferences will be concentrated in the following areas of the DCA ordination diagram:

- Wet soils and low stress: high ordination axes 1 and 2 scores
- Acidic and low fertility soils: low ordination axis 1 and high axis 2 scores
- High stress: low ordination axes 1 and 2 scores
- Basic and high fertility soils: high ordination axis 1 and low axis 2 scores
- Light conditions: high ordination axis 2 scores
- Shaded conditions: low ordination axis 2 scores.

Character	**R value and Correlation: species** **Axis 1**	**Axis 2**
Ellenberg indicator values		
L	r = 0.074 V. weak	r = 0.662 **Modest +ve**
F	r = 0.154 **Very weak +ve**	r = 0.503 **Modest +ve**
R	r = 0.722 **Strong +ve**	r = 0.142 V. weak –ve
N	r = 0.812 **Strong +ve**	r = 0.267 **Weak -ve**
CSR-strategies		
C	r = 0.417 **Modest +ve**	r = 0.160 **V. weak +ve**
S	r = 0.769 **Strong -ve**	r = 0.281 **Weak -ve**
R	r = 0.469 **Modest +ve**	r = 0.163 **V. weak +ve**
Eigen value	0.422	0.308
Notes: **Bold** denotes statistically significant at P 0.01 levels of significance		

Table 5.4 Statistical significance of species found within lowland *Alnus glutinosa* woodlands DCA ordination axes and character variable correlations based on species preferences (Ellenberg indicator values, Hill *et al.*, 2004: see Table 2.9; CSR-Strategy, Hunt, 2007b: see Table 2.10)

Figures 5.11 to 5.15 illustrate the distribution of species across DCA ordination space in relation to the CoaHs identified in Section 5.2.1 and confirm the expectations noted above.

The species in Figure 5.10 are depicted by the TWINSPAN group in which they occur (see Appendix 11, Section A11.2). Although there is overlap, species in the same TWINSPAN groups are also generally clustered in the same ordination space. The mean conditions for each TWINSPAN group (Table 5.3) correspond to the positioning of the species in ordination space.

Figure 5.11, illustrates the species distribution in ordination space in terms of their CSR-CoaHs and can broadly be described by a CSR-Triangle with the apices at the following locations:

- C: high ordination scores on axis 1 and axis 2
- R: high ordination scores on axis 1, middle ordination scores on axis 2
- S: low ordination scores on axis 1, middle ordination scores on axis 2.

Generally species with low stress CSR-values have high ordination scores on axis 1 and those with high stress CSR-values have low ordination scores on axis 1. Species with high disturbance CSR-values are generally towards the higher end of axis 1, whilst those with a non-extreme strategy (i.e. CSR) are concentrated in the central cluster of species. Species not assigned a CSR-strategy have a high ordination score on axis 2.

The species in TWINSPAN groups with a mean CSR-strategy of moderate to high disturbance (001, 0001, 0111, 0100, 0000, Figure 5.9) primarily occur in DCA ordination space where C-, CR-, and R-strategists are concentrated towards the higher end of axis 1 (i.e. CoaH-A, C and D; Table 5.1). The species in the group of the least stress and disturbance (100, 0110, Figure 5.9) are primarily located where C-species are positioned in DCA ordination space (i.e. CoaH-A). Species in groups comprising species with the highest stress-CSR-values (110, 1110, 1111, Figure 5.9) have low ordination axis 1 scores where stress tolerant species are concentrated (CoaH-B). Constituent species of groups with the lowest disturbance (1111, 100, 110, 0110, Figure 5.9) have low to middle ordination scores on axis 1 values where S, SC-, C- and CSR-species are concentrated (i.e. predominately CoaHs-A, B, E and G). Species forming groups of non-extreme strategies (0101, 1010, 1011, Figure 5.9) generally occur in the central cluster in DCA ordination space where CSR-species are concentrated (i.e. CoaH-G). However, there is much overlap of species comprising the TWINSPAN groups in DCA ordination clusters on axes 1 and 2.

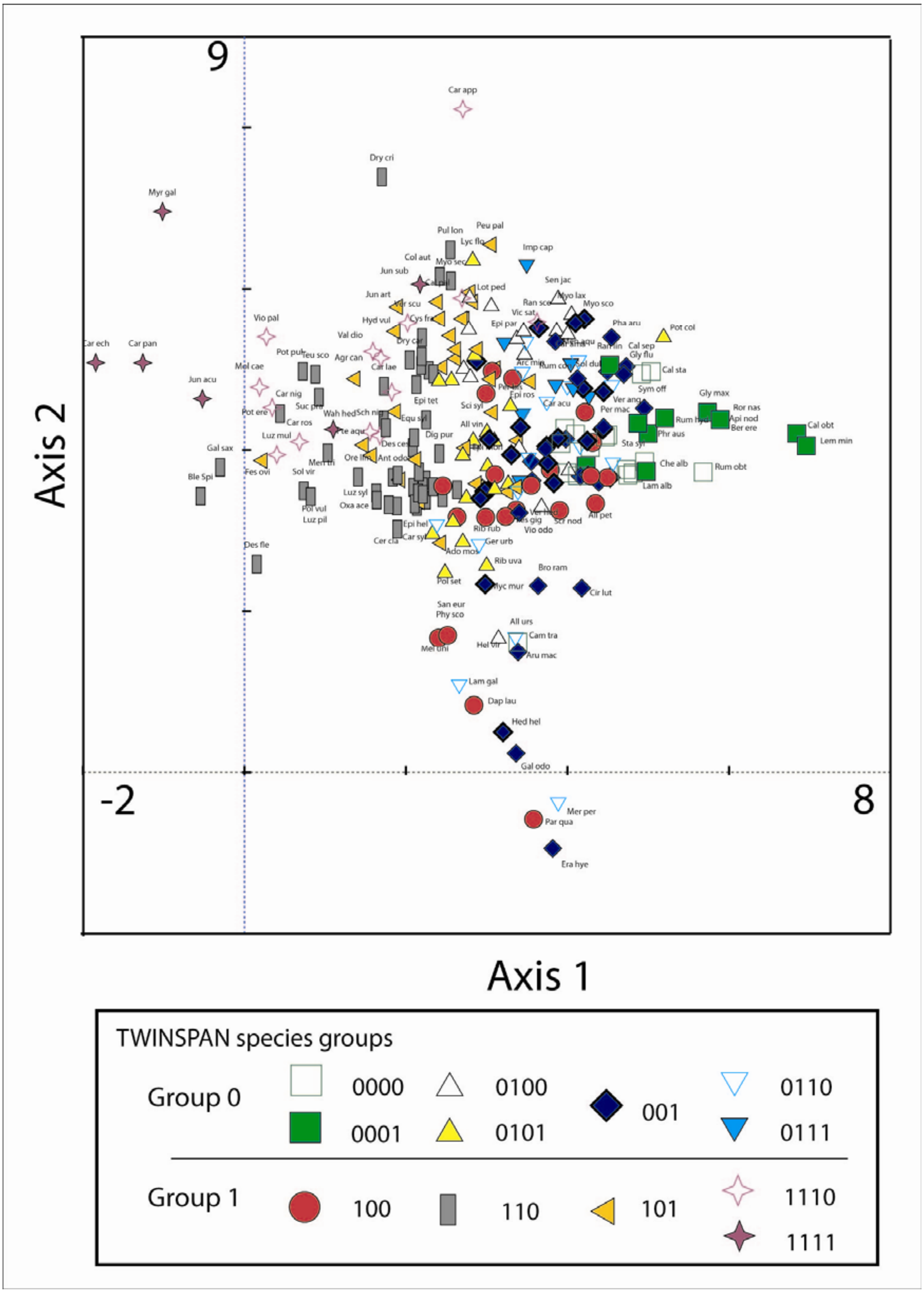


Fig. 5.10 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups derived from the same species x character matrix input

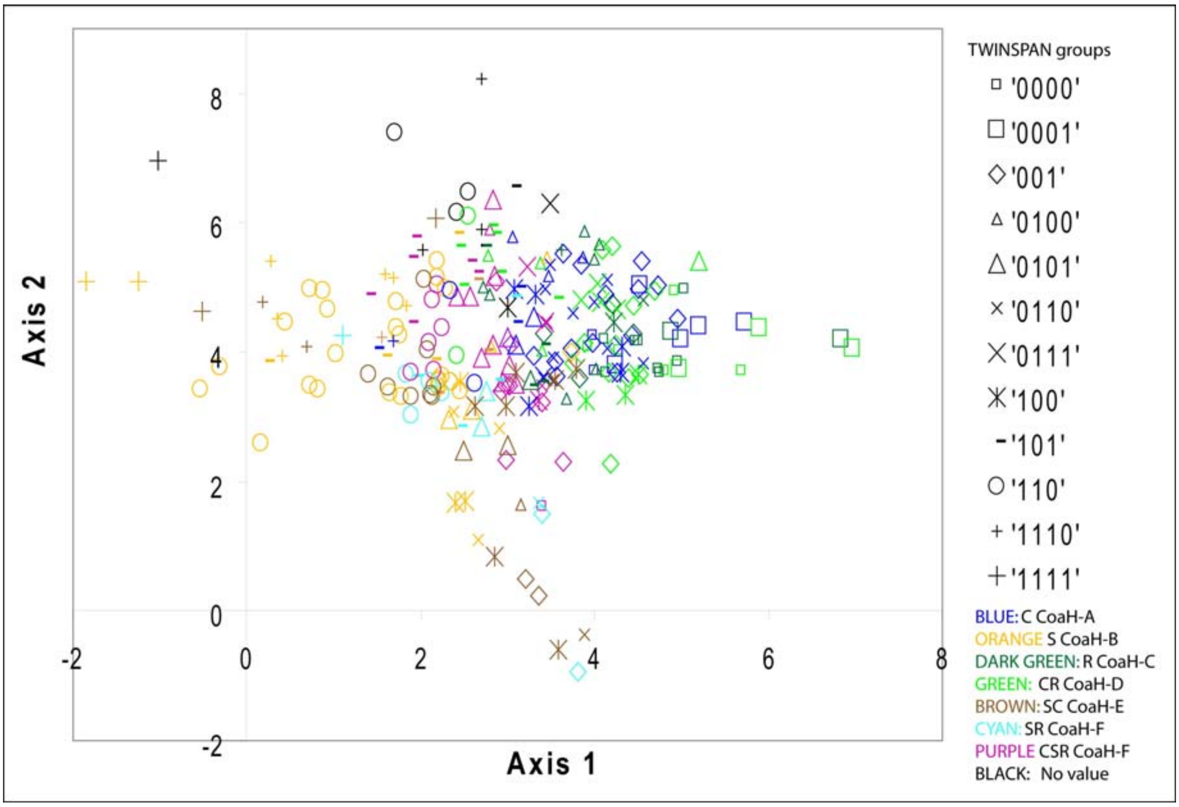


Fig. 5.11 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species x character input matrix and CoaH-CSR conditions (Table 5.1)

Figure 5.12 depicts the species in ordination space and TWINSPAN groups in relation to Light-CoaHs and shows that species with a preference for shaded conditions are located as a loose clustering with non-extreme axis 1 ordination scores and low axis 2 ordination scores. The main central cluster of species is dominated by species with preferences for semi-shade with those preferring well and very well lit conditions occurring at the periphery. Generally species preferring very well lit conditions have lower axis 1 ordination scores to those of well lit conditions.

The species in TWINSPAN groups with mean well lit light conditions (see Table 5.3 – 0000, 0001, 001, 0100) are located in areas in DCA ordination space represented by well lit CoaH-J, i.e. high axis 1 scores. Although Group 001 also includes species with lower axes 2 scores, i.e. shaded conditions (CoaH-H). Groups with mean very well lit conditions (1110 and 1111, Table 5.3) are concentrated at the lower end of axes 1, i.e. very well lit CoaH-K. Although species in the remaining TWINSPAN groups (i.e. groups with a mean semi-shade) are concentrated in the centre of DCA ordination space where CoaH-I species are also concentrated, species also occur across all the CoaH-Light conditions.

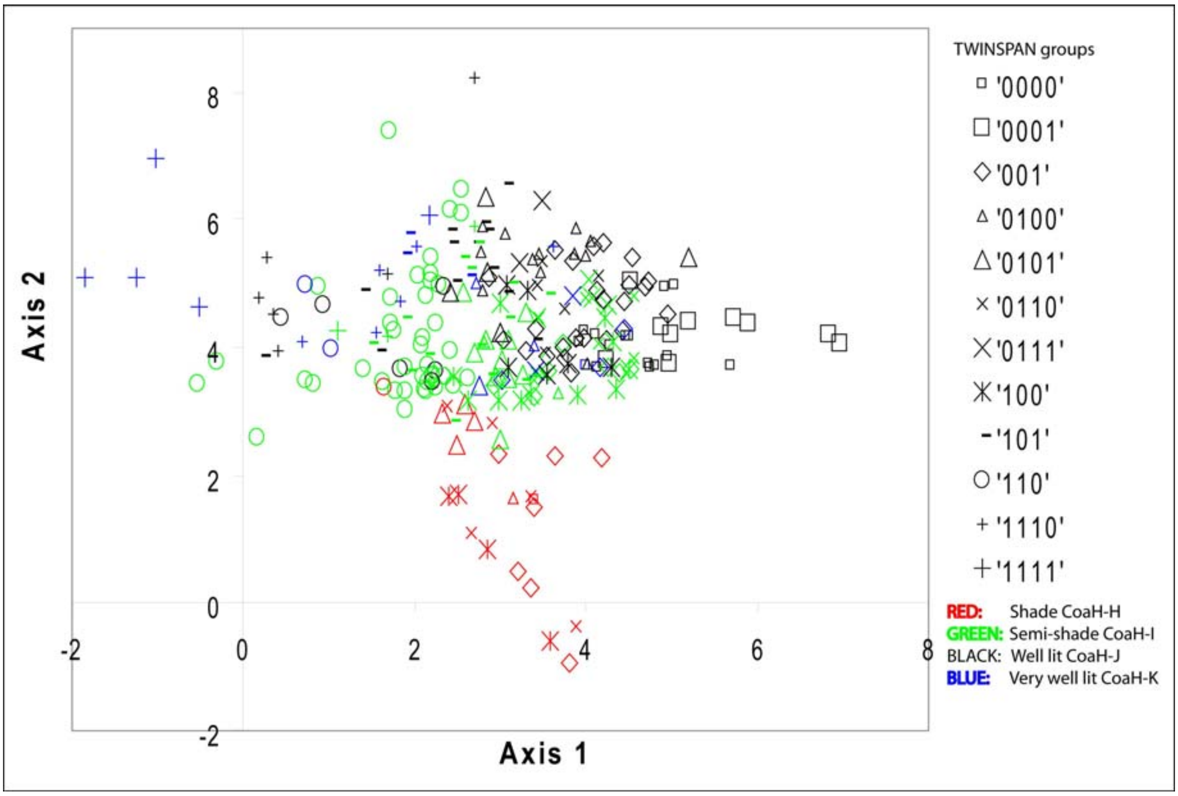


Fig. 5.12 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species x character input matrix and CoaH-light conditions (Table 5.2)

Figure 5.13 shows that plants associated with very wet conditions primarily have high ordination scores on axis 1 and middle scores on axis 2. These species dominate the loose cluster of species to the right of the main central cluster. Plants associated with wet soils are located on the top edge of the central cluster, while plants with preferences for drier/moist conditions dominate the loose cluster with low axes 2 scores, although they also occur in the central cluster. Plants with preferences for constantly moist soils dominate the central cluster, i.e. generally plants outside the average (moist) occur at the periphery and as outliers of the main species cluster in DCA ordination space.

Species in the TWINSPAN group with a mean soil moisture condition of very wet (0001, Table 5.3) have high ordination scores on axis 1, corresponding to the DCA ordination space dominated by species with preferences for very wet soils. The species of groups with a mean soil moisture value of wet soils (010, 0111, 1110, 1111; Table 5.3) have high ordination scores on axis 2 and middle-high scores on axis 1, i.e. the same area as species in CoaH-N (wet soils). Species of TWINSPAN group 0000, with mean preferences for drier soils have mid-high axis scores, corresponding to CoaH-L, but do also include those associated with very wet conditions. The species in the remaining TWINSPAN groups (i.e. groups with mean soil moisture of constantly moist) are primarily located in the central species cluster in DCA ordination space, i.e. correspond to CoaH-M (constantly moist).

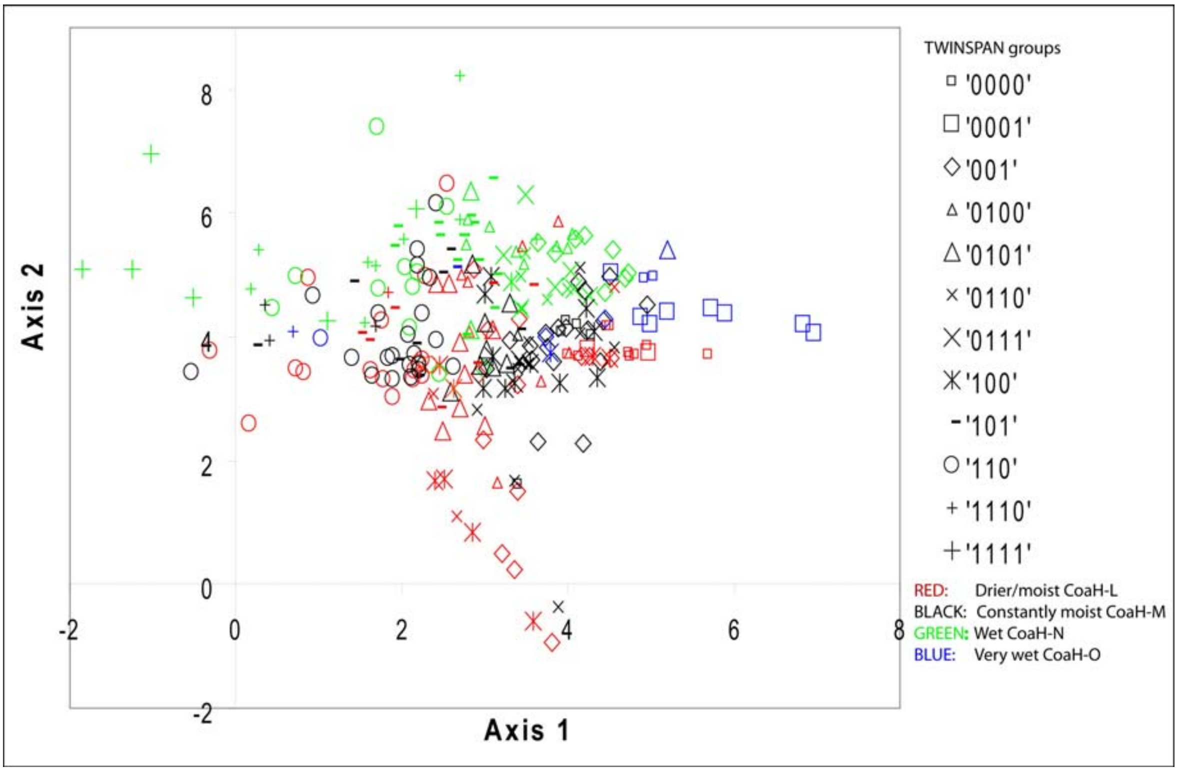


Fig. 5.13 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species x character input matrix and CoaH-moisture conditions (Table 5.2)

Figure 5.14 shows that species associated with acidic soils are concentrated at the lower end of axis 1 while species with near neutral soils at the mid-higher end. Subsequently the main central cluster of species primarily comprises species with preferences for more neural soils, the loose cluster with low ordination scores on axis 1 is dominated by species with a preference for acidic conditions while the cluster with low ordination scores on 2 with near neutral species.

The species forming the TWINSPAN groups with a more acidic mean soil condition (101, 1110, 1111, Table 5.3) are concentrated towards the lower end of axis 1 and therefore correspond to CoaH-P (acidic). The remaining species, i.e. those in the near neutral (acidic bias) and near neutral TWINSPAN groups, are located towards the higher end of axis 1 and subsequently correspond to CoaH-Q (near neutral). The exception is group 101 which, comprising species of both acidic and near neutral species, has low-mid axis 1 scores.

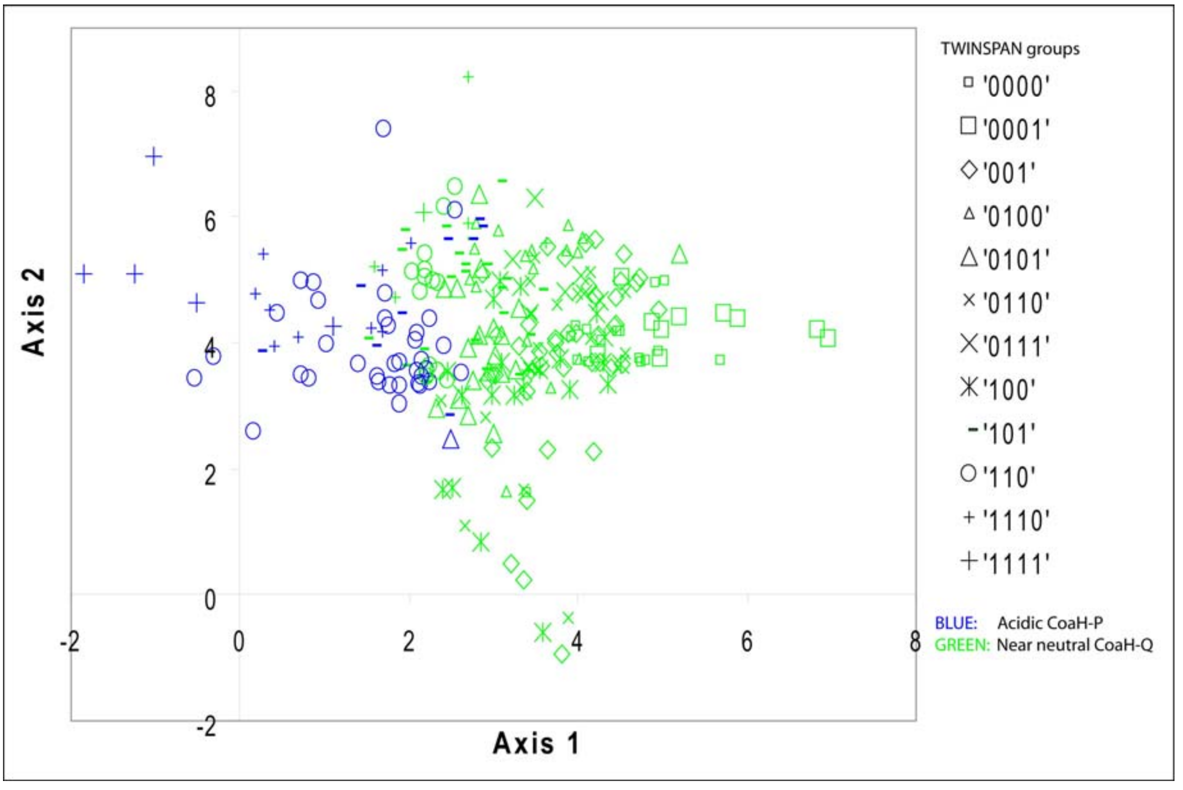


Fig. 5.14 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species x character input matrix and CoaH-acidity conditions (Table 5.2)

Figure 5.15 shows a transition from species associated with low fertility soils to those with preferences for high soil fertility from low to high scores on axis 1. Subsequently the loose cluster of species at the low end of axis 1 is dominated by species with a preference for low fertility conditions whilst those at the high end with high fertility species. The loose cluster at the low end of axis 2 primarily comprises species of intermediate soil fertility.

The species in the TWINSPAN groups with a high mean soil fertility (0001, Table 5.3) have higher ordination scores on axis 1 so correspond to CoaH-T (high fertility). Similarly the species in TWINSPAN groups with low mean soil fertility (101, 110, 1110, 1111,

Table 5.3) generally have lower ordination scores on axis 1, corresponding to CoaH-R (low fertility), although groups 101 and 110 include species with mid-axes 1 scores and correspond to CoaH-S. Species of TWINSPAN groups with intermediate mean soil fertility generally occur between these two extremes, although species also occur among both CoaH-T and CoaH-R.

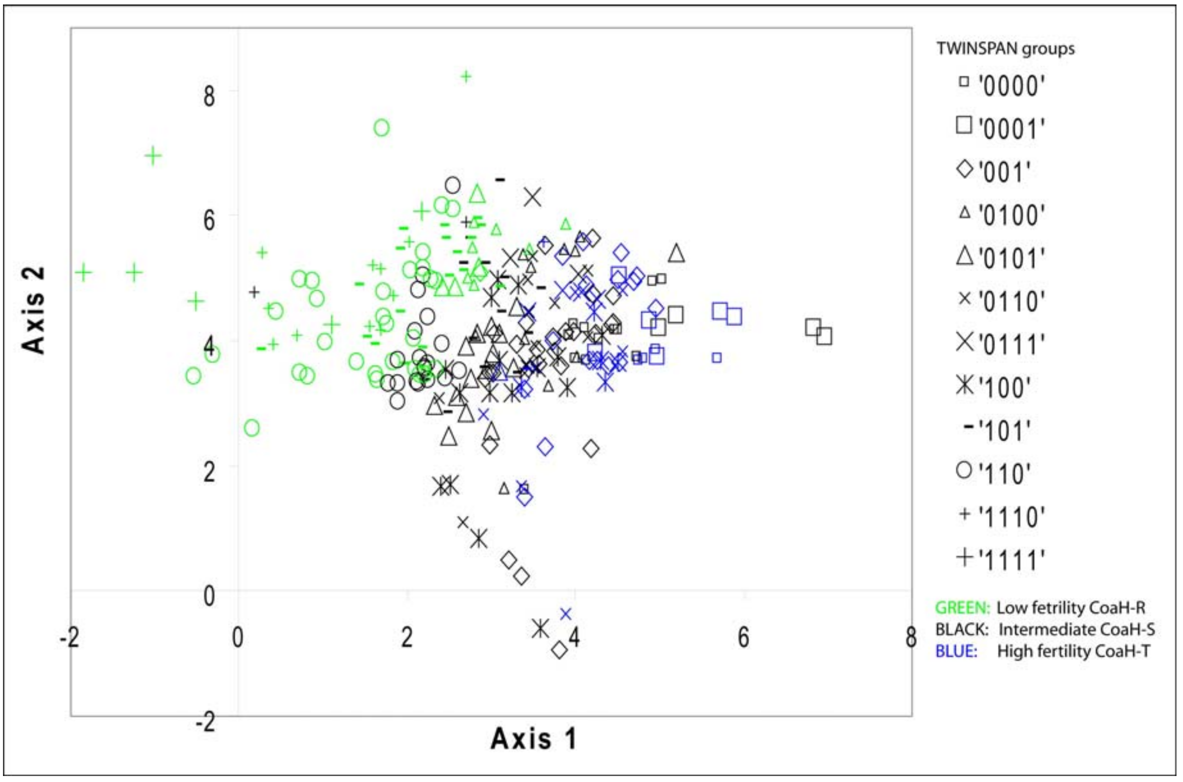


Fig. 5.15 DCA output (axes 1 and 2) of binary species x character matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species x character input matrix and CoaH-fertility conditions (Table 5.2)

5.4 Determining and Defining Potential NoaHs in Lowland *Alnus glutinosa* Woodland

This section utilises the following to determine and define potential NoaHs in lowland *Alnus glutinosa* woodland:

- results of the analyses detailed in Sections 5.2 and 5.3;
- examples and species autoecology from the literature;
- data collected during the initial stages of the research when identifying the component species of the target habitat.

Several studies (e.g. Rodwell, 1991; Douda, 2008) have pointed to a number of factors and situations which give rise to intra-site variation, for example, Douda found the following in various *Alnus glutinosa* woodland types in the Czech Republic:

- varied micro-relief, e.g. drier hummocks and waterlogged hollows;
- nutrient gradients;
- moisture gradients;
- substrate gradients in response to flood events;
- springs.

The current analysis of the groundflora component has shown that such situations are also likely to occur in lowland *Alnus glutinosa* woodlands, and that there is some similarity of species despite the different geographic regions, i.e. UK and Czech Republic. The determination and occurrence of potential NoaHs within lowland *Alnus glutinosa* woodlands is developed in Sections 5.4.1 to 5.4.5. Initially the individual conditions, i.e. CoaHs, are considered singly and then they are combined (NoaHs) to take account of the interaction of such conditions in the lowland *Alnus glutinosa* woodland ecosystem.

Section 5.2 identified and defined groups of species based on their reduced CSR-strategies and Ellenberg values, i.e. CoaHs, and Section 5.3 showed that these species generally occurred in similar TWINSPAN groups and clusters in DCA ordination space. For each characteristic, i.e. CSR-strategy, light, soil moisture, acidity and fertility, generally the majority of species were associated with a particular CoaH. Whilst these CoaHs are likely to describe the main characteristics within a site, the remaining, smaller groups of species are likely to represent the intra-site variation of conditions. However, if particular conditions prevail across the majority of the site one of the CoaHs comprised by fewer species can represent the main character of the site. Similarly different woodlands may have different proportions of each condition. This is illustrated (Figure 5.16) by the four Rother sites (Liss, Hampshire) (Figure 5.17) and is discussed further in relation to on the ground conditions in Chapter 7. These four sites represent four distinct, yet adjacent, areas of lowland *Alnus glutinosa* woodland along the River Rother that were assessed as part of the initial investigations to identify species associated with the target habitat.

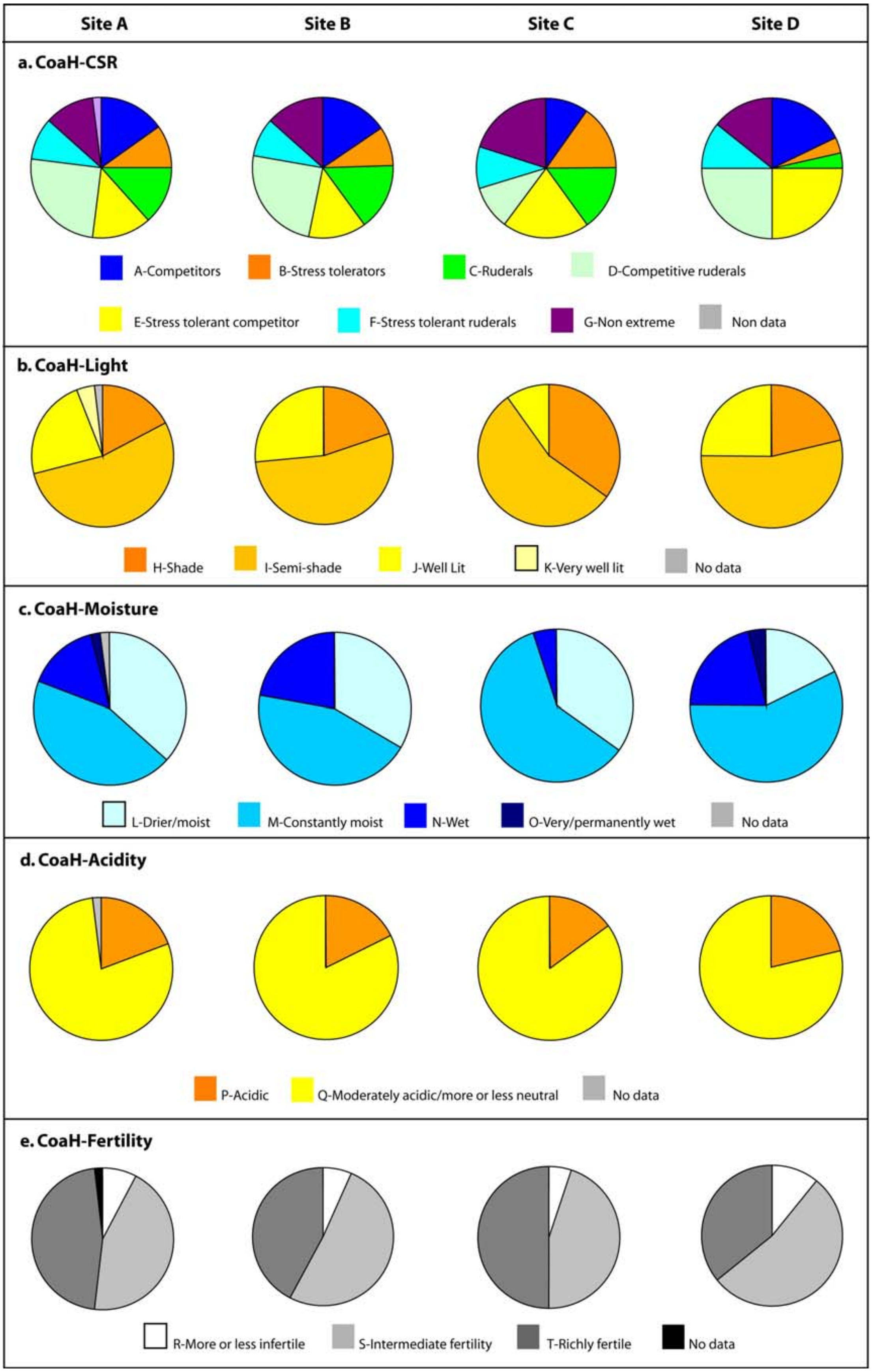


Fig. 5.16 Component CoaHs of four distinct sites in Liss - Rother Sites A-D. Each pie chart comprises species associated with each CoaH based on presence/absence data collected between 2004 and 2005 during the current research

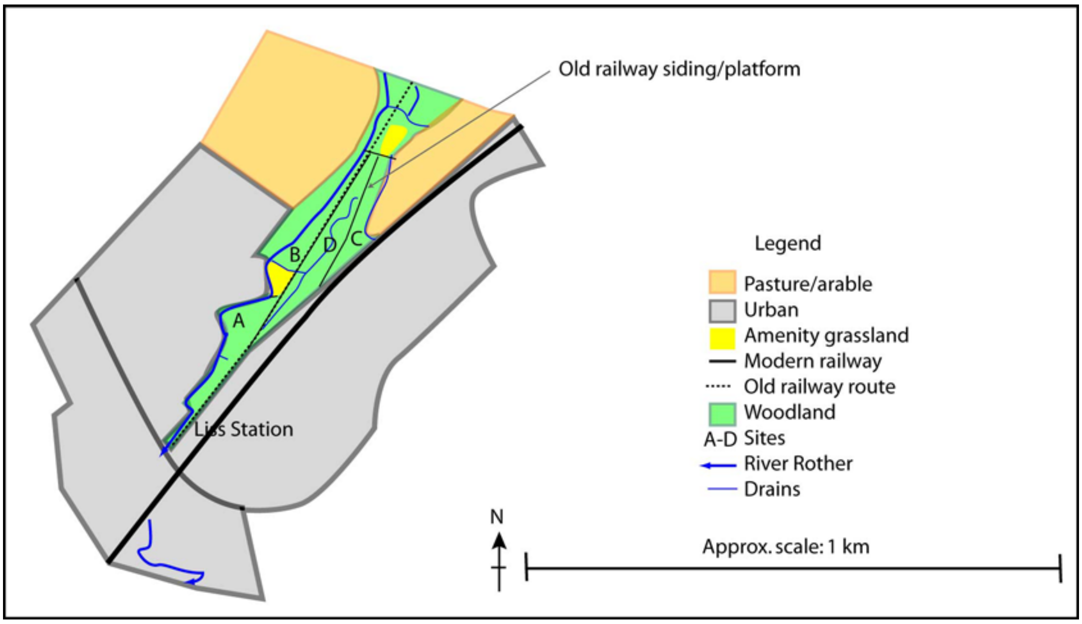


Fig. 5.17 Schematic map of Rother Sites A-D in relation to each other and key habitat features

5.4.1 Life-history strategies of species in lowland *Alnus glutinosa* woodlands

The species comprising the seven CSR-strategy groups (CoaH-CSR, defined in Section 5.2) illustrated in Figure 5.3 potentially represent intra-site variation within lowland *Alnus glutinosa* woodlands. CoaH-A (Competitors) will occur in productive, stable situations which do not experience high levels of disturbance or stress, e.g. beyond frequent flood limits, low annual fluctuation of water table, low grazing pressure. CoaH-B (Stress-tolerators) may occur at the edge of a hollow which experiences low water table drawdown in summer, but frequently flooded in winter; the centre of the wood or north side of a topographic feature where little light penetrates; slopes beyond the edge of a floodplain on free draining soils and subsequent leaching; i.e. high stress environments. Highly disturbed environments where bare soils are frequently exposed, e.g. riverbank, seasonal hollows, localised grazing or stock access/collect points, will be represented by CoaH-C (Ruderals).

Transitional zones between the three main situations described above (i.e. stable, stressed and disturbed) will be represented by the intermediate CoaHs (D- Competitive ruderals, E-Stress tolerant-competitors, F-Stress tolerant ruderals). Where there are no extremes of conditions, species of CoaH-G (Competitive, stress tolerant, ruderals) will occur.

5.4.2 Light conditions of species in lowland *Alnus glutinosa* woodlands

The four light conditions shown in Figure 5.4 could correspond to localised intra-site variation responding to, for example, the extent of shading created by the canopy species, a topographic feature, or lighter conditions, such as those found in glades. The shaded areas could correspond to the centre of the woodland, while the lighter conditions occur on the woodland edges and in glades. Alternatively light values may reflect the seasonal nature of plants, for example those associated with well lit conditions may occur throughout the woodland, but are vernals which have completed their reproductive cycle by the time the canopy trees create shaded conditions. However, on review of the species in the well lit, and very well lit, conditions none are considered vernals. Light conditions will also be affected by the topography and aspect of the site, for example, woodland on the north side of a hill is likely to experience less light than one, in otherwise identical conditions, on the south side.

5.4.3 Soil conditions of species in lowland *Alnus glutinosa* woodlands

Figure 5.5 shows that the majority of species recorded in lowland *Alnus glutinosa* woodlands are more or less evenly distributed across three soil moisture CoaHs:

1. CoaH-L Drier/moist soils (34%)
2. CoaH-M Constantly moist soils (29%)
3. CoaH-N Wet, badly aerated soils (29%)

The remaining species, several of which have gregarious or monocultural growth habits, are associated with very wet conditions, CoaH-O. Therefore any of these conditions have the potential to either dominate or form localised intra-site variation in soil moisture conditions, i.e. wet, saturated soils; open water and dry conditions.

Figure 5.6 shows that the majority (74%) of lowland *Alnus glutinosa* woodland groundflora species are associated with moderately acidic to near neutral soils (values 6-8), with only a quarter associated with acidic soils (values 2-5). Within a specific site, either of these conditions has the potential to be dominant or represent localised changes in soil acidity and, therefore, reflect intra-site variation. Alternatively this variation may reflect soil conditions in different geographical regions of the UK. Although not a strict calcifuge, *Alnus glutinosa* shows a preference for slightly acidic conditions (McVean, 1953), therefore, as the habitat is defined by *Alnus glutinosa* being the dominant canopy species, it could be expected that the soils would have a slightly acidic bias. However, it is noted that the *Alnus glutinosa* dominated woodlands described by the NVC (Rodwell, 1991) occur on a range of soils from acidic to base-rich.

Figure 5.7 shows that the majority of lowland *Alnus glutinosa* woodland groundflora species (49%) are associated with intermediate fertile soils (values 5-6). 30% and 20% of species are associated with more or less infertile soils (values 2-4) and richly fertile soils (values 7-9) respectively. As with the soil moisture and acidity, each condition has the potential to dominate or reflect localised intra-site variation. Areas of leached soils at the back of the floodplain may be represented by CoaH-R (more or less infertile), while areas of high fertility (CoaH-T) may be more frequent in hollows and near the river bank where fertile silt deposits may collect. As noted by Tansley (1965) high fertility areas also have the potential to occur below large bird roosts.

5.4.4 Life-history strategies combined with light and soil conditions of species in lowland *Alnus glutinosa* woodlands

The TWINSPAN group representing species with preferences for drier soil conditions (Group 0000; Table 5.3) only comprises 17 species (6% of the groundflora) while Figure 4.3 shows that the groundflora species comprise 34% with preferences for such conditions (Ellenberg F values 4 and 5). Although TWINSPAN group 0000 was dominated by species with preferences for drier conditions and therefore, described as a 'drier' group, many of the other TWINSPAN groups also included species with drier soil preferences. Subsequently, the remaining 26% of groundflora species with preferences for drier soils are spread across different TWINSPAN groups but do not form a significant component of the groups. Such species are likely to have wider ecological amplitudes and were subsequently reviewed when refining the species composition of the NoaHs which is discussed further below and in Chapter 7.

Figure 5.10 shows that the output species groups following TWINSPAN analysis broadly coincide with the DCA output ordination depicting axis 1 and 2. When the component species of the TWINSPAN groups are considered in relation to their CoaH association, generally a single CoaH dominates, although the group also includes species representative of other CoaHs. Also, while the species in the same TWINSPAN group are positioned in close ordination space, there is much overlap between groups. This illustrates the range of conditions within each group, even when only one life-strategy or environmental condition is considered.

Although both TWINSPAN and DCA ordination analyses identified similar groups of species, and the groups were statistically different in terms of their mean environmental and CSR-strategies, such analysis does not account for the ecological amplitude of species or the level at which conditions can be economically managed or altered. For example, it is not readily feasible, without micro-scale management techniques, to implement an economical form of woodland management (see Section 2.4-2.7) that could create conditions for both drier and very wet soils within part of a wood. When considered in relation to the influence of management some groups show little practical difference. Additionally, when the component species of each group are considered, the groups often included species of widely different conditions of the same CSR-strategy or environmental variable, e.g. TWINSPAN Group 0000 includes species of both shaded and well lit conditions. Therefore, the composition of the groups can be adjusted by reviewing the individual species furthest from the mean in each variable (i.e. light, soil conditions and CSR-strategies) to see if they could also be included within another TWINSPAN group. In addition the mean conditions for each group should be reviewed in relation to their ability to be altered by management: for example moist soils are not going to be managed differently to damp soils. In a practical situation it is the extremes of conditions that would be managed differently, with the species of the intermediate condition being accommodated by either option. For example, since species generally have a tolerance of conditions outside the optimal provided by the CSR-strategies and Ellenberg values (which were used in the analysis), management for drier soil conditions is likely to also create conditions for species of moist soils, but not very wet soils. Equally management for wet soils will create conditions for moist, but not drier species.

As an example of reviewing the species composition of the TWINSPAN groups in relation to their preferred Ellenberg values and CSR-strategies and the manageability of the subsequent conditions, three species from TWINSPAN group '0000' are considered:

1. *Callitriche stagnalis*: R/CR, L7, F10, R6. N6
2. *Glyceria fluitans*: CR, L7, F10, R6. N6
3. *Veronica beccabunga*: CR, L7, F10, R6. N6

For light and soil acidity and fertility preferences and CSR-strategy, these three species are similar to each other and the mean conditions of group '0000', i.e. Well lit (L7), near neutral soil (R6-7), intermediate soil fertility (N5-6) and CSR-strategy Competitive ruderal (CR, CR/CSR) (Table 5.3 and Figure 5.9) but are significantly different in terms of preferences for soil moisture: very wet (F10-11) compared to drier (F4-5) soils of the TWINSPAN group. As seen in Table 5.3 and Figure 5.9, TWINSPAN group '0001' is almost identical to TWINSPAN group '0000' except in soil moisture (very wet) and soil fertility (high). Therefore, the three species listed above are also very similar to the conditions of TWINSPAN group '0001', although have a preference for intermediate, rather than high, soil fertility. However, when the specific Ellenberg N values are considered, group '0001' comprises species, almost equally, with values 6 and 7 and group '0000' species with values 6 with some 7. Therefore, the three species listed above could equally be placed in either group based on their N-values.

Given the similarities of TWINSPAN groups '0000' and '0001', it could be argued that division 3 (group '000') should be considered rather than division 4 (groups '0000' and '0001'). However, the forth division divides the species on soil moisture conditions at opposite ends of the gradient (drier and very wet) which can be managed for differently. Although Ellenberg soil fertility values 6 and 7 fall into intermediate and high fertility groupings, 6 is an intermediary level of fertility between 5 (intermediate fertility) and 7 (high fertility) (see Table 2.6) so could arguably be considered as either; a cut-off level has to be put somewhere in terms of simplifying the Ellenberg values in terms of management (see Section 5.2.1).

In conclusion it is considered more appropriate, in terms of woodland management and species preferences, to re-group *Callitriche stagnalis*, *Glyceria fluitans* and *Veronica beccabunga* with species from group '0001' rather than group '0000' which were determined statistically based on subtle differences in Ellenberg values and CSR-strategies.

Following the approach described above, reviewing the individual autoecology of individual species of the TWINSPAN groups and subsequently the manageability of mean conditions, 10 'new' groups (i.e. Niches of a Habitat; NoaH) were identified. These NoaHs are summarised in Table 5.5 and illustrated in relation to the TWINSPAN groups and DCA ordination space in Figure 5.18 (for clarity, the groups are illustrated on two ordination diagrams, a: groups 1-5 and b: groups 6-10).

NoaH	Light	Soil Moisture	Soil Acidity	Soil Fertility	CSR	No. species
1	Well lit	Wet	Near neutral	Low	Non-extreme	43
2	Well lit	Very wet	Near neutral	Intermediate-high	Moderate disturbance. Low stress	17
3	Semi-shade	Constantly moist	Near neutral	Intermediate-high	Moderate disturbance. Low stress	25
4	Well lit	Drier/moist	Near neutral	Intermediate-high	Moderate disturbance. Low stress	18
5	Shade	Drier/moist	Near neutral	Intermediate	Low disturbance. Moderate stress	32
6	Semi-shade – well lit	Drier/moist	Near neutral	Low-intermediate	Moderate disturbance. Moderate stress	32
7	Well lit	Constantly moist	Near neutral	Intermediate	Moderate disturbance. Low stress	26
8	Well lit	Wet	Near neutral	Intermediate-high	Low disturbance. Low stress	26
9	Semi-shade	Constantly moist	Acidic	Low	Low disturbance. Moderate stress	36
10	Semi-shade	Wet	Acidic	Low	Low disturbance. Moderate stress	14

Table 5.5 Summary of total species of light, soil (moisture, acidity, fertility) and life history strategies of groups (NoaHs) derived from TWINSPAN analysis using data for groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Environmental conditions are based on Ellenberg indicator values (Hill *et al.* 2004) and CSR-strategies (Hunt, 2003a)

Figure 5.18 shows that the species comprising the NoaHs remain clustered in ordination space and much of the overlap/noise seen in Figure 5.10 is reduced. The Figure also shows that the NoaHs, although generally dominated by species from one TWINSPAN group, also comprise species from other TWINSPAN groups, Table 5.6. This table shows that where the NoaH comprises species from more than one TWINSPAN group, the TWINSPAN groups are closely related and could be considered at a lower classification division level, e.g. NoaH-10 comprises species in TWINSPAN groups 1110 and 1111 which are in the same TWINSPAN group if considered at division level three: 111.

TWINSPAN Group	NoaH										Total spp. TWINSPAN group
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
0000		3		12	1		1				**17**
0001		10		1	1						**12**
001		2	5	2	9	3	14	11			**46**
0100	8		1	1	1	4	2	1			**18**
0101	1	1	3	2	8	4		1			**20**
0110	3		3		7	1	1	3			**18**
0111	1		1				1	5			**8**
100	3	1	10		6	2	2				**24**
101	13		1			5	3	4	7		**33**
110	1		4			13		1	26	7	**52**
1110	9						1		3	1	**14**
1111	1									6	**7**
Total spp./NoaH	**40**	**17**	**28**	**18**	**33**	**32**	**25**	**26**	**36**	**14**	

Table 5.6 NoaHs in relation to TWINSPAN Classification output groups

The individual environmental conditions and CSR-strategies (CoaHs) of each NoaH are given in Table 5.7 and illustrated in Figures 5.19 and 5.20.

Group: NoaH		Light	Soil		
			Moisture	Acidity	Fertility
NoaH 1	Mean	7.2	8.4	5.9	3.9
	Min	6	4	3	2
	Max	8	10	8	5
NoaH 2	Mean	7.1	10.2	6.8	6.4
	Min	7	10	6	5
	Max	8	11	8	8
NoaH 3	Mean	5.5	6.2	6.7	6.7
	Min	4	5	5	6
	Max	6	8	8	8
NoaH 4	Mean	7.2	5.1	6.6	6.4
	Min	6	5	6	6
	Max	8	6	7	7
NoaH 5	Mean	4.2	5.4	6.8	5.8
	Min	3	5	5	4
	Max	6	7	8	7
NoaH 6	Mean	6.4	5.0	6.2	4.5
	Min	5	4	5	3
	Max	8	7	8	7
NoaH 7	Mean	7.1	6.0	6.7	6.2
	Min	6	5	6	5
	Max	8	8	8	9
NoaH 8	Mean	6.5	8.4	6.6	6.5
	Min	5	8	6	6
	Max	8	9	7	7
NoaH 9	Mean	5.8	5.9	4.2	3.8
	Min	4	4	2	2
	Max	7	7	5	6
NoaH 10	Mean	6.5	8.4	4.2	3.4
	Min	5	8	3	2
	Max	8	9	5	5

Table 5.7 Mean, range, total species of light, soil (moisture, acidity, fertility) of groups (NoaHs) derived from TWINSPAN analysis using data for groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3).
Environmental conditions are based on Ellenberg indicator values (Hill *et al.* 2004)

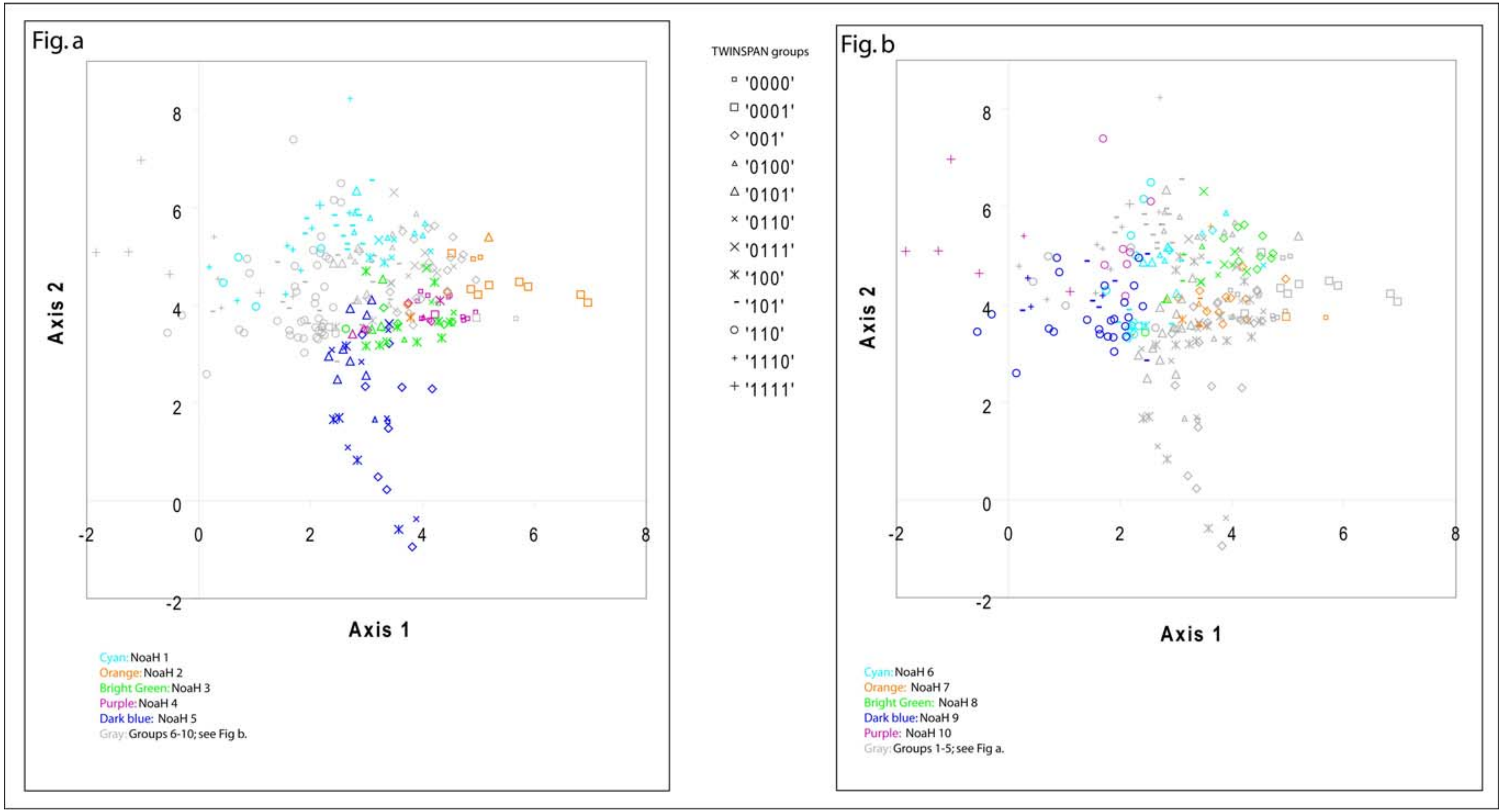


Fig. 5.18 DCA output (axes 1 and 2) of binary species x environmental variable matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3). Species coded to depict TWINSPAN output groups of the same species matrix and revised groupings from review of constituent species of the TWINSPAN groups

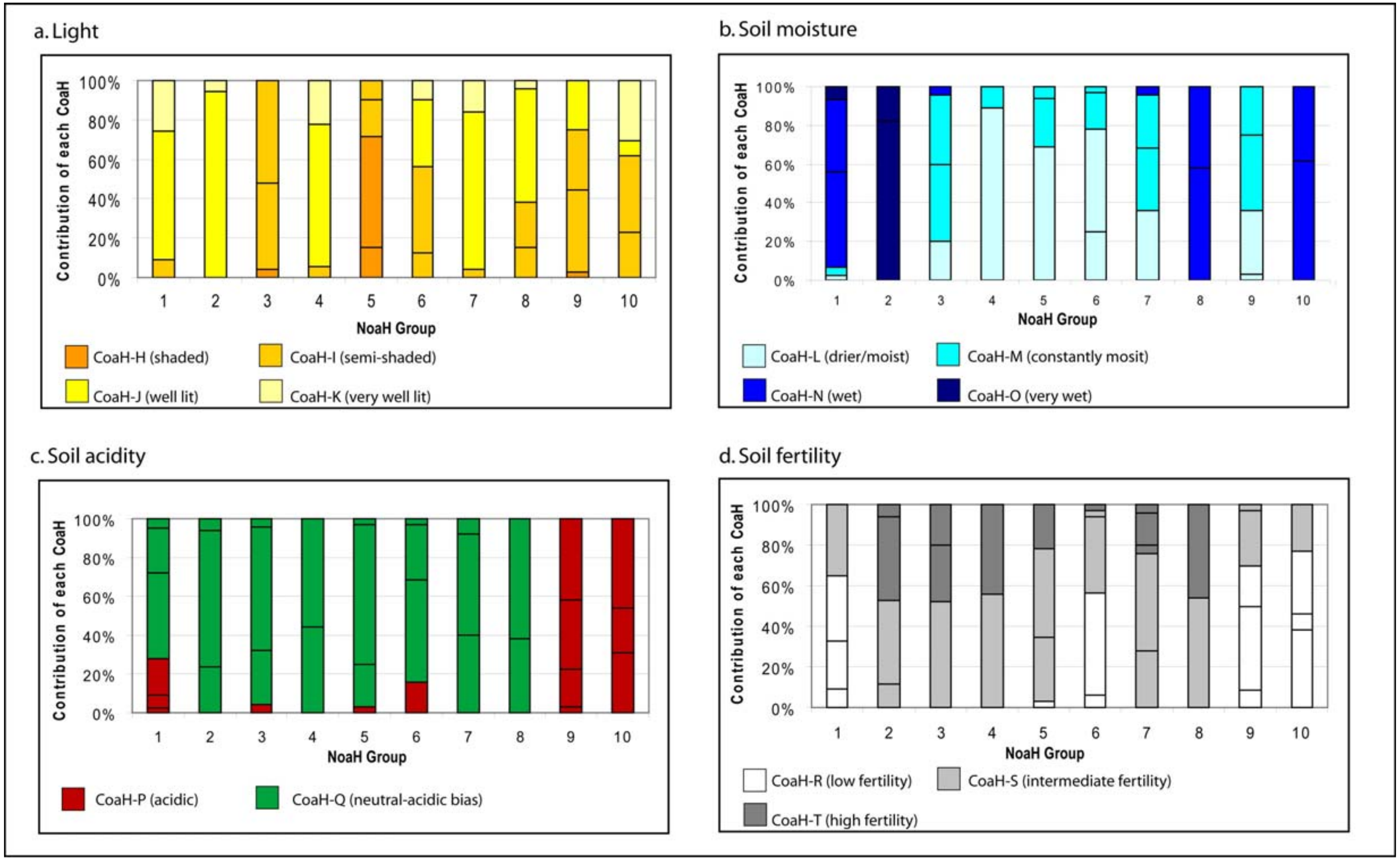
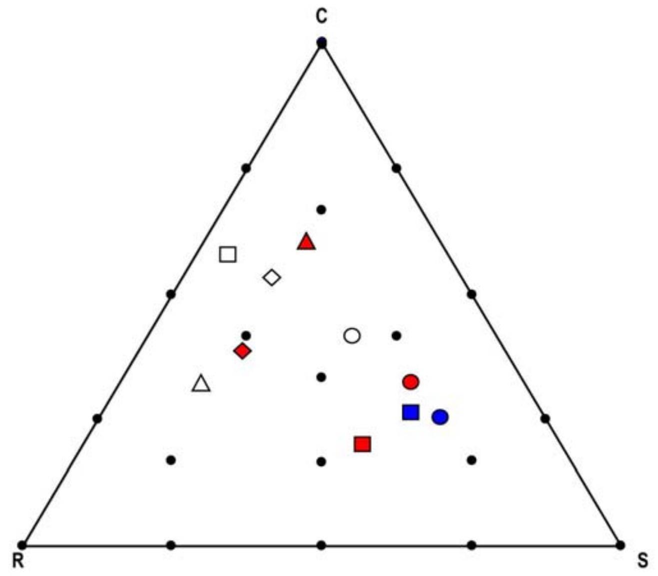


Fig. 5.19 Percentage of each CoaH (light, soil moisture (revised), acidity and fertility) in each NoaH derived from TWINSPAN analysis using binary species x environmental variable matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3)



		C	S	R	CSR value
NoaH 1	○	0.417	0.342	0.241	SC/CSR
NoaH 2	□	0.578	0.049	0.373	CR
NoaH 3	◇	0.532	0.146	0.322	CR/CSR
NoaH 4	△	0.324	0.130	0.546	CR/CSR
NoaH 5	●	0.323	0.488	0.189	SC/CSR
NoaH 6	■	0.200	0.466	0.334	SR/CSR
NoaH 7	◆	0.388	0.167	0.445	CR/CSR
NoaH 8	▲	0.605	0.167	0.228	C/CSR
NoaH 9	●	0.253	0.572	0.175	S/CSR
NoaH 10	■	0.265	0.516	0.219	S/CSR

Fig. 5.20 Mean CSR-strategies (as calculated using UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)) for each NoaH derived from TWINSPAN analysis using binary species x environmental variable matrix (Ellenberg indicator values (Hill, 2004) and CSR-strategy (Hunt, 2007b)) of groundflora species found in lowland *Alnus glutinosa* woodland (Section 4.3)

When the component species of each NoaH are considered in relation to the individual CoaH-types (i.e. CSR, light moisture, acidity and fertility) it is seen that the majority of species occur in a single CoaH (Figure 5.19). These dominant and general trends are detailed in Table 5.5. However, in a number of cases there are a minority of species that are beyond the dominant character of the group. As previously discussed (Chapter 4) the Ellenberg values and CSR-strategies, from which the CoaHs are derived, provide the plants general preferred conditions. Since plants will also occur outside these optima, the groupings are not as unexpected as initially indicated. Such situations are discussed further in Chapter 7.

As with the CoaHs, different woodlands may show a bias towards particular NoaHs. Again, this is illustrated at the four sites along the River Rother, Figure 5.21. How these conditions, predicted from a species list, relate to on the ground conditions is discussed in Chapter 7.

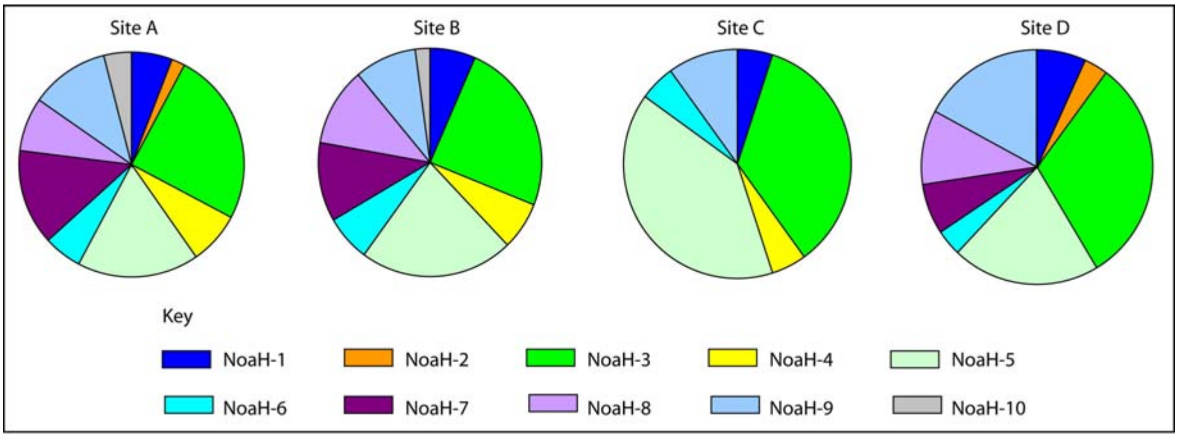


Fig. 5.21 Component NoaHs of four distinct sites in Liss - Rother Sites A-D. Each pie comprises species associated with each NoaH based on presence/absence data collected between 2004 and 2005 during the current research

5.5 Conclusions

This chapter considered species in terms of their preferred growing conditions and grouped them first on the basis of a single character (e.g. CSR-strategy, light and soil moisture, acidity and fertility) and then by considering all characters simultaneously. Section 5.2 identified the component species of each of the CoaHs and showed the contribution of species found in lowland *Alnus glutinosa* woodland to each CoaH. Table 5.8 summarises the CoaHs, their characteristics and potential situations that they may represent within a woodland. The component species of each CoaH are listed in Appendix 10. These CoaHs will be considered further in the later chapters.

Having identified groups of species that could represent localised conditions of individual environmental conditions (i.e. CoaHs), a more holistic approach was taken (Sections 5.3 and 5.4) and 10 potential NoaHs, based on the interactions of Ellenberg indicator values and CSR-strategies, were identified. Table 5.9 summarises the 10 NoaHs that will be considered further in the following chapters. The species representing each NoaH are listed in Appendix 12.

CoaH	Potential intra-site variation represented	Component CSR-strategies and Ellenberg values
A. Competitors	Fertile conditions Areas beyond frequent flood events Low grazing pressure	C, C/CR, C/CSR, C/SC
B. High stress	High or very low water table Extreme fluctuations of water table Very dense shade	S, S/CSR, S/SC, S/RS
C. High disturbance	Areas regularly disturbed by flood events, e.g. river banks Seasonal hollows Livestock aggregation points	R, R/CR, R/CSR, R/RS
D. Low stress	Transitional between A and C; low stress and moderate disturbance	CR, CR/CSR
E. Low disturbance	Transitional between A and B; low disturbance and moderate stress	SC, SC/CSR
F. Moderate stress & disturbance	Low productivity and moderate disturbance	RS, RS/CSR
G. Non-extreme	Non extreme situations; moderate stress, disturbance and productivity	CSR
H. Shade	Dense canopy. Centre of woodland North facing wood/shading created by topographic feature	L3 & 4
I. Semi-shade	Light canopy. Edge habitat Small glade	L5 & 6
J. Well lit	Large glade. Edge habitat, particularly south facing	L7
K. Very well lit	Large glade Edge not obstructed by topographic features/adjacent vegetation	L8
L. Drier conditions	Low water table. Areas furthest from river bank Raised mound Slope leading away from flood plain	F4 & 5
M. Moist-constantly damp	Hollow. Edge of seepage/permanently wet hollow	F6 & 7
N. Wet	High water table for much of the year Seepage	F8 & 9
O. Very/permanently wet	Open water. Water table above ground level for majority of the year	F10 & 11
P. Acidic	Acidic soils	R2 – 5
Q. Neutral - acidic bias	Near neutral soils with slight acidic bias	R6 - 8
R. More or less infertile	Away from areas where silt is deposited during flood events Sandy/free draining or leached soils	N2 – 4
S. Intermediate fertility	Average conditions	N5 & 6
T. Richly fertile	Localities where silt during flood events can collect, e.g. nearer river banks, in hollows	N7 – 9

Table 5.8 Intra-site variation that can potentially occur in lowland *Alnus glutinosa* woodlands defined by CoaHs (derived from CSR-strategies (Hunt, 2007b) and Ellenberg indicator values (Hill *et al.*, 2004)) of the component groundflora species

NoaH	Conditions	Examples of potential intra-site variation represented
1	Non-extreme stress and disturbance. Well lit, wet, near neutral and low fertility	Large glade/edge habitat with at least periodic surface water; water at or just below surface. Away from area that frequently received flood water/run-off
2	Low stress and moderate disturbance well lit environment. Shallow water on neutral soils of intermediate to rich fertility	Areas where surface water remains more often than not that also receive nutrient inputs, e.g. from flood events or run-off, with an open canopy, e.g. woodland edge or glade.
3	Low stress with moderate disturbance in semi-shaded conditions on constantly moist, neutral intermediate to richly fertile soils	Grazed partially shaded areas with a high water table for much of the year or areas which are frequently disturbed through flood events.
4	Low stress, moderate to high disturbance in well lit conditions on drier, near neutral intermediate to high fertility soils	High grazed areas with minimal shrub layer with a topography that does not retain surface water, even where experiences flood events
5	Moderate to high stress with low disturbance in shaded conditions. Drier, near neutral, intermediate fertile soils.	Dense canopy/shrub layer away from impact of frequent flood events.
6	Moderate stress with moderate-high disturbance in semi-shade, although with a light bias, conditions. Drier, near neutral, low-intermediate fertile soils.	Grazed shaded areas away from impact of frequent flood events, with shade a result of topographic features. Topography may be such that soils fertility is leached and water not retained on site.
7	Low stress, moderate-high disturbance in well lit conditions on constantly moist, near neutral, intermediate fertile soils	Low lying ground in a glade or on woodland edge. Disturbance may be a result of floods or grazing.
8	A low stress, low disturbance environment in well lit conditions on wet, near neutral soils of intermediate to high fertility	Seepage (with flowing water) in a glade.
9	Moderate stress, low disturbance in semi-shade. Constantly moist, acidic soils of low fertility	Seasonal seepage (with minimal flow/stagnant waters) in partial shade
10	Moderate stress, low disturbance in semi-shade. wet, acidic soils of low fertility	Seepage (with minimal flow/stagnant waters) in partial shade

Table 5.9 Intra-site variation that can potentially occur in lowland *Alnus glutinosa* woodlands defined by NoaHs (derived from the interactions of CSR-strategies (Hunt, 2007b) and Ellenberg indicator values (Hill *et al.*, 2004)) of the component groundflora species

This chapter has identified potential intra-site variation conditions (CoaHs and NoaHs) that could be found in lowland *Alnus glutinosa* woodland, based on the species found in the habitat (as determined in Chapter 4) and their preferred growing conditions as defined by Ellenberg indicator values (Hill *et al.*, 2004) and CSR-strategies (Hunt, 2007b). Chapter 6 describes a study site that is subsequently used in Chapter 7 to verify the occurrence of the potential CoaHs and NoaHs in selected woodland.

6. STONEBRIDGE MEADOWS

6.1 Introduction and Aims of Chapter

Chapter 4 described the generic conditions and characteristics of lowland *Alnus glutinosa* woodlands that were used in Chapter 5 to identify potential Niches of a Habitat (NoaH). The occurrence and composition of the theoretical NoaHs require confirmation on the ground in an actual woodland. Therefore study sites had to be identified and described to provide real life evidence to achieve the aims of the research and this subsequently the aim of Chapter 6.

6.2 Identifying Study Sites

From the 64 sites surveyed at the beginning of this research (see Sections 3.1 and 3.5.2), three woodlands at Stonebridge, within close proximity, were chosen to undertake a detailed study of the variation in the groundflora. The three sites at Stonebridge (Sites A, B and C) were chosen for the following reasons, they:

1. occur within a small spatial extent (within about 500 m of each other) and therefore geographic variations (e.g. geology, climate) were minimised;
2. have documentary and field evidence of different histories (e.g. each has developed under different situations):
    - A has established on grazed acidic/neutral grassland and developed naturally;
    - B on wet seepage at the base of a wooded/scrub slope and developed naturally;
    - C was originally planted as a plantation and managed for woodland products;
3. have different current management:
    a. A is cattle grazed and selective intervention;
    b. B and C are managed on minimal/selective intervention;
4. have distinct characteristics and groundflora species composition;
5. are managed primarily for nature conservation;
6. are commutable and had open access, enabling regular visits during the research period.

6.3 DESCRIPTION OF STUDY SITES

As the three study sites are located in close geographical proximity, this section describes Stonebridge Meadows Nature Reserve in which they occur to provides context for the detailed vegetation study.

6.3.1 Administration details of Stonebridge

Stonebridge Meadows (referred to as 'Stonebridge' in this thesis), a Local Nature Reserve and Wildlife Trust Site, is located to the south-east of Coventry, Warwickshire at NGR: SP 348756 (see Figure 3.1). It is owned by Coventry City Council and managed by Warwickshire Wildlife Trust.

6.3.2 Geology and soils of Stonebridge

The geology is glaciofluvial, or river terrace drift, which produces deep, well drained coarse loamy and sandy soils. Occasionally, these soils occur locally over gravel, can be affected by groundwater, and have a slight risk of water erosion (Soilscape, 2008). On low lying ground by the river the soil is heavy clay and silt, while the upper slopes in the south are sandy soils (Wright, 2009).

6.3.3 Description of habitats at Stonebridge and the immediate adjacent land

Stonebridge, totalling 7.85 ha, comprises acid/neutral grazed meadow (including some seasonally wet/marshy grassland), scrub/derelict hedgerows and three main areas of *Alnus glutinosa* woodland (see Figure 6.1):

A. Central – grazed. 0.12 ha;
B. East – seepage. 0.38 ha;
C. West – former plantation. 0.84 ha.

Although small and likely to be affected by edge effects, Site A has been included as representative of small, more isolated, field *Alnus glutinosa* woodlands. Table 6.1 summarises the main characteristics of these woodlands. The northern part of Stonebridge generally floods annually during the winter period, however, it is noted during both 2007 and 2008 significant floods occurred in spring/summer.

The habitats adjacent to the woodlands comprise grazed meadows (neutral with acidic tendency), river and main road. North of the River Sowe is a mosaic of wetland, grass/tall ruderal and woodland/scrub habitats. Two ponds were created in the southern meadows, 2010/11.

Site	Canopy	Groundflora	Structure	Soil	Water influence	Habitat diversity
A	Single closed canopy layer dominated by *Alnus glutinosa.*	Grass dominated. Diversity mainly restricted to the bases of the trees and along the southern bank/hedgerow boundary.	Limited variation comprising a high forest, plantation-type, structure.	Poached. Generally dry underfoot, except where the drains occur it is damp (except after heavy rain, then wet).	Drain passes east-west through the site. Run-off from field to the south. Site is above the flood level of the river to the north.	Minimal. Deadwood habitats are poor comprising small branches less than 5 cm diameter.
B	Primarily a single canopy layer, dominated by *Alnus glutinosa*, with some gaps.	*Urtica dioica* dominated but varied, especially diverse in damp hollows. *Urtica dioica* generally occurring on the drier/less waterlogged ground. Locally abundant swamp species, e.g. *Carex* sp., *Caltha palustre* and *Rorippa nasturtium-aquaticum.*	Generally limited vertical structural diversity but some age variation.	Wet under foot along seepage/damp hollows, otherwise damp. Dry and sandy on southern bank.	Occasional flooding from the river to the north of the area. Seepage/spring within site. Run-off from the scrub/field to the south.	Seepage/wet hollow with seasonal standing water and after rain. Deadwood habitats are poor generally comprising branches less than 10 cm diameter. Some old coppice stools. Areas of more open canopy. Dry slope in the south.
C	Single canopy layer, dominated by *Alnus glutinosa*, with some small gaps due to fallen trees.	*Urtica dioica* and *Poa trivialis* dominated. Grass dominates where there is a gap in the canopy.	Generally poor, comprising a naturalising plantation. Some age variation, including *Fraxinus excelsior* regeneration.	Dry underfoot, although at least damp following heavy rain/flood in location of old drains.	Occasional flooding from the river to the north of the area. Several drains transverse the site. Run-off from the field to the south.	Some deadwood habitat comprising stumps, snags and fallen branches/trees. Some old coppice stools. Post flood events standing water remains along drains. Areas of more open canopy. Dry slope/embankment in the south.

Table 6.1 Summary of the Stonebridge *Alnus glutinosa* woodland sites characteristics based on direct observation

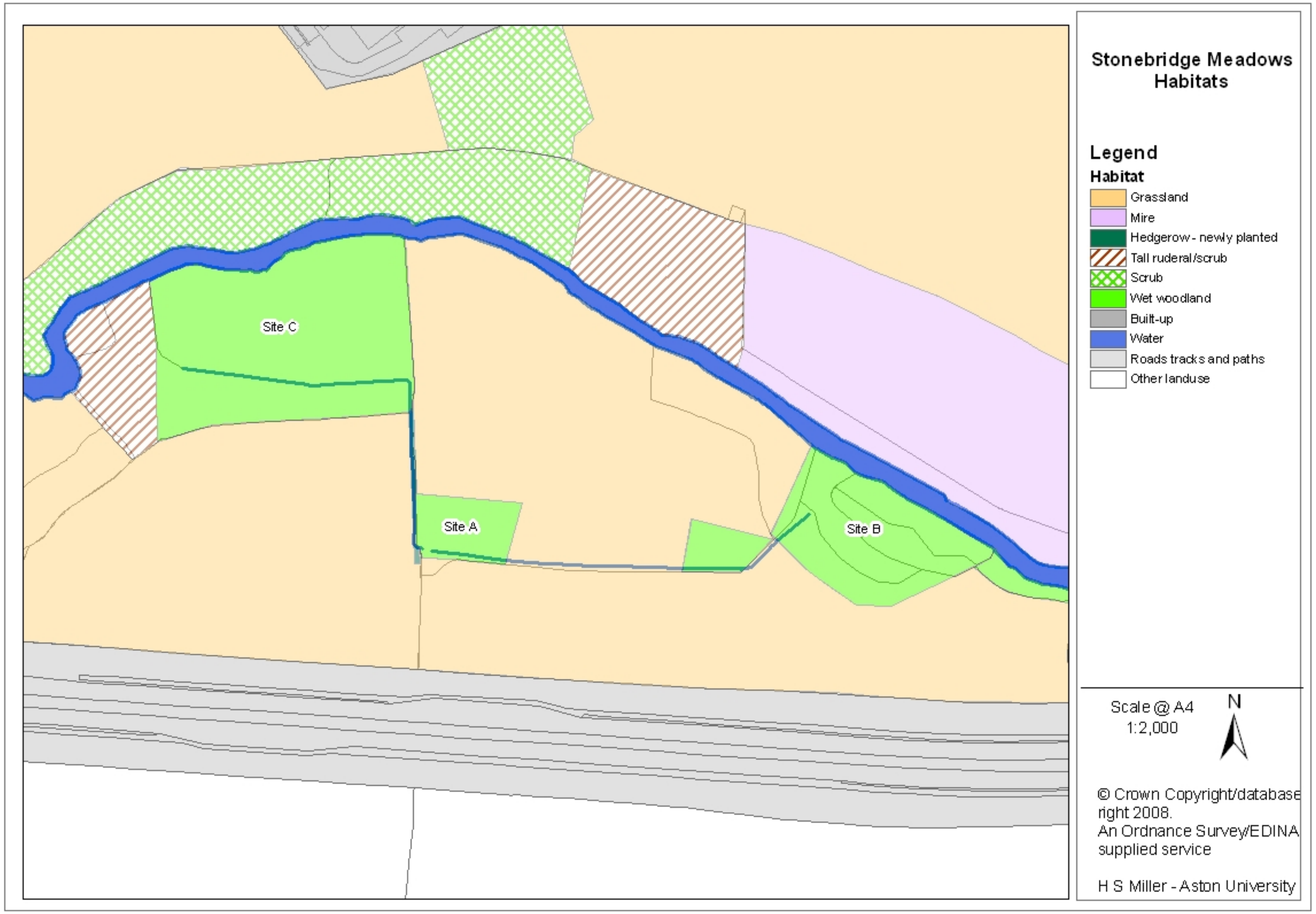


Fig. 6.1 Habitats at Stonebridge Meadows, Warwickshire, as determined by a survey as part of this research

6.3.4 History of the woodland at Stonebridge

Ancient Woodland Inventory

The areas of woodland are not indicated as ancient woodland on the Ancient Woodland Inventories (Lean and Robinson, 1989). This may not necessarily reflect secondary woodland, but it is more likely that the areas fell below the minimum threshold of 2 ha to be recorded. However, Peterken and Hughes (1995) noted that traditionally trees were confined to riverbanks, boundaries and swampy areas of most watercourses with the majority of the floodplain used for meadow and pasture.

1800s maps

Site A (grazed) at Stonebridge is not depicted as woodland on the 1889 maps (as provided by Old Maps, 2010), but both the Sites in the east (B) and west (C) of Stonebridge are depicted as woodland. The area north of the River Sowe, north of the sites, is noted as '*liable to flood*' and individual trees are indicated along some of the field boundaries. Later maps, 1913 – 1938, depict Sites B and C as marsh with scrub.

6.3.5 Stonebridge habitat management

The current (Wright, 2009) and previous (Laidlow and Hamilton, 1992) management plans identify three main areas of woodland at Stonebridge.

The 1992 management plan described the largest area of woodland/scrub as being an old *Alnus glutinosa* coppice and subject to winter flooding. It is assumed from the previous management plans that prior to 2000, livestock had greater access into Sites B and C.

Site C was selectively thinned in February 2007 and winter 2008/09. During the 2007 thin, the trees were retained on site, either completely fallen or at an angle supported by other trees, while in 2008/09 selected trees were coppiced with timber removed off site. Also in 2008/09 several trees in Site A were felled and removed off-site, with the subsequent stumps being fenced off to protect the coppiced re-growth from cattle grazing. In winter 2010/11 three-four trees were coppiced, and the majority of the timber removed off site, in Site B.

Table 6.2 summarises the past management of Stonebridge with emphasis on the woodland areas.

Date	Brief description	Management	Other	Ref.
Pre-1850	*Salix viminalis* bed	*Salix viminalis* beds	Used to provide material for basket weaving	1
c. 1850	*Alnus glutinosa* woodland	*Alnus glutinosa* planted	Used to supply wood for clog making	
Pre-1930s	*Alnus glutinosa* coppice with standards	Coppiced on rotation	-	
c. 1930s	*Alnus glutinosa* woodland	Last coppice	-	
Post 1930s	*Alnus glutinosa* woodland	Limited/no management	Resulted in a more even canopy with subsequent loss of diversity	
Prior to 1980s to *c.* 2000	Whole site	Grazed by ponies prior to the 1980s, this was followed by periodic grazing until the current highland cattle regime (see below) was established in *c.* 2000.	-	3
1992	Canopy: fairly high Low tree and shrub diversity. Generally poor groundflora dominated by *Urtica dioica*. Suffers from horse trampling and grazing	Suggested: re-introduction of coppice on a 20 year rotation with 5 coupes. Retain standards. Pollard trees along the river bank. Create rides. Fence off area. Apply herbicide or cut *Urtica dioica* in small experimental areas to reduce their dominance post coppice to increase diversity	Long rotation will ensure continuity of present canopy conditions. Resumption of coppice management regime would provide greater diversity of age structure, denser cover for birds and the increased light will lead to improvement in the diversity and number of marshy groundflora species. Increase in light post coppice will encourage groundflora but *Urtica dioica* maybe encouraged	1
1996	*Alnus glutinosa* regenerating in area adjacent to coppice	Re-instate coppice in a small area	-	2
c. 2000 – present	Meadows (including Site A)	Grazed by highland cattle at a maximum of 6-8 livestock units	-	4
Ref. **1.**Laidlow & Hamilton (1992); **2.**Skinner & Clark (1997); **3.**Wright (2009); **4.**Asbery *pers comm.* 2010				

Table 6.2 Summary of past management of Stonebridge (with emphasis on the woodland areas) as indicated by the site management plans

The current management plan (Wright, 2009) indicates that 2-4 mature trees are to be felled annually in Sites B and C with the understory around the felled trees in Site B being coppiced. In both Sites, the cut timber is to remain on site.

The grassland within Stonebridge, which includes Site A, is grazed by highland cattle at a maximum of 6-8 livestock units. Although fenced off (*c.* 2000), Sites B and C show evidence that the cattle, at least occasionally, get in. The paths along the north edges of Sites B and C are maintained by periodic cutting. During 2009 there was increased effort to remove the *Impatiens glandulifera* in Sites B and C and more regular cutting of the paths; subsequently in 2010 there was notably less of this invasive species and lower dominance of *Urtica dioica* along the paths (personal observation).

6.3.6 Location of transects used for detailed vegetation data collection

Figure 6.2 illustrates the location of the transects (Section 3.5.3) in each of the three *Alnus glutinosa* woodlands at Stonebridge used to demonstrate the occurrence of NoaHs in a woodland (see Chapter 7). Transects were located at 10 m intervals with the exception of Site C which were located at 25 m intervals as a result of the homogeneous nature of the ground vegetation; more closely positioned transects were not considered beneficial. The Transects were the length of the woodland being sampled:

- Site A: all 26 m (total: 17% of the woodland area)
- Site B: all between 28 m and 46 m (total: 13% of the woodland area)
- Site C: all between 72 m and 80 m (total: 6% of the woodland area).

6.4 Species occurring in Stonebridge *Alnus glutinosa* Woodland

In total 111 species have been recorded in the woodlands at Stonebridge since 1992 (from historic data and surveys conducted during the current research) and are listed in Appendix 13. The 1992 and 1996 records (Warwickshire Wildlife Trust) have not been divided into areas and are presence only. Of these 111 species found in the Stonebridge *Alnus glutinosa* woodlands:

- 101 are groundflora species
- 7 shrub layer species
- 3 canopy layer species.

In terms of the individual woodland areas:

- 68 species (64 groundflora, two shrub, two canopy) were found in Site A
- 78 species (69 groundflora, six shrub, three canopy) were found in Site B
- 64 species (55 groundflora, six shrub, three canopy) were found in Site C.

Fig. 6.2 Location of transects at Stonebridge to enable detailed vegetation data to be collected

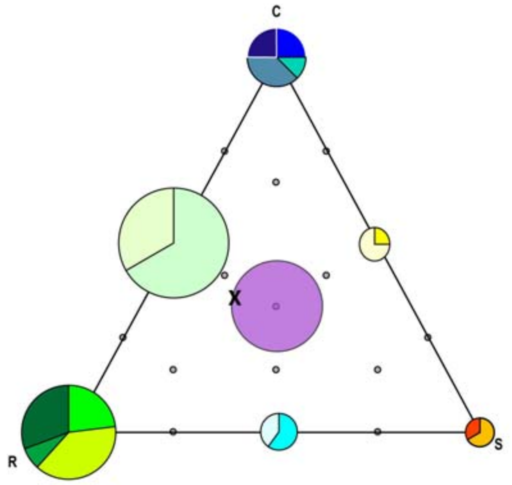
6.5 ENVIRONMENTAL CHARACTERISTICS OF STONEBRIDGE *ALNUS GLUTINOSA* WOODLANDS

As discussed in Chapters 3 and 4, Ellenberg indicator values and CSR-strategies are accepted tools to describe the characteristics of a site or habitat. As discussed in Section 5.2.1, Ellenberg indicator values and CSR-strategies were reduced into 20 (A-T) CoaHs (Characteristics of a Habitat – *Alnus glutinosa* woodland). Using the methods detailed and discussed in Sections 3.3.1, 3.3.2 and 3.3.4, the environmental characteristics, based on the CSR-strategies and Ellenberg values of the component species, are described in terms of CoaHs (see Chapter 4) for each of the three lowland *Alnus glutinosa* woodlands at Stonebridge. Each site (A – C) is described separately in terms of stress and disturbance (CSR), light and soil conditions (moisture, acidity and fertility).

6.5.1 Site A: Environmental characteristics

<u>Stress and disturbance characteristics</u>

Figure 6.3 shows that if the groundflora species in Site A are assumed to occur at equal cover values, the mean CSR-strategy is CR/CSR, i.e. competitive-ruderals (as calculated using the UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)). The figure also illustrates the distribution and contribution of species across the CSR-triangle and shows the same conclusion, i.e. the woodland is dominated by competitive-ruderals, although a slightly more ruderal tendency.



Strategy	No. spp.	%
A. Competitors	**8**	**13.3**
C	2	3.3
C/CR	1	1.7
C/CSR	3	5.0
C/SC	2	3.3
B. Stress-tolerators	**3**	**5.0**
S	0	0.0
S/CSR	2	3.3
S/SC	1	1.7
S/SR	0	0.0
C. Ruderals	**13**	**21.7**
R	3	5.0
R/CR	5	8.3
R/CSR	1	1.7
R/SR	4	6.7
D. Competitive ruderals	**15**	**25.0**
CR	10	16.7
CR/CSR	5	8.3
E. Stress tolerant-competitors	**4**	**6.7**
SC	1	1.7
SC/CSR	3	5.0
F. Stress tolerant ruderals	**5**	**8.3**
SR	3	5.0
SR/CSR	2	3.3
G. Competitive, stress tolerant ruderals		
CSR	**12**	**20.0**
No strategy data	**0**	**0.0**
UCPE CSR-Signature (X): C/CSR		
C: 0.357 S: 0.219 R: 0.424		

Fig. 6.3 Site A: Mean CSR-strategy (as calculated using UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)), distribution and proportions of Stonebridge *Alnus glutinosa* woodland groundflora species across the CSR-triangle (Pie charts are proportionate to number of different species in each group)

Light and soil characteristics

Figure 6.4 shows that the majority of groundflora species at Site A have preferences for semi-shaded to well-lit conditions with few (<10% each) associated with shaded or very well lit conditions.

In terms of soil conditions Figure 6.4 shows that the majority of species have preferences for:

- drier to moist conditions with less than 20% preferring wet to very wet conditions;

- moderately acidic to near neutral soils. The remaining species (*c*. 30%) show a bias towards acidic soils;
- intermediate soil fertility, indicating that the woodland is neither predominately infertile nor richly fertile.

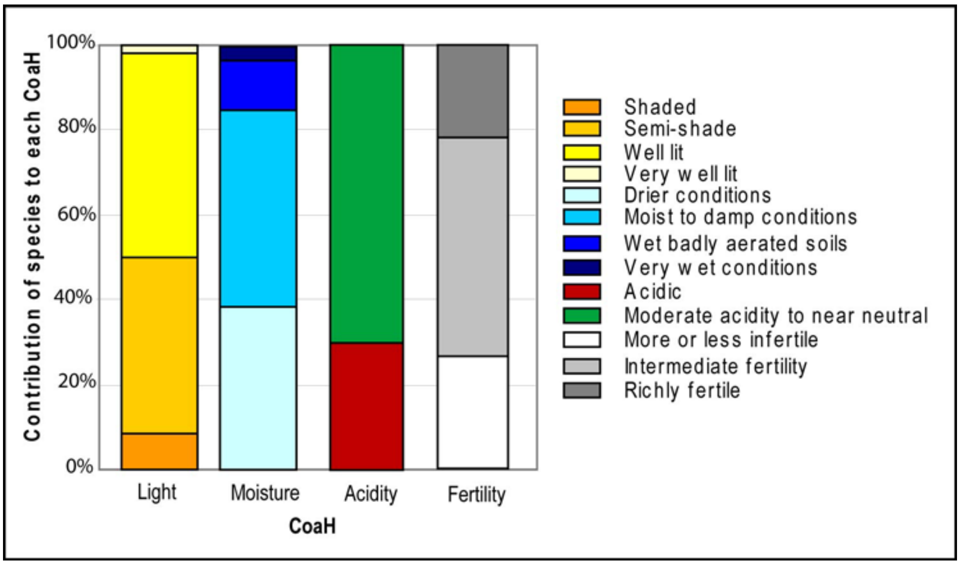
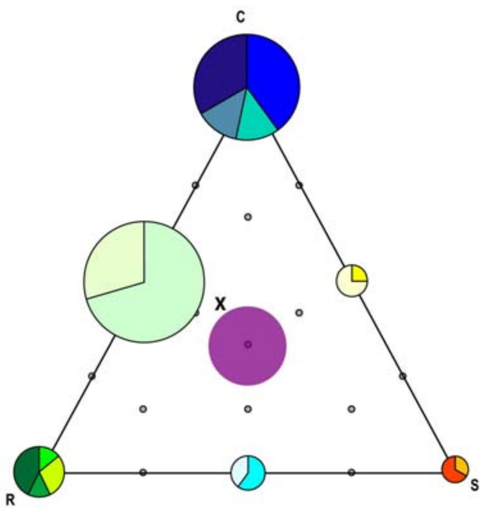


Fig. 6.4 Site A: Percentage of light and soil CoaHs, defined by the component Stonebridge *Alnus glutinosa* woodland groundflora species

6.5.2 Site B: Environmental characteristics

<u>Stress and disturbance characteristics</u>

The output of the UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007) for groundflora species at Site B indicates that the mean CSR-strategy is CR/CSR, i.e. competitive-ruderals (Figure 6.5). The distribution of species across the CSR-triangle (Figure 6.5) shows the same conclusion although this indicates that there is a slight bias towards C-strategists, rather than ruderal.



Strategy	No. spp.	%
A. Competitors	**15**	**23.8**
C	6	9.5
C/CR	2	3.2
C/CSR	2	3.2
C/SC	5	7.9
B. Stress-tolerators	**3**	**4.8**
S	1	1.6
S/CSR	2	3.2
S/SC	0	0.0
S/SR	0	0.0
C. Ruderals	**7**	**11.1**
R	1	1.6
R/CR	2	3.2
R/CSR	1	1.6
R/SR	3	4.8
D. Competitive ruderals	**17**	**27.0**
CR	12	19.0
CR/CSR	5	7.9
E. Stress tolerant-competitors	**4**	**6.3**
SC	1	1.6
SC/CSR	3	4.8
F. Stress tolerant ruderals	**5**	**7.9**
SR	3	4.8
SR/CSR	2	3.2
G. Competitive, stress tolerant ruderals		
CSR	**11**	**17.5**
No strategy data	**1**	**1.6**
UCPE CSR-Signature (X): C/CSR C: 0.443 S: 0.213 R: 0.344		

Fig. 6.5 Site B: Mean CSR-strategy (as calculated using UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)), distribution and proportions of Stonebridge *Alnus glutinosa* woodland groundflora species across the CSR-triangle (Pie charts are proportionate to number of different species in each group)

Light and soil characteristics

Figure 6.6 shows that the majority of groundflora species at Site B have preferences for semi-shaded to well-lit conditions with few (<10% each) associated with shaded or very well lit conditions.

In terms of soil conditions Figure 6.6 shows that the majority of species have preferences for:

- drier to moist conditions, although *c.* a third prefer wet to very wet conditions;

- moderately acidic to near neutral soils. The remaining species (< 20%) show a bias towards acidic soils;
- intermediate soil fertility, indicating that the woodland is neither predominately infertile nor richly fertile, although there is a bias towards richer soils.

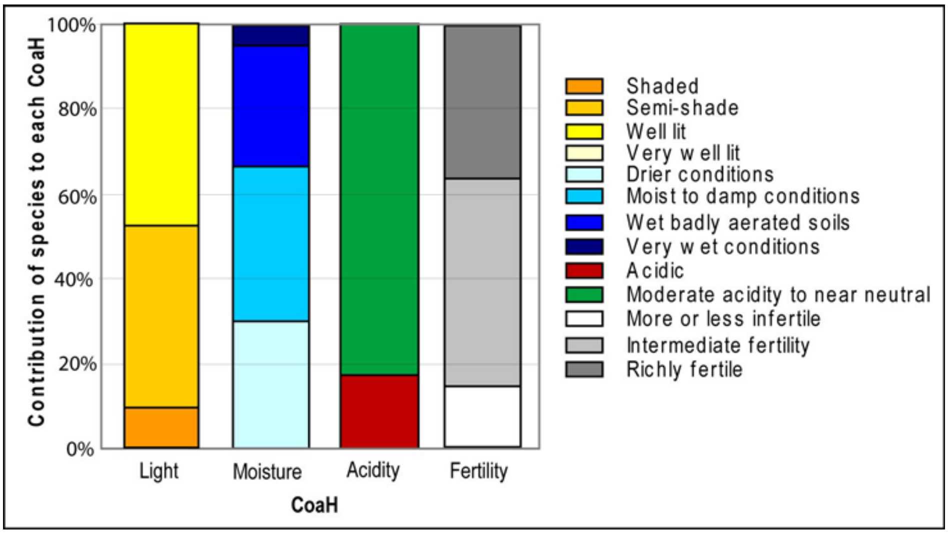
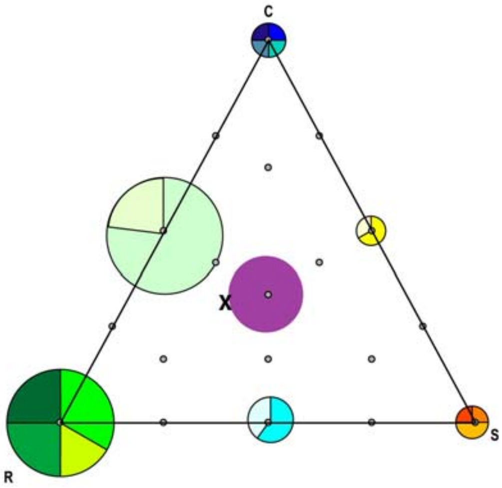


Fig. 6.6 Site B: Percentage of light and soil CoaHs, defined by the component Stonebridge *Alnus glutinosa* woodland groundflora species

6.5.3 Site C: Environmental characteristics

<u>Stress and disturbance characteristics</u>

If the groundflora species in Site C are assumed to occur at equal cover values, the mean CSR-strategy is CR/CSR, i.e. competitive-ruderals (as calculated using the UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)); see Figure 6.7. The distribution and contribution of species across the CSR-triangle shows a bias towards R- and CR-strategists, again indicating the woodland is dominated by competitive-ruderals with a slight ruderal element.



Strategy	No. spp.	%
A. Competitors	**4**	**7.8**
C	1	2.0
C/CR	1	2.0
C/CSR	1	2.0
C/SC	1	2.0
B. Stress-tolerators	**4**	**7.8**
S	1	2.0
S/CSR	2	3.9
S/SC	1	2.0
S/SR	0	0.0
C. Ruderals	**12**	**23.5**
R	4	7.8
R/CR	2	3.9
R/CSR	3	5.9
R/SR	3	5.9
D. Competitive ruderals	**13**	**25.5**
CR	10	19.6
CR/CSR	3	5.9
E. Stress tolerant-competitors	**3**	**5.9**
SC	2	3.9
SC/CSR	1	2.0
F. Stress tolerant ruderals	**5**	**9.8**
SR	3	5.9
SR/CSR	2	3.9
G. Competitive, stress tolerant ruderals	**9**	**17.6**
CSR		
No strategy data	**1**	**2.0**
UCPE CSR-Signature (X): C/CSR **C: 0.319 S: 0.235 R: 0.446**		

Fig. 6.7 Site C: Mean CSR-strategy (as calculated using UCPE Sheffield (V1.2) CSR-signature calculator (Hunt, 2007)), distribution and proportions of Stonebridge *Alnus glutinosa* woodland groundflora species across the CSR-triangle (Pie charts are proportionate to number of different species in each group)

Light and soil characteristics

The majority of groundflora species at Site C have preferences for semi-shaded to well-lit conditions with few (<10% each) associated with shaded or very well lit conditions; Figure 6.8.

Figure 6.8 shows that the majority of species have preferences for the following soil conditions:

- drier to moist conditions, although *c.* a third prefer wet to very wet conditions;

- moderately acidic to near neutral soils. The remaining species (< 20%) show a bias towards acidic soils;
- intermediate soil fertility, indicating that the woodland is neither predominately infertile nor richly fertile.

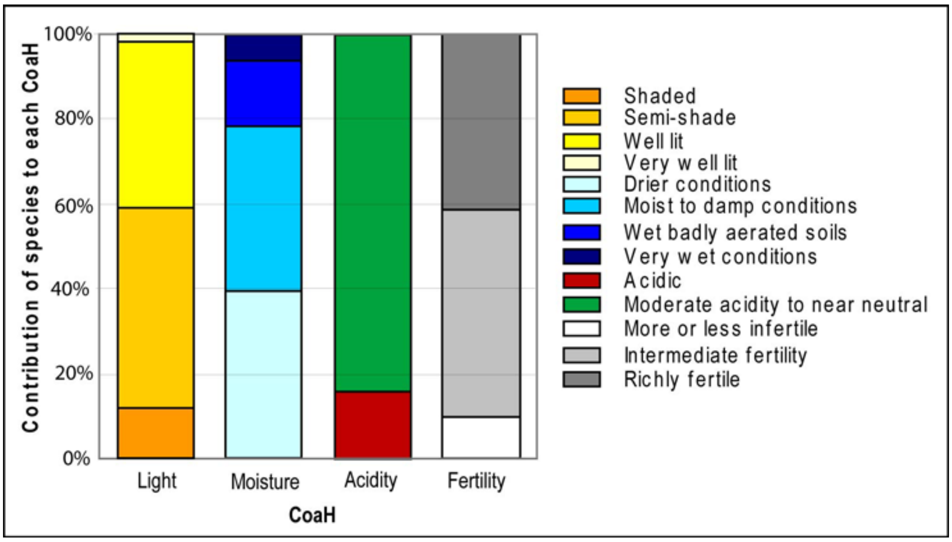


Fig. 6.8 Site C: Percentage of light and soil CoaHs, defined by the component Stonebridge *Alnus glutinosa* woodland groundflora species

6.6 Discussion

6.6.1 Component species

A total of 111 species were found in the three woodlands at Stonebridge; this represents 34% of species that have the potential to occur in lowland *Alnus glutinosa* woodland (see Section 4.3). When the number of species in each Site is considered in relation to the species associated with lowland *Alnus glutinosa* woodlands in general (see Section 4.3):

- Site A represents 25%
- Site B represents 29%
- Site C represents 24%.

6.6.2 Life-history strategies of species in Stonebridge *Alnus glutinosa* woodlands

As demonstrated by the CSR-signature calculations and distribution of species across the CSR-triangle (Figures 6.3, 6.5, 6.7) all three woodlands at Stonebridge are predominately a productive environment with occasional disturbance, from for example one-off events.

This is indicated by CoaH-D, Competitive ruderals, which comprises the majority of species found in each woodland.

The bias towards competitive ruderals characterising the woodlands at Stonebridge are consistent with observations of Grime (2001. p.118), who noted that vegetation communities dominated by CR-strategists includes those which experience "*seasonal flood damage, silt deposition, and soil erosion on river terraces and at the margins of ponds, lakes, and ditches*" (e.g. riverside habitats, *cf* Site B and C) or seasonal damage as a result of grazing (e.g. fertile/productive grasslands and meadows, *cf* Site A). In terms of disturbance resulting from flooding, it would be expected that Sites B and C would receive similar levels. However, the groundflora component suggest Site B is less disturbed than Site C, i.e. species in Site B show a bias towards C-strategists, while Site C has a bias towards R-strategists. A review of the management plans and direct observation, during the course of this research, shows Site C to have experienced more management and periodic 'invasion' by cattle; such activities will result in more disturbed conditions.

6.6.3 Light and soil conditions in Stonebridge *Alnus glutinosa* woodlands

The dominance of species associated with semi-shaded and well lit conditions in each of the Stonebridge woodlands (Figures 6.4, 6.6, 6.8) indicate that these light conditions prevail and that other conditions (i.e. shade and very well lit) will be more localised.

Species associated with drier and moist to damp conditions dominate in the three Stonebridge woodlands (Figure 6.4, 6.6, 6.8). Site B has a greater proportion of species associated with very wet soils (Figure 6.6) suggesting that, at least locally, the soils are noticeably wetter than in Sites A and C. No more than three species, associated with very wet soil conditions, are represented in any of the three woodlands suggesting that such soils are unlikely to occur across a significant spatial area. However, as discussed in Section 5.2.1, several of the species associated with very wet soils are gregarious and can cover extensive areas. This is the case in Site B were three such species (*Caltha palustris, Carex acutiformis* and *Rorippa nasturtium-aquaticum*) form a swath through the site (see Figure 5.1 and 5.2).

The groundflora species in all three woodlands have a preference for more acidic conditions than basic with at least 70% of species preferring at least moderately acidic soils; all remaining species preferred more acidic soils.

All three woodlands have a bias towards high fertility soils, with the majority of species prefering intermediate soil fertility and more associated with richly fertile soils than low fertility. However, Site A shows equal numbers of species associated with high and low fertile conditions compared to Sites B and C. This can at least in part be explained by its position within the flood plain and frequency of flooding. Site A is above the floodline, while Sites B and C are flooded on an annual basis so would receive regular and frequent influxes of nutrient and silt deposits; see Figures 6.9 and 6.10.

Fig. 6.9 Flooding at Stonebridge, July 2007, taken from flood level.
The trees in the distance behind the fence are Site C. Site A is behind
and to the left of the shot, well above the flood level (H S Miller, 22/07/07)

Fig. 6.10 Site C, Stonebridge, flooded. Site A was completely above the flood level (H S Miller, 22/07/07)

6.7 Summary of Characteristics of the Three *Alnus glutinosa* Woodlands at Stonebridge

The characteristics of the three woodlands at Stonebridge are summarised in Table 6.3 and fall within the general characteristics of lowland *Alnus glutinosa* woodland detailed in Section 4.7.

Characteristic[1]	Site A	Site B	Site C
Spatial characteristics			
Size (ha)	0.12	0.38	0.84
Age	Stands < 100 years		
Origin	Natural establishment on grassland	Natural establishment around seepage	Planted
Location	River floodplain, UK lowlands	Adjacent to river, UK lowlands	
Isolation/association with other woodlands	Form fragmented network of wet & mesic woodlands along R. Sowe		
Association with other habitats	Form a mosaic with grassland, scrub, woodland, hedgerow and riverside habitats		
Management			
Past	Grazed	Grazed	Woodland products, e.g. clogs, coppice. Grazed
Current	Nature conservation Grazed. Individual tree coppice	Nature conservation	Nature conservation Selective thin, retained on site
Floristic species composition			
No. species	68	78	64
Endemic species	None	None	None
Reflection of adjacent habitats	Includes a number of grassland species	Includes a number of grassland and scrub species	Includes a number of grassland, tall ruderal and scrub species
Environmental conditions			
Variable habitat features	Dry bank. Drainage ditch	Dry bank. Seepage	Dry bank
Relatively stable environment with no extremes of stress or disturbance	Low stress, moderate disturbance	Low stress, moderate disturbance	Low stress, moderate disturbance
Semi-shaded to well lit	✓	✓	✓
Moist to wet soils	✓	✓	✓
More or less neutral soils	✓ - slight acidic bias	✓ - slight acidic bias	✓ - slight acidic bias
Intermediate to richly fertile soils creating a high productive habitat	✓	✓	✓
Notes **1.** See Section 4.7.			

Table 6.3 Summary of characteristics of woodlands at Stonebridge

Chapter 7, using the data collected at Stonebridge and described in this chapter, will test the occurrence of the potential CoaHs and NoaHs (as identified in Chapter 5 from the species found within general lowland *Alnus glutinosa* woodlands) in the field.

7. VERIFYING THE OCCURANCE OF NICHES OF A HABITAT – LOWLAND *ALNUS GLUTINOSA* WOODLAND

7.1 INTRODUCTION AND AIMS OF CHAPTER

Chapter 5 identified groups of plants that could potentially represent intra-site variation of conditions (CoaHs and NoaHs) within lowland *Alnus glutinosa* woodlands and Chapter 6 described three *Alnus glutinosa* woodlands at Stonebridge Meadows, Warwickshire. The current chapter utilises data from these two preceding chapters together with detailed quantitative data collected at Stonebridge (see Section 3.5.3), to verify the occurrence of Niches of a Habitat in lowland *Alnus glutinosa* woodlands. The aim of Chapter 7 is therefore to investigate intra-site variability in species and environmental conditions.

The analyses, detailed and discussed in Section 3.6.1 and 3.6.2, were carried out on both the spring and summer data collected at Stonebridge in 2008. Both data sets led to similar conclusions and therefore, for clarity, only the results for the summer data are included in the current chapter. To review the validity of the use of qualitative data the spatial distribution of C/NoaHs are reviewed using presence/absence data from four sites along the River Rother, Liss, Hampshire (see Section 3.6.3).

7.2 DETERMINING IF SPECIES WITH SIMILAR OPTIMAL ENVIRONMENTAL CONDITIONS OCCUR TOGETHER ON THE GROUND

This section uses the results of data collected in summer 2008 at three *Alnus glutinosa* woodlands at Stonebridge, to determine if the species that defined the CoaHs and NoaHs in Chapter 5, are similarly grouped in a real woodland. This is achieved by putting the quantitative data (percentage cover of all species within the quadrat) through TWINSPAN and DCA ordination and considering the groupings and positioning in ordination space of species in relation to their assigned C/NoaH. If species are in close proximity in DCA space or in the same TWINSPAN group it indicates that the species are found in the same or quadrats of similar composition, therefore do occur together on the ground.

A species x quadrat (percentage cover) matrix, using data collected from the transect surveys at three *Alnus glutinosa* woodlands at Stonebridge in summer 2008, was analysed using TWINSPAN and DCA ordination multivariate techniques (see Section 3.6). The TWINSPAN output groups stabilised, in terms of conditions occupied by the constituent species, by division 4 of the classification, although there still remained some variation of Ellenberg and CSR values, within the groups. Table 7.1 details the number of species, mean and range of environmental conditions of the nine TWINSPAN output species groups; the species occurring in each group are listed in Appendix 14. The table shows much overlap and similarity of conditions between groups. However, the first division appears to be based on soil moisture with species occurring in the negative group (pre-fixed ‘0’) having wetter preferences than those in the positive groups (pre-fixed ‘1’). The species in the negative groups also have a tendency for intermediate to high soil fertility and low acidity, while the positive group species have a bias towards low fertility and more acidic soils. Although, the differences are slight and the TWINSPAN divisions not strongly separated on a particular condition, the differences and similarities of the TWINSPAN groups are more clearly seen when the same input data are displayed in ordination space following DCA. The association of species within each TWINSPAN group, as determined by DCA ordination, is shown in Figure 7.1 and the groups' constituent species are considered in relation to C/NoaHs (see Section 5.2) in Figures 7.3 to 7.8.

The output of the DCA ordination analysis (axes 1 and 2) is shown in Figure 7.1. This Figure shows that the species are clustered towards the high and low ends of axis 1 and scattered between the two extremes. There is also a tight cluster of species towards the higher range of axis 2 and low axis 1 scores. Figure 7.1 shows that the species grouped by TWINSPAN classification are similarly grouped following DCA ordination. Generally species on the negative side of the TWINSPAN output, i.e. groups pre-fixed by ‘0’, have ordination axis 1 scores greater than 1 while those on the positive side (pre-fixed ‘1’), have scores less than 1. This can be seen by the species in TWINSPAN groups 1111 and 1110 which show distinct clusters at the lower end of axis 1 while species in groups 0000 and 0001 are clustered at the higher end of the axis. Although there are a few anomalies, species in TWINSPAN groups 0010 and 0011 have axis 2 scores greater than *c*. 1, while groups 0000 and 0001 have scores less than *c*. 1. Although species with axis 1 scores between about 0 and 1.5 represent a number of TWINSPAN groups, they still form localised clusters, albeit of mixed groups.

TWINSPAN Species group	Light		Moisture		Acidity		Fertility		CSR-C		CSR-S		CSR-R		No. species
	range	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	**range**	**mean**	
01	5-7	6.29	5-9	6.00	5-7	5.71	4-9	6.14	0-0.67	0.298	0-0.5	0.226	0.17-1	0.476	7
	Semi-shade to well lit		Moist to constantly damp		Moderately acidic		Richer		CR/CSR						
0000	5-7	6.67	7-10	8.53	6-7	6.60	4-8	6.20	0-1	0.595	0-1	0.184	0-1	0.221	15
	Well lit		Wet		Near neutral – acidic bias		Variable		C/CSR						
0001	6-7	6.67	8-8	8.00	6-7	6.33	5-7	5.67	0.5-0.75	0.667	0-0.25	0.083	0-0.5	0.250	3
	Well lit		Constantly damp to wet		Moderately acidic		Intermediate		C/CSR						
0010	4-8	6.00	5-10	6.42	5-8	6.58	5-8	6.67	0-0.5	0.375	0-1	0.146	0-1	0.479	12
	Semi-shade to well lit		Variable		Near neutral – acidic bias		High		CR/CSR						
0011	4-7	5.67	5-6	5.50	6-7	6.83	7-8	7.17	0.17-0.67	0.347	0-1	0.222	0.17-0.75	0.431	6
	Semi-shade to well lit		Moist to constantly damp		Near neutral – acidic bias		High		CR/CSR						
10	4-7	5.71	5-7	5.71	4-7	5.71	5-6	5.71	0-1	0.202	0-1	0.274	0-1	0.524	7
	Semi-shade to well lit		Moist to constantly damp		Moderately acidic		Richer		R/CSR						
110	5-6	5.75	4-7	5.75	6-7	6.50	5-7	6.50	0.25-1	0.354	0-0.17	0.167	0-0.75	0.479	4
	Semi-shade to well lit		Moist to constantly damp		Near neutral – acidic bias		Intermediate		CR/CSR						
1110	5-7	6.62	4-10	6.54	3-7	5.08	2-6	4.38	0-1	0.352	0-0	0.218	0-0.75	0.430	13
	Well lit		Constantly damp		Moderately acidic		Variable		CR/CSR						
1111	6-8	6.85	4-10	6.23	4-7	5.69	3-7	5.08	0-0.67	0.417	0-0.67	0.167	0.17-0.75	0.416	13
	Well lit		Constantly damp		Moderately acidic		Variable		CR/CSR						

Table 7.1 Mean and range, light, soil (moisture, acidity, fertility) and life history strategy and total number species of TWINSPAN species output groups using quantitative data of groundflora species recorded in summer 2008 at three *Alnus glutinosa* woodland at Stonebridge (Chapter 5) Environmental conditions are based on Ellenberg indicator values (Hill *et al.* 2004) and CSR-strategies (Hunt, 2007b)

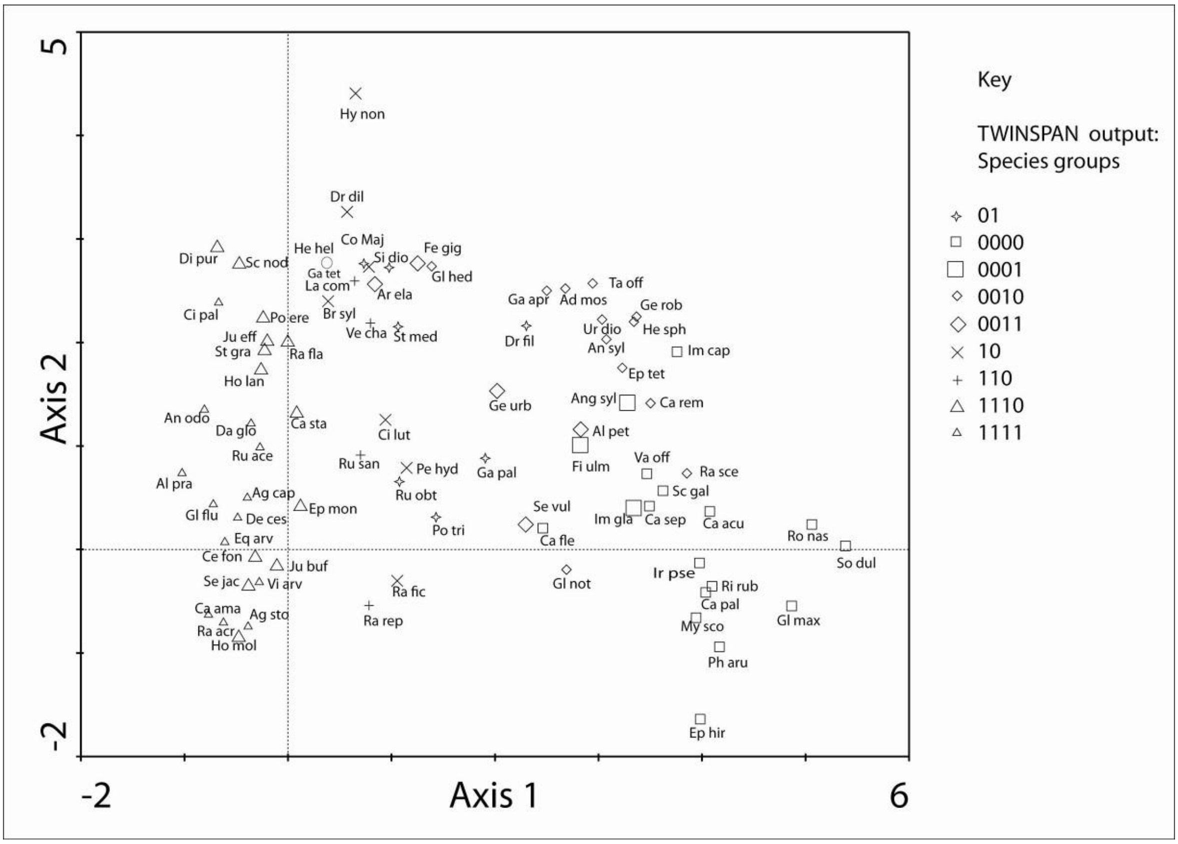


Fig. 7.1 DCA output (axes 1 and 2) of species x quadrat (percentage cover) matrix of transect survey undertaken in summer 2008 in *Alnus glutinosa* woodland at Stonebridge (Section 3.6.3). Species symbols depict TWINSPAN output of species groups of the same input matrix

Linear regression and product moment correlation coefficients of the axes scores against Ellenberg and CSR-strategy values, (Table 7.2) suggest that the distribution of species along the first axis is best described by soil moisture, acidity and fertility, while axis two, although the correlations are only weak, is best described by light and soil moisture. From the correlations between the axes scores and the Ellenberg indicator values and CSR-strategies detailed in Table 7.2, it can be expected that species with the following preferences will be concentrated in the following areas of the DCA output ordination of axes 1 and 2:

- Shade: high axis 2 scores
- Light: low axis 2 scores
- Wetter soils: high axis 1, low axis 2 scores
- Drier soils: low axis 1, high axis 2 scores
- Acidic and low fertility: low axis 1 scores
- Basic and high fertility: high axis 1 scores.

Variable	R value and Correlation: species	
	Axis 1	Axis 2
L	r = 0.01 V. weak -ve	r = 0.33 **Weak -ve**
F	r = 0.47 **Modest +ve**	r = 0.32 **Weak -ve**
R	r = 0.47 **Modest +ve**	r = 0.13 V. weak –ve
N	r = 0.44 **Modest +ve**	r = 0.06 V. weak +ve
C (CSR)	r = 0.15 V. weak +ve	r = 0.23 *Weak -ve*
S (CSR)	r = 0.08 V. weak -ve	r = 0.18 Weak +ve
R (CSR)	r = 0.14 V. weak -ve	r = 0.04 V. weak +ve
Eigen value	0.510	0.343
Notes: **Bold** denotes statistically significant at P 0.01 levels of significance *Italics* denotes statistically significant at P 0.05 levels of significance		

Table 7.2 Statistical significance of species found within Stonebridge *Alnus glutinosa* woodlands (summer 2008) along DCA ordination axes and environmental/life history variable correlations based on species preferences (Ellenberg indicator values, Hill *et al.*, 2004 and CSR-Strategy, Hunt, 2007b)

These generalisations derived from the interpretation of the axis scores (Table 7.2) correspond to the conditions preferred by the indicator and preferential species of the TWINSPAN sample (quadrat) output groups in these locations in DCA space (Table 7.3). Figure 7.2 illustrates the TWINSPAN quadrat output groups in DCA ordination space from the same species x quadrat data detailed above, i.e.:

- High axis 2 scores: Group Q11 – semi-shade
- Low axis 2 scores: Group Q10, Q01 and Q00 – well lit
- High axis 1, low axis 2 scores: Group Q00 – wet soils
- Low axis 1, high axis 2 scores: Group Q11 – drier to moist soils
- Low axis 1 scores: Group Q10 and Q11 – acidic bias and intermediate fertility soils
- High axis 1 scores: Group Q00 and Q011 – neutral and intermediate to richly fertile soils.

The trends and generalisations detailed above are also confirmed in Figures 7.3 to 7.7 which illustrate the distribution of species across DCA ordination space in relation to the CoaHs identified in Section 5.2.

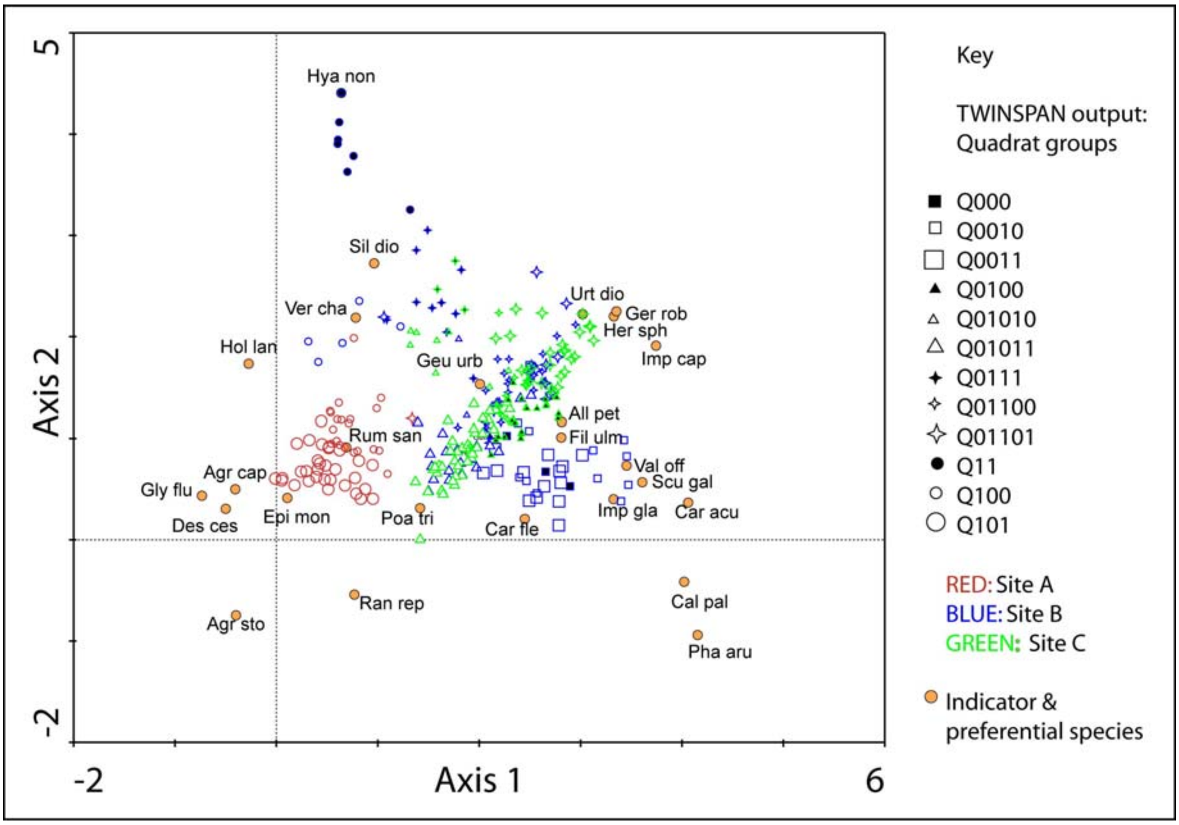


Fig. 7.2 DCA output (axes 1 and 2) of species x quadrat (percentage cover) matrix of transect survey undertaken in summer 2008 in *Alnus glutinosa* woodland at Stonebridge (Section 3.6.3). Quadrat symbols depict TWINSPAN output groups of the same matrix and coloured to illustrate the woodland Sites (A-C) in which they occur. Indicator and preferential species indicated; see Table 7.3.

Indicator/preferential species of TWINSPAN samples output	Light	Moisture	Acidity	Fertility	CSR-strategy	TWINSPAN sample (quadrat)[1]				
						Q00	Q01	Q011	Q10	Q11
Caltha palustris	Well lit	Wet	Near neutral	Infertile	Stress	x				
Cardamine flexuosa	Semi-shade	Moist-damp	Near neutral	Intermediate	Ruderal	x				
Carex acutiformis	Well lit	Wet	Near neutral	Intermediate	Competitor	x				
Filipendula ulmaria	Well lit	Wet	Near neutral	Intermediate	Competitor	x				
Phalaris arundinacea	Well lit	Wet	Near neutral	Richly	Competitor	x				
Valeriana officinalis	Semi-shade	Wet	Near neutral	Intermediate	CSR	x				
Ranunculus repens	Semi-shade	Moist-damp	Near neutral	Richly	Competitor-ruderal	x			x	
Rumex sanguineus	Semi-shade	Moist-damp	Near neutral	Richly	CSR	x			x	
Galium palustre	Well lit	Wet	Acidic	Infertile	Competitor-ruderal	x				
Geranium robertianum	Semi-shade	Moist-damp	Near neutral	Intermediate	Ruderal	x				
Impatiens capensis	Well lit	Wet	Near neutral	Intermediate	-	x				
Impatiens glandulifera	Semi-shade	Wet	Near neutral	Richly	Competitor-ruderal	x				
Scutellaria galericulata	Well lit	Wet	Near neutral	Intermediate	Competitor-ruderal	x				
Anthoxanthum odoratum	Well lit	Moist-damp	Acidic	Infertile	Stress-ruderal		x			
Urtica dioica	Semi-shade	Moist-damp	Near neutral	Richly	Competitor		x	x	x	
Alliaria petiolata	Semi-shade	Moist-damp	Near neutral	Richly	Competitor-ruderal		x			
Silene dioica	Semi-shade	Moist-damp	Near neutral	Richly	CSR		x			
Heracleum sphondylium	Well lit	Drier	Near neutral	Richly	Competitor-ruderal			x		
Holcus lanatus	Well lit	Moist-damp	Near neutral	Intermediate	CSR				x	
Poa trivialis	Well lit	Moist-damp	Near neutral	Intermediate	Competitor-ruderal				x	
Agrostis capillaris	Semi-shade	Drier	Acidic	Infertile	CSR				x	
Agrostis stolonifera	Well lit	Moist-damp	Near neutral	Intermediate	Competitor-ruderal				x	
Deschampsia cespitosa cespitosa	Semi-shade	Moist-damp	Acidic	Infertile	Stress-competitor				x	
Epilobium montanum	Semi-shade	Moist-damp	Near neutral	Intermediate	CSR				x	

Table 7.3 Environmental (based on Hill *et al.*, 2004) and CSR-strategy (based on Hunt, 2007a) preferences of species of TWINSPAN classification quadrat output (Table continues)

Indicator/preferential species of TWINSPAN samples output	**Light**	**Moisture**	**Acidity**	**Fertility**	**CSR-strategy**	**TWINSPAN sample (quadrat)[1]**				
						Q00	**Q01**	**Q011**	**Q10**	**Q11**
Geum urbanum	Shade	Moist-damp	Near neutral	Richly	Stress				x	
Veronica chamaedrys	Semi-shade	Drier	Near neutral	Intermediate	CSR				x	
Dryopteris dilatata	Semi-shade	Moist-damp	Acidic	Intermediate	Stress-competitor					x
Hyacinthoides non-scripta	Semi-shade	Drier	Acidic	Intermediate	Stress-ruderal					x

Notes. **1.** Only indicator and preferential species of Quadrat groups Q00 (inc. Q000, Q0010, Q0011), Q01 (incl. Q0100, Q01010, Q01011, Q0110, Q01101, Q0111), Q011 (incl. Q01100, Q01101, Q0111), Q10 (incl. Q100, Q101) and Q11

Table 7.3 cont. Environmental (based on Hill *et al.*, 2004) and CSR-strategy (based on Hunt, 2007a) preferences of species of TWINSPAN quadrat output

The species recorded in the three *Alnus glutinosa* woodlands at Stonebridge show a bias towards CoaHs-A and C, i.e. C- and R-strategists. Generally the C-strategists are located towards the higher end of axis 1 in ordination space (Figure 7.3) with the R-strategists at the lower end of the axis. The few species with S-based strategies (CoaH-B) show a slight tendency to havet higher axis 2 scores and lower axes 1 scores. The intermediate strategists are located between these three broad areas.

The C-strategist species (CoaH-A) dominate the TWINSPAN groups with a mean of C/CSR-strategies (0000, 0001, Table 7.1) and are positioned towards the higher end of axis 1. However there is a smaller, looser cluster of species at the lower end of axis 1 from TWINSPAN groups 1111 and 1110. The species of the most disturbed TWINSPAN group (10, Table 7.1) are primarily R- and CR-strategists and located towards the lower end of axis 1. The remaining TWINSPAN groups, all with a mean strategy of CR/CSR (CoaH-D), occur in localised clusters in ordination space but comprise a range of CSR-strategists.

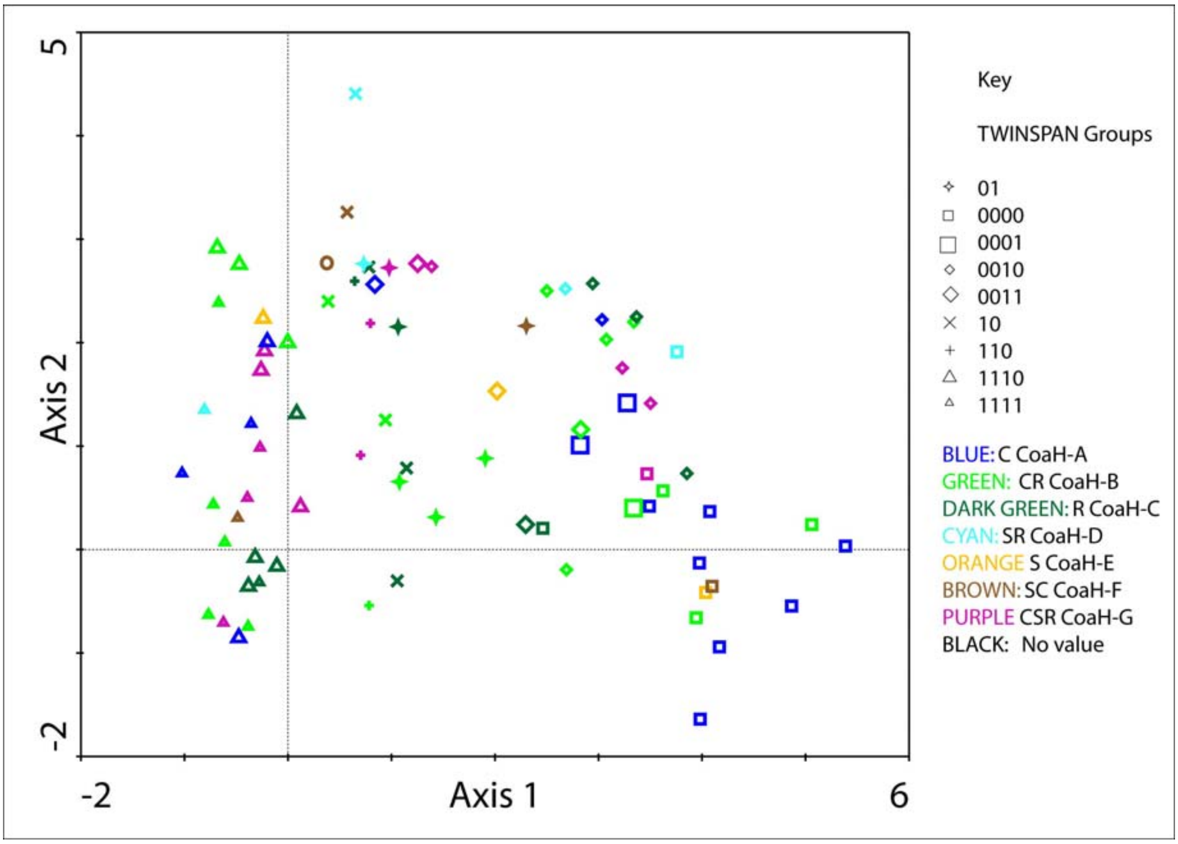


Fig. 7.3 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6). Species coded to depict TWINSPAN output groups of the same species matrix and CoaH-CSR conditions (see Section 5.2)

Figure 7.4 shows that species with a preference for well lit conditions are generally located as two clusters at the high and low ends of axis 1. These two clusters correspond to TWINSPAN groups 000 (0000 and 0001) and 111 (1110 and 1111), each of which have a mean light condition of CoaH-J: well lit (Table 7.1). The remaining species, located between these two clusters are dominated by semi-shade species (CoaH-I).

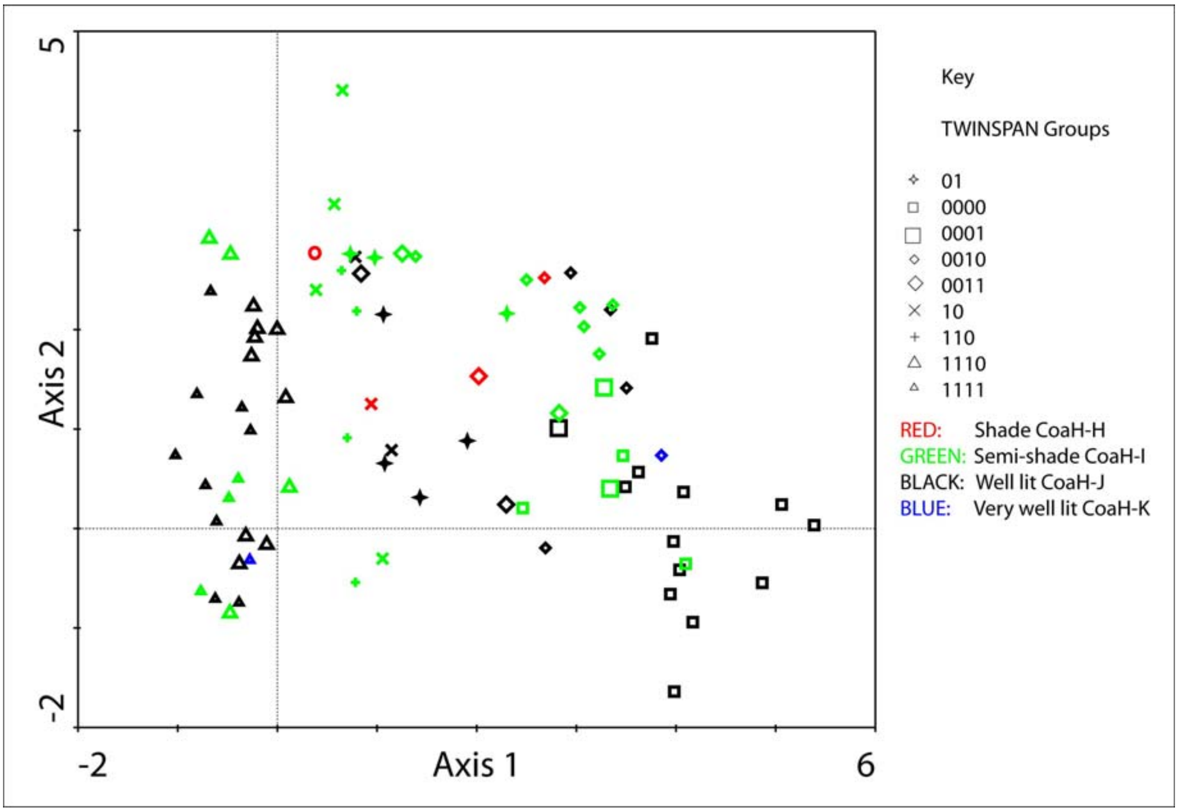


Fig. 7.4 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6). Species coded to depict TWINSPAN output groups of the same species matrix and CoaH-Light conditions (see Section 5.2)

Figure 7.5 shows that plants associated with wet (CoaH-N) and very wet (CoaH-O) conditions are primarily located in positions of high axis 1 values and low axis 2 values. Species in these clusters are mainly in TWINSPAN groups 111 (1111 and 1110) and 000 (0000 and 0001). These four groups are the wetter of the TWINSPAN groups and have constantly damp to wet mean soil moisture conditions. Although the remaining species are scattered between the clusters at either end of axis 1, species of the same CoaH (L: drier and M: moist) are generally locally clustered in ordination space and TWINSPAN group.

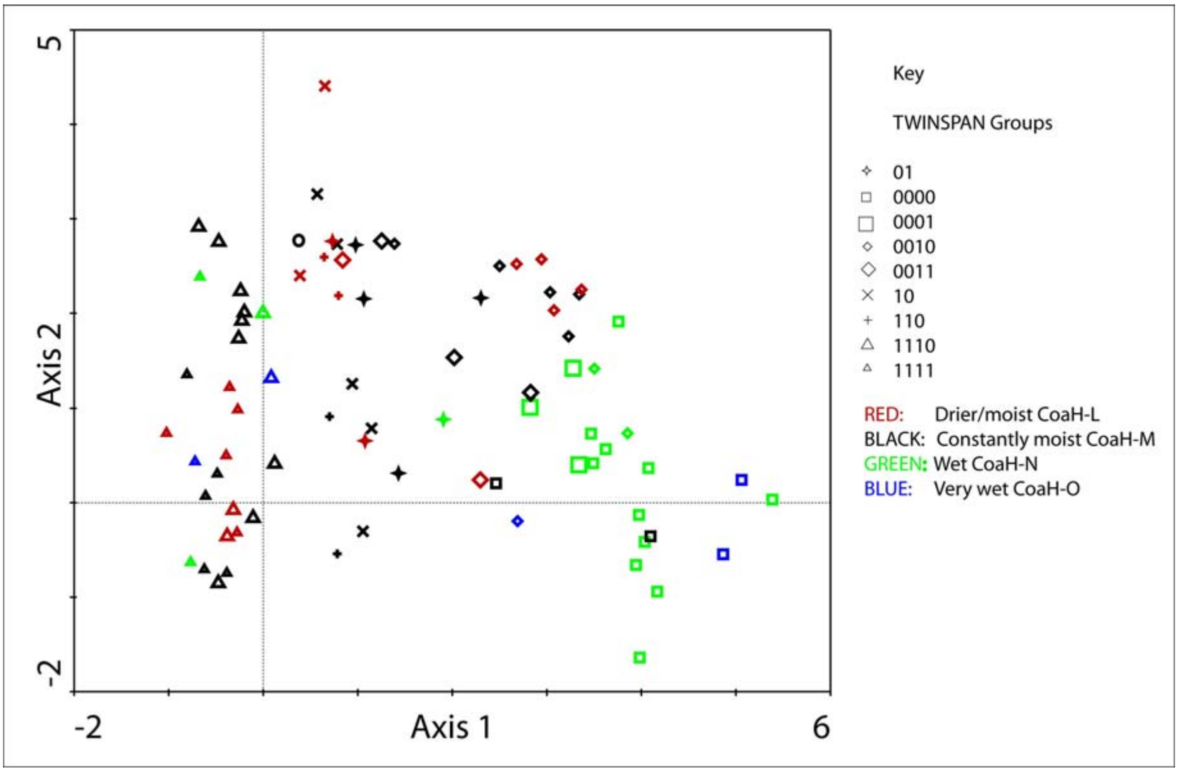


Fig. 7.5 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6). Species coded to depict TWINSPAN output groups of the same species matrix and CoaH-Moisture conditions (see Section 5.2)

Figure 7.6 shows that species associated with acidic soils (CoaH-P) are predominately concentrated at the lower end of axis 1 and correspond to TWINSPAN groups 1111 and 1110. Both these TWINSPAN groups have a mean soil acidity of moderately acidic (Table 7.1). TWINSPAN group 01 also has a mean soil acidity of moderately acidic and the component species are loosely clustered in ordination space between the main species clusters at the high and low ends of axis 1.

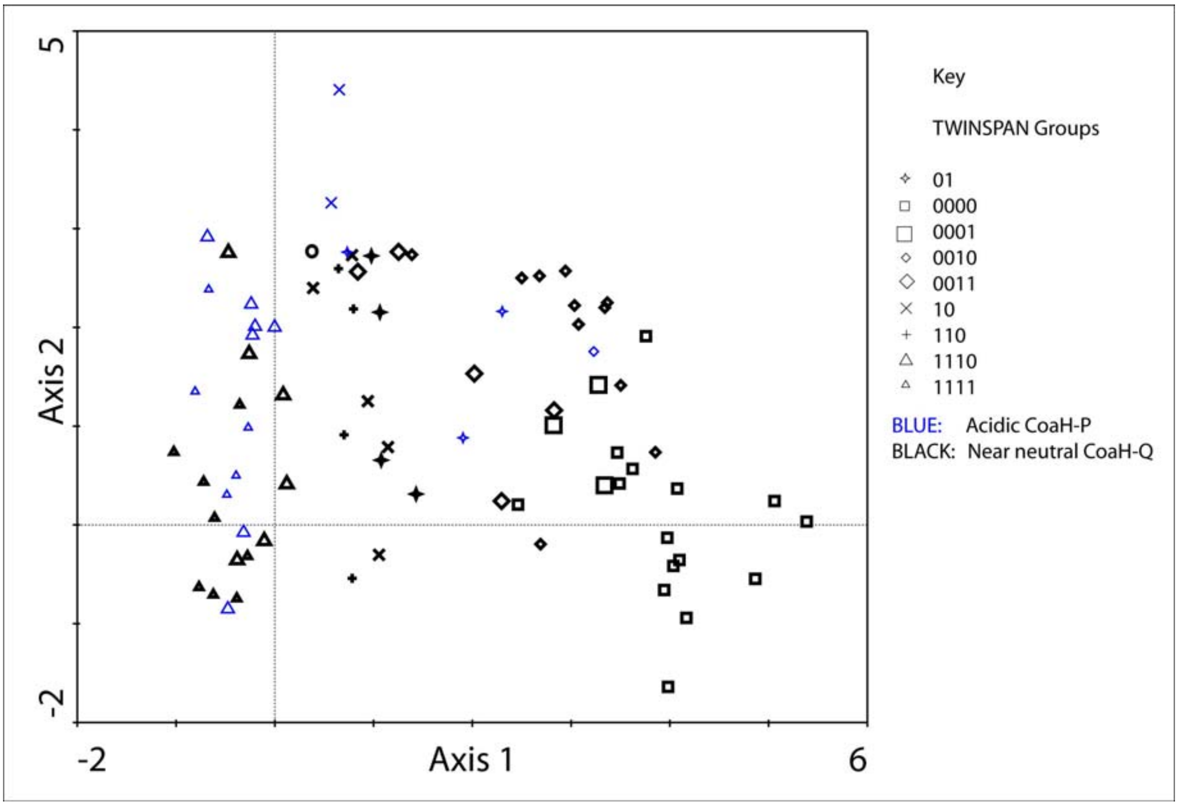


Fig. 7.6 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6).
Species coded to depict TWINSPAN output groups of the same species matrix and CoaH-Acidity conditions (see Section 5.2)

Figure 7.7 shows species in CoaH-R (low fertility) to be located at the lower end of axis 1 in ordination space and are in TWINSPAN groups 1110 and 1111. Although species of intermediate and rich soil fertility (CoaH-S and T) occur across ordination space, there is a tendency for species of CoaH-T to occur at higher axis 1 scores. Generally, the TWINSPAN groups with a higher mean soil fertility (Table 7.1) are comprised of species in CoaH-T (high fertility) and located at higher axis 1 scores.

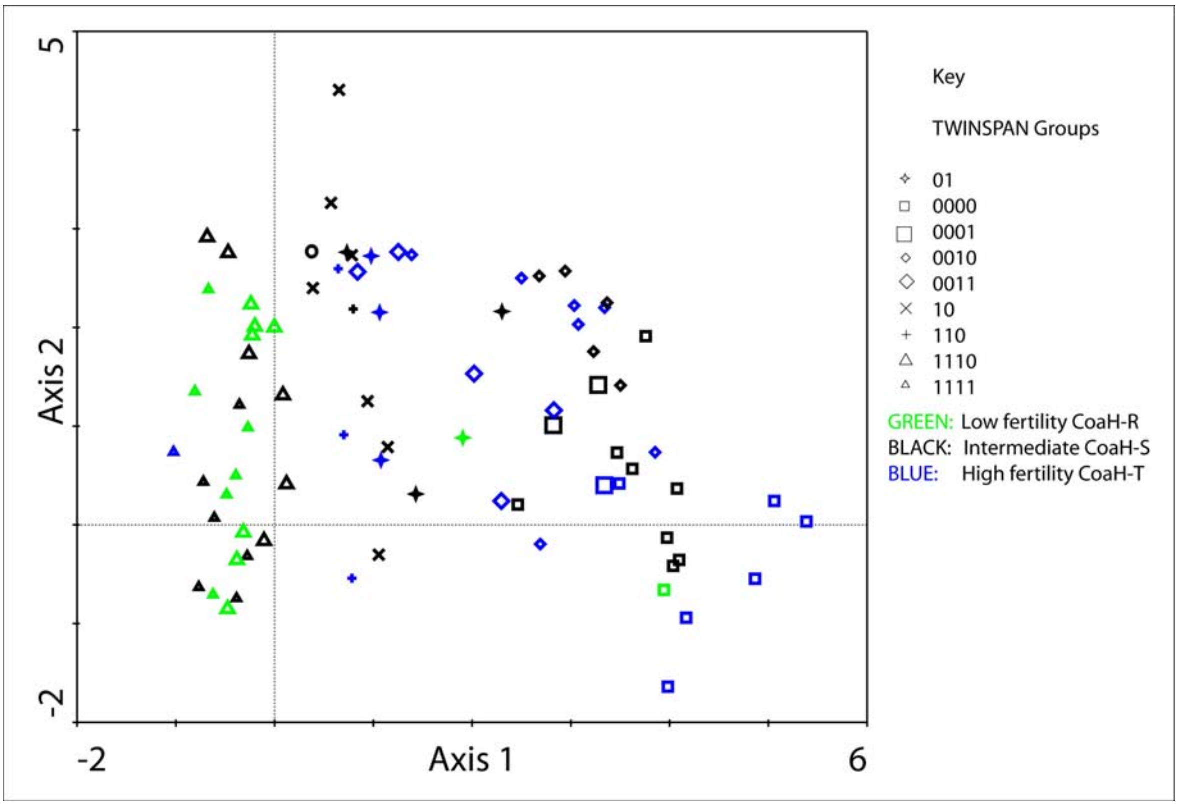


Fig. 7.7 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6). Species coded to depict TWINSPAN output groups of the same species matrix and CoaH-Fertility conditions (see Section 5.2)

Figures 7.3 to 7.7 considered the species, recorded in the quadrats at Stonebridge in summer 2008, in relation to individual conditions (CSR-strategy and Ellenberg indicators), i.e. CoaHs. Figure 7.8 depicts the same species in relation to their NoaH (Niche of a Habitat) which simultaneously takes each CoaH into account (see Section 5.4). Figure 7.8 shows that species occurring in the same NoaH are at least loosely clustered in ordination space. However, there are overlaps and sub-divisions, e.g. at ordination position *x*1, *y*1 there is a group of NoaH-7 species (in TWINSPAN groups 01 and 10) with two species from NoaH-5 (TWINSPAN group 10 and 110). A second example is NoaH-2, although only four species (*Callitriche stagnalis, Glyceria fluitans, Glyceria maxima*, *Rorippa nasturtium-aquaticum*) are represented in the Stonebridge *Alnus glutinosa* woodlands, they occur in two distinct locations and two distinct TWINSPAN groups: TWINSPAN group 0000 at the high end of axis 1 and TWINSPAN group 111 at the low end of axis 1.

Although species in the same NoaH may occur in different TWINSPAN groups (Figure 7.8), the latter are related if a lower level classification division is considered, see Table 7.4. For example, NoaH-8 comprises species in three TWINSPAN groups (0000, 0001 and 1111) but if considered at division level three only occur in two groups: 000 and 111 with majority of species in the former group.

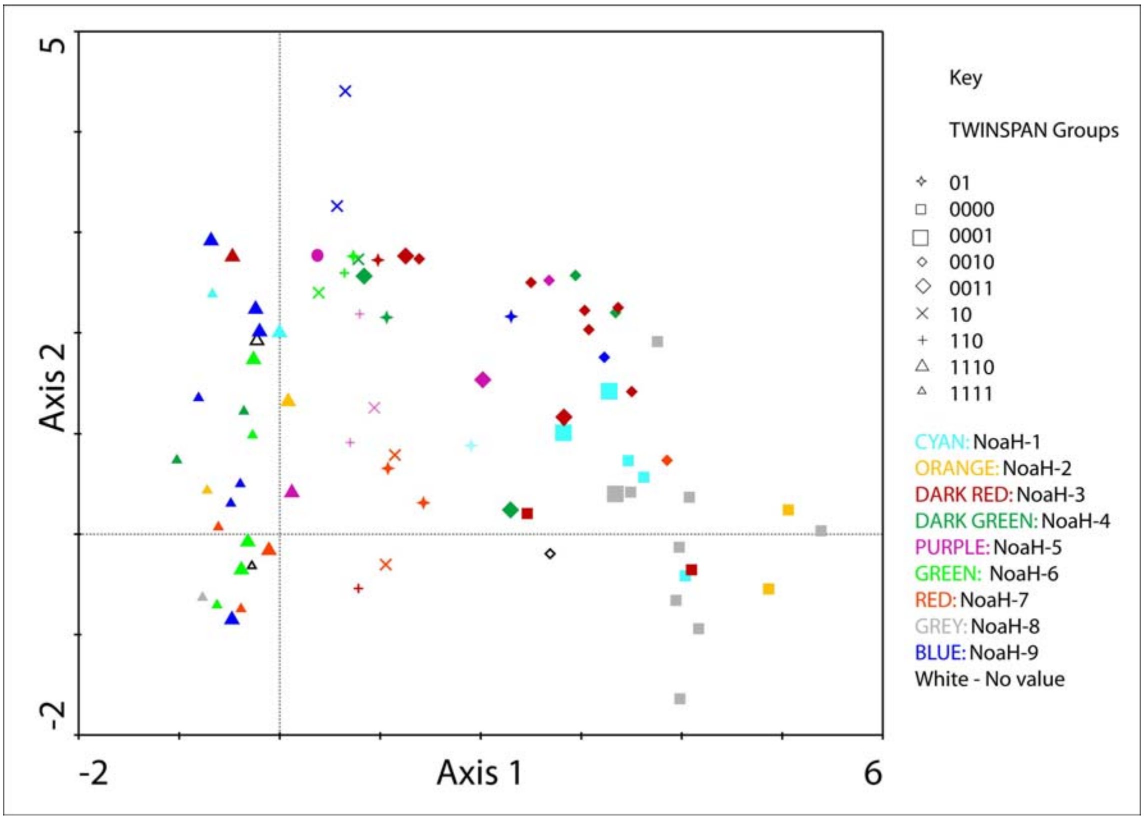


Fig. 7.8 DCA output (axes 1 and 2) of species x quadrat (percentage cover) of transect data (summer, 2008) of *Alnus glutinosa* woodland at Stonebridge (Section 3.6). Species coded to depict TWINSPAN output groups of the same species matrix and assigned NoaH (see Section 5.4).

TWINSPAN Group	NoaH										Total spp. TWINSPAN group
	1	2	3	4	5	6	7	8	9	10	
0000	3	2	2					8			**15**
0001	2							1			**3**
0010			6	2	1		1		1		**12**
0011			2	3	1						**6**
01	1		1	1		1	2		1		**7**
1110	1	1	1		1	3	1		4		**7**
1111	1	1		2		2	2	1	3		**4**
110			1		2	1					**13**
10				1	1	1	2		2		**13**
Total spp./NoaH	**8**	**4**	**13**	**9**	**6**	**8**	**8**	**10**	**11**	**0**	

Table 7.4 NoaHs in relation to TWINSPAN Classification output groups of species x quadrat data collected at Stonebridge, summer 2008

7.3 Spatial Distribution of Species in CoaHs and NoaHs in *Alnus glutinosa* Woodland at Stonebridge

Section 7.2 detailed the results of the associations of species (as determined by multivariate analysis), found in the *Alnus glutinosa* woodlands at Stonebridge in summer 2008, in relation to the C/NoaHs defined in Chapter 5. Using the same data, i.e. quadrats surveyed in summer 2008, this section shows how the species, and therefore CoaHs and NoaHs, are spatially distributed across the woodlands. This will be achieved through the consideration of the species composition and spatial distribution of the quadrats (Section 3.6.2). It will show if the plants representing different C/NoaHs are distributed across the sites or are located in discrete areas, which could subsequently be managed with targeted management.

Each of the three sites (A-C) were assessed using the methods detailed in Section 3.6.2. However, for clarity, only the results of Site B are provided here (results for Sites A and C are provided in Appendix 15). Site B is illustrated and discussed in more detail on account of it being more diverse in terms of intra-site variation compared to Sites A and C. Figures 7.9 to 7.14 graphically represent the transects (see Figure 6.2) and quadrats, with constituent species, sampled in Site B, Stonebridge, in relation to the C/NoaHs of the component species. For each quadrat, the component species (and % cover) occurring in each quadrat are depicted and coded by their associated C/NoaH. In these figures, columns represent quadrat composition while rows represent occurrence of species in the quadrats (see Figure 3.2 for a fuller explanation). Although only transects of Site B are depicted here, Sites A and C showed similar trends and led to similar conclusions being drawn (see Appendix 15).

The Figures show that many of the species recorded at Site B occur across the site, e.g. *Urtica dioica* and *Poa trivialis*. Some species, however, e.g. *Adoxa moschatellina* and *Geum urbanum*, are more localised, occurring in a few adjacent quadrats. Generally the extremes of the various environmental conditions (e.g. shade, well lit, drier, very wet; Figures 7.9 and 7.10) were more localised along the transects; species of the intermediate conditions (e.g. semi-shade, moist, intermediate fertility; Figures 7.9, 7.10, 7.12) being more ubiquitous. The ruderal (CoaH-C) and stress tolerant competitors (CoaH-E) show localised occurrence along the transects while the component species of the remaining CSR-CoaHs are more ubiquitous (Figure 7.13). With the exception of NoaH-3 and -7, the species comprising each NoaH are generally fairly localised along the transects (Figure 7.14).

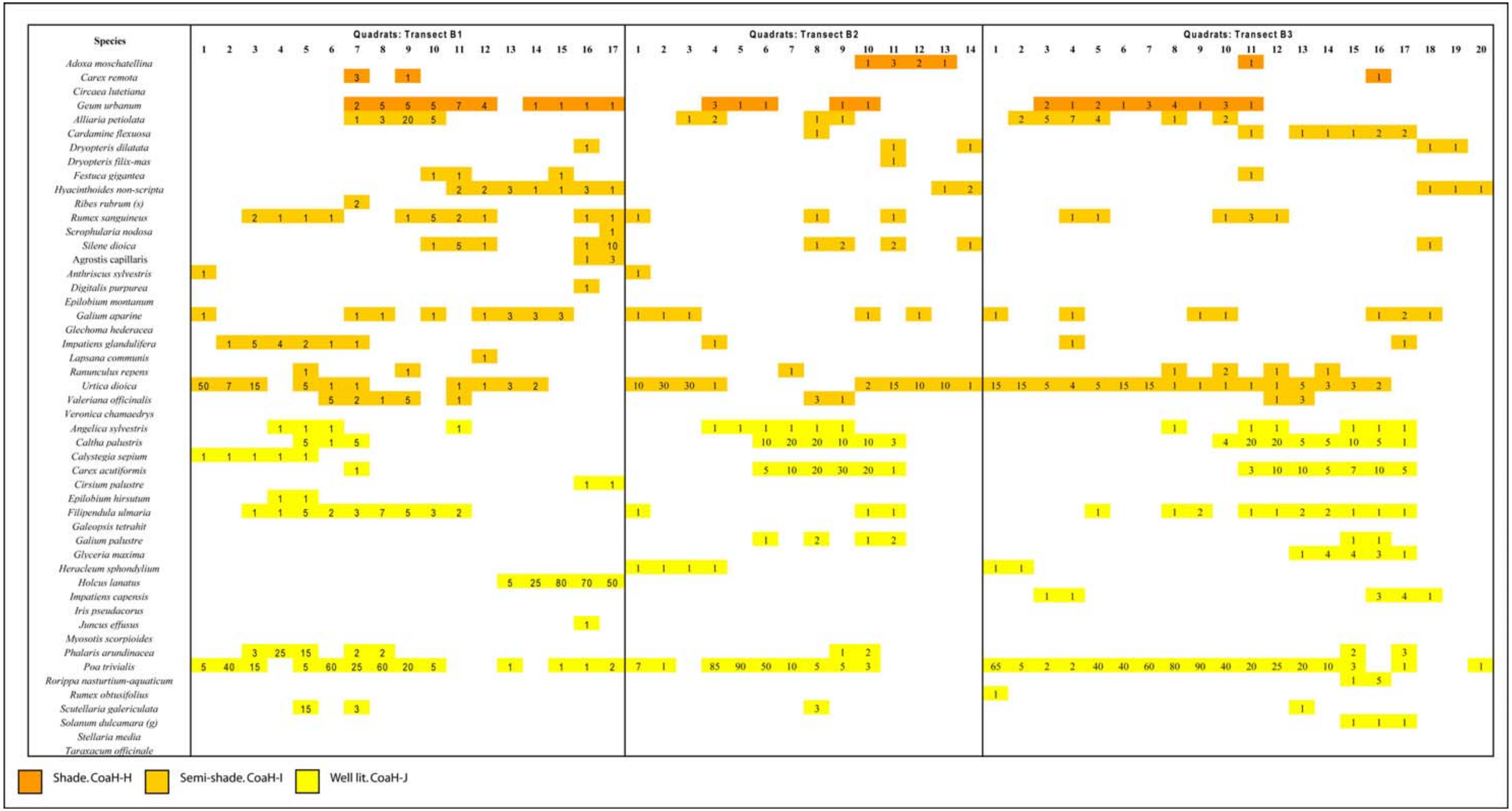


Fig. 7.9a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

Fig. 7.9b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

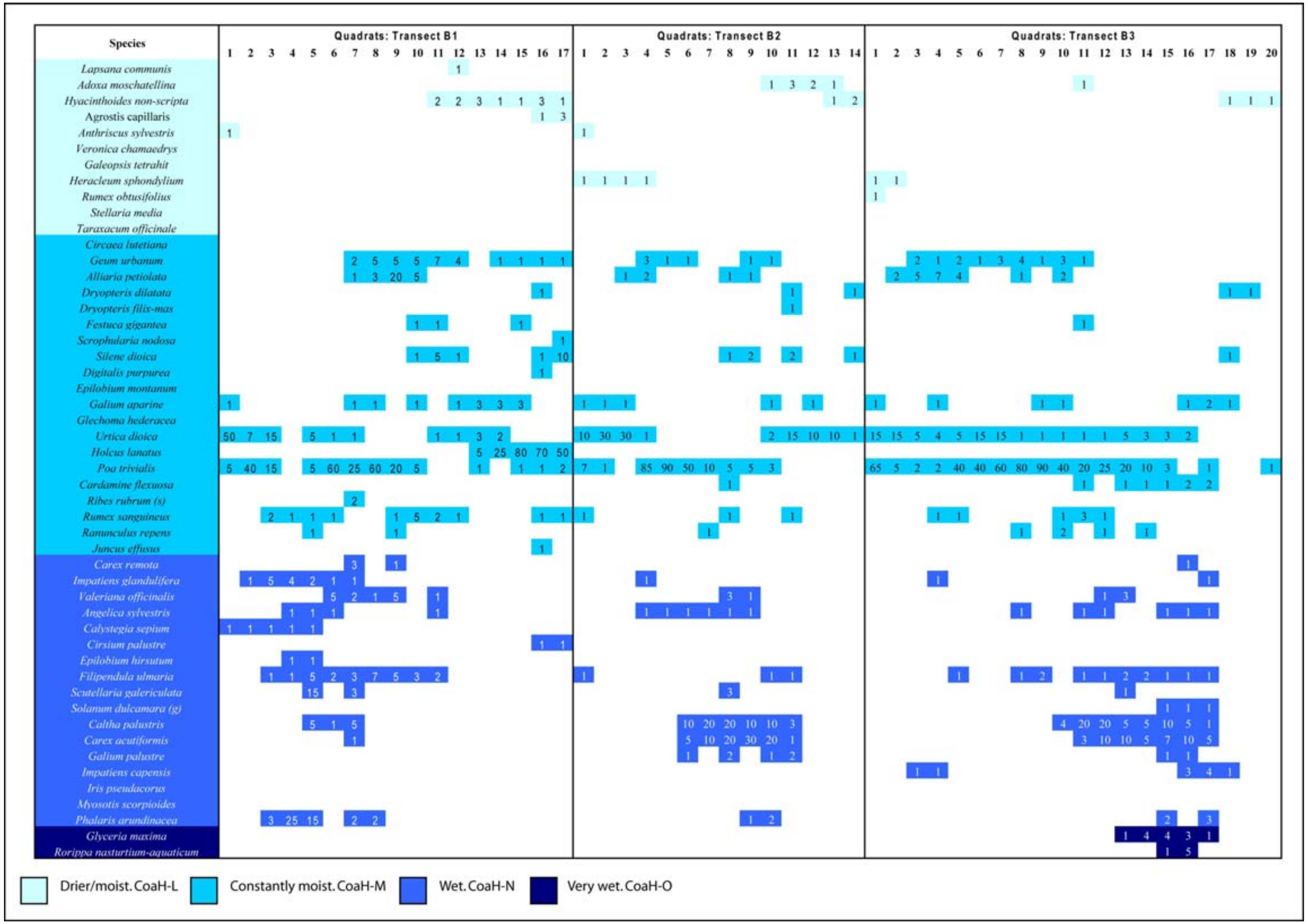


Fig. 7.10a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

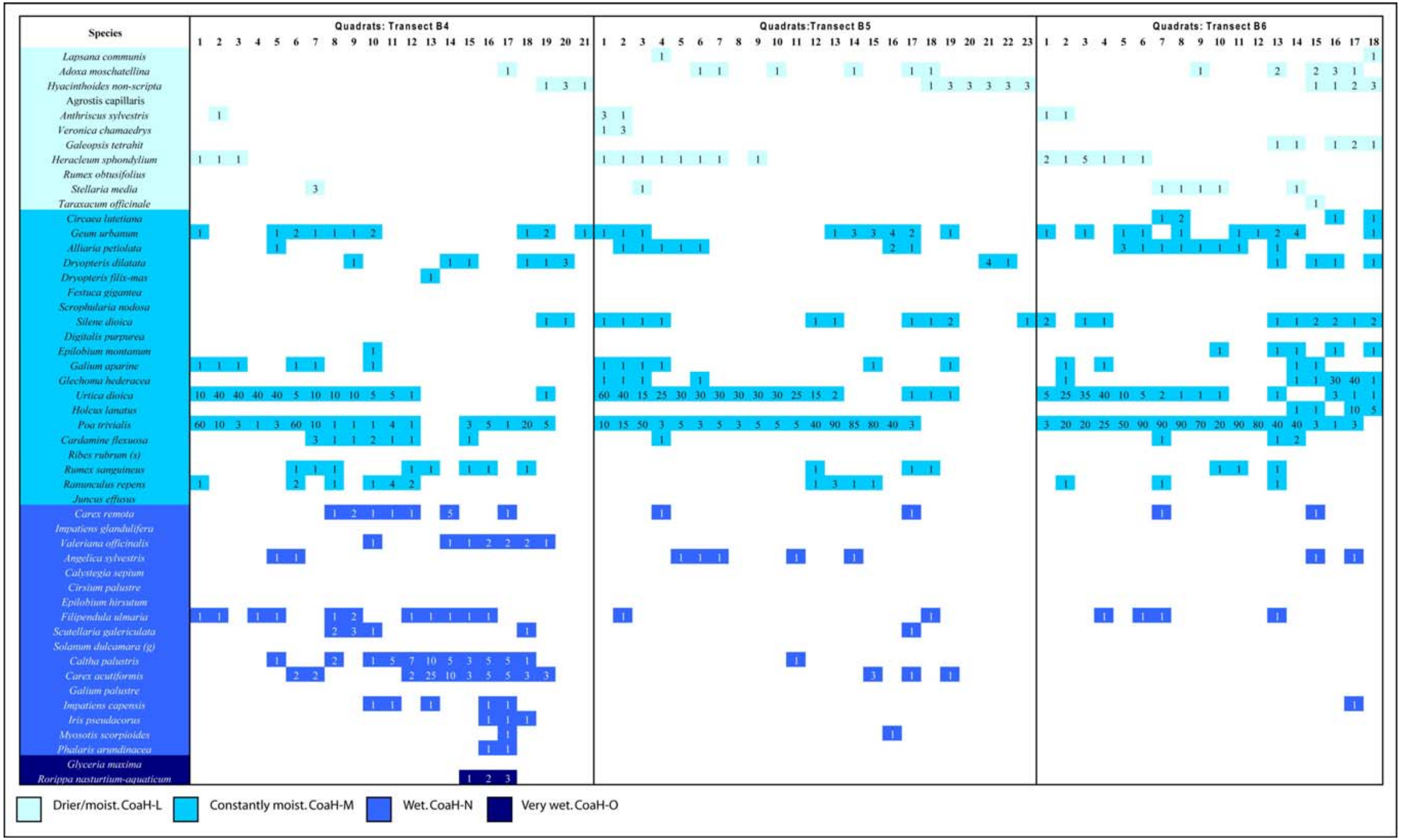


Fig. 7.10b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

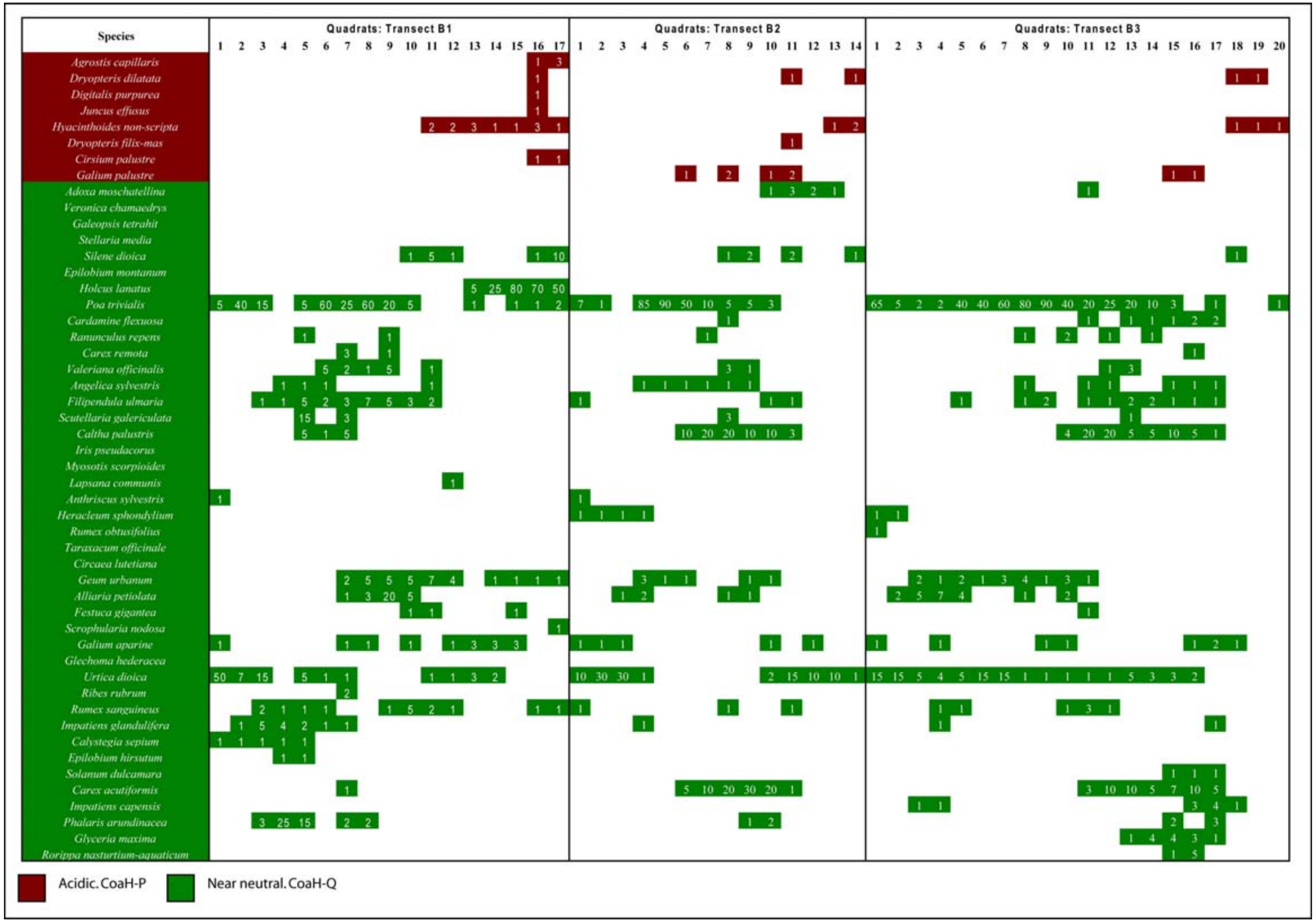


Fig. 7.11a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Acidity (summer 2008 data)

Fig. 7.11b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Acidity (summer 2008 data)

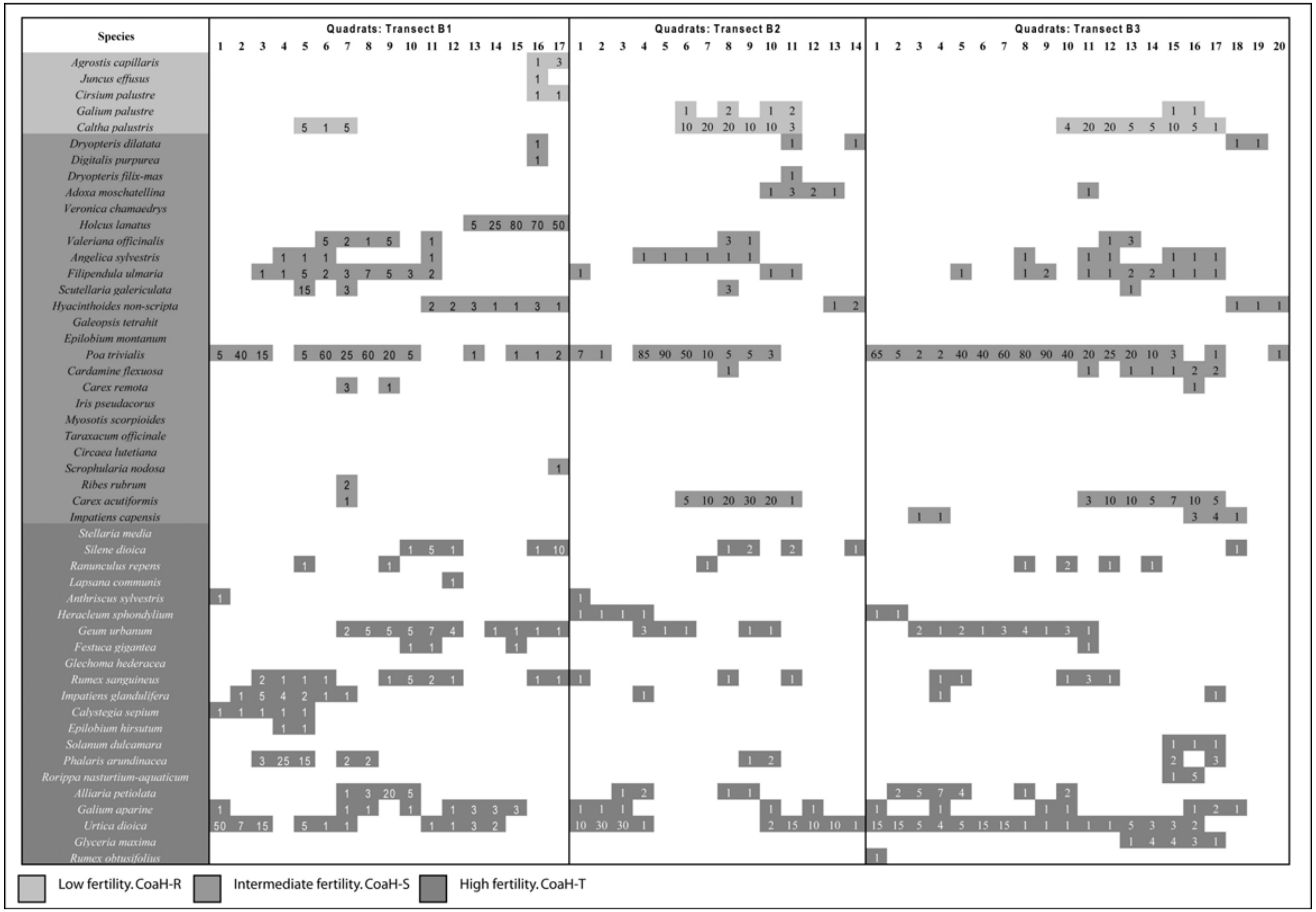


Fig. 7.12a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

Fig. 7.12b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

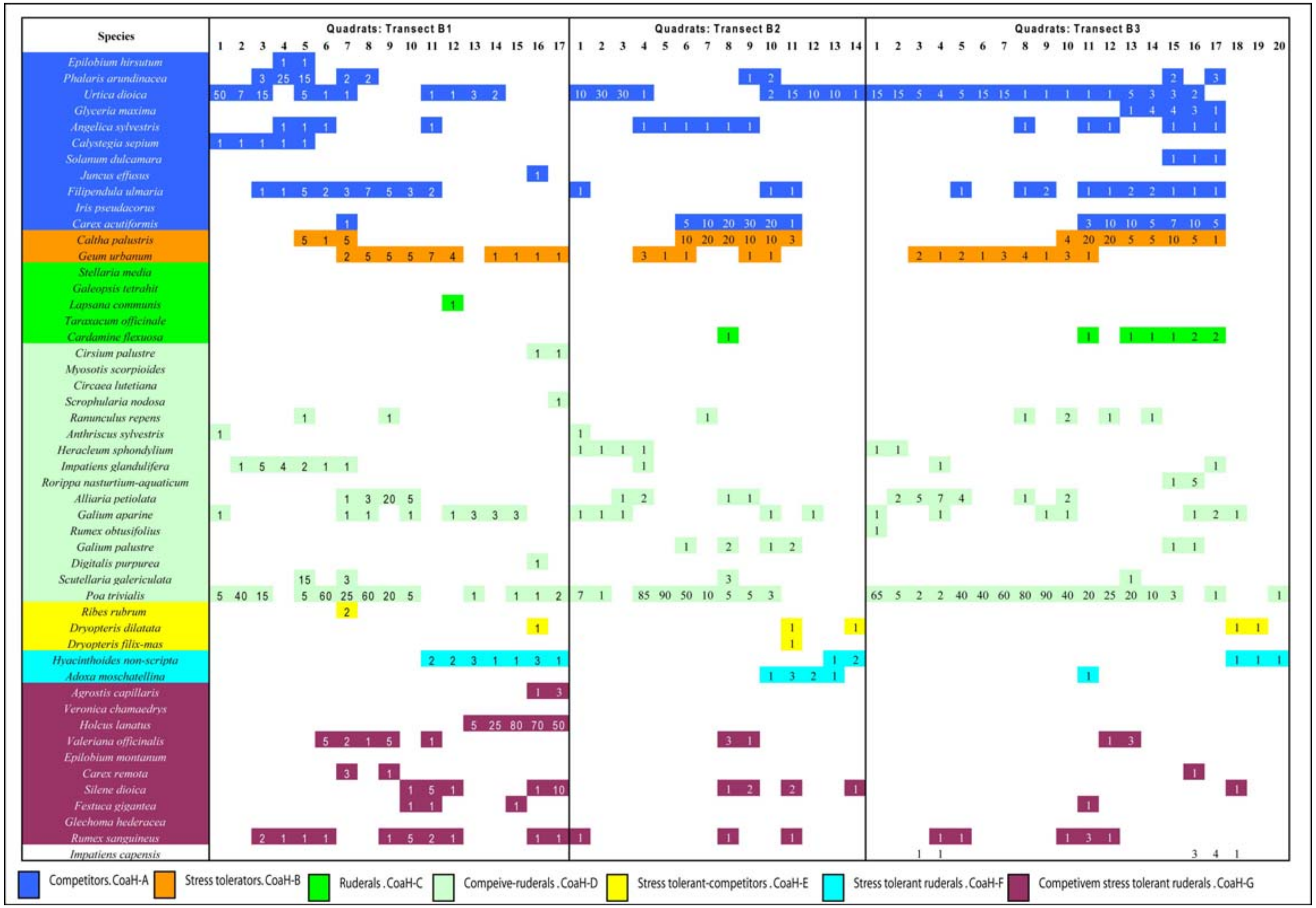


Fig. 7.13a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

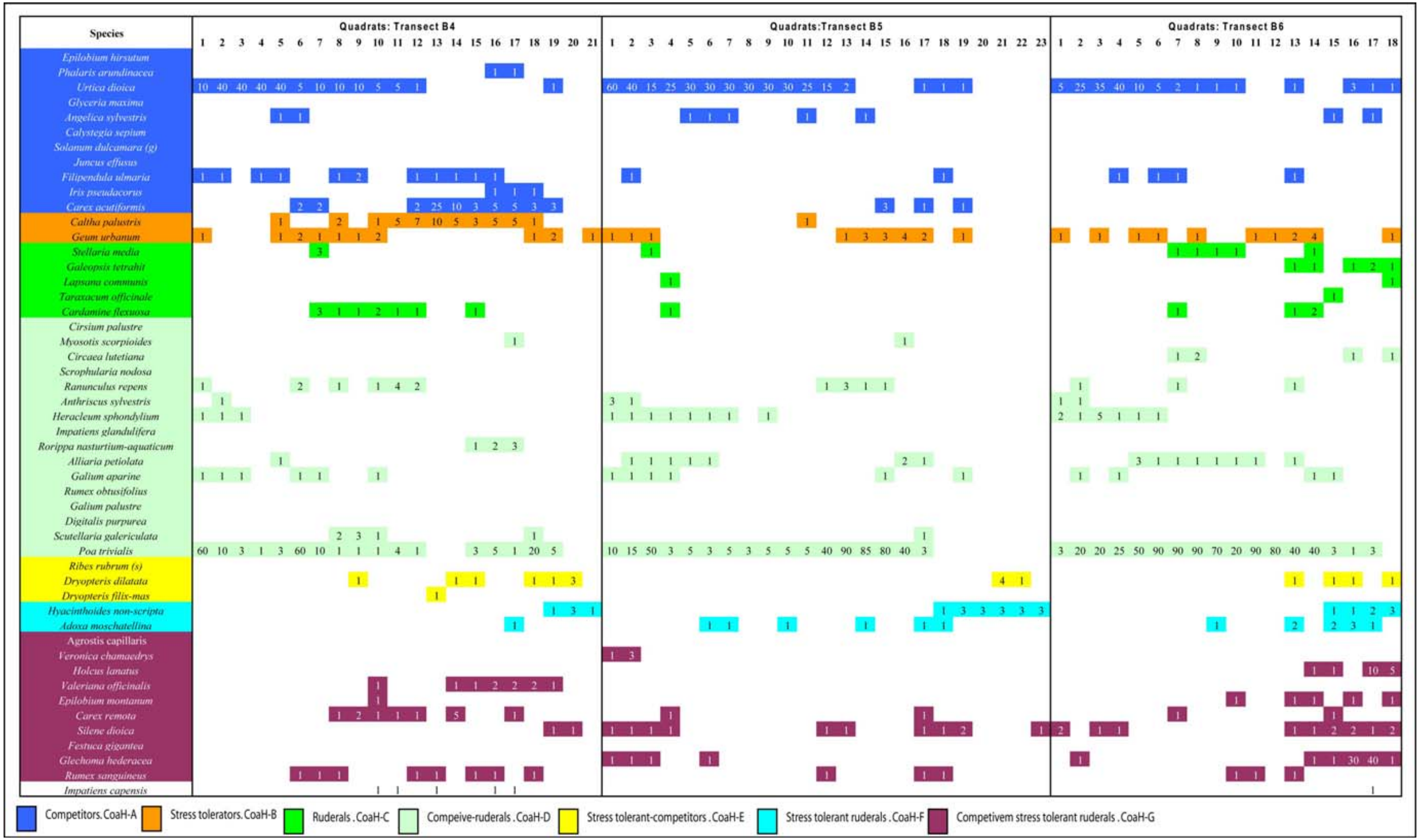


Fig. 7.13b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

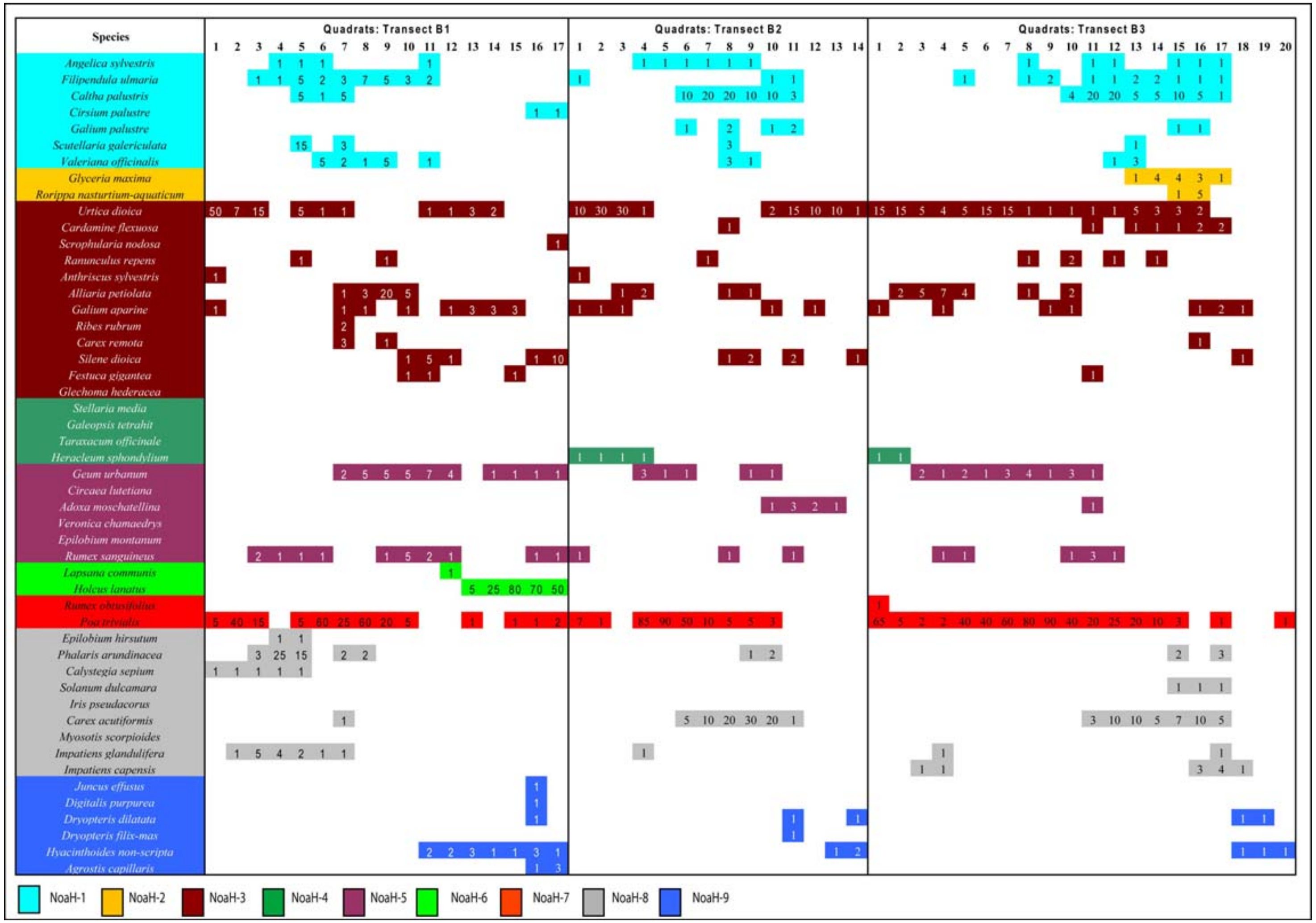


Fig. 7.14a Distribution & percentage cover of species in each quadrat along transects (1-3) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)

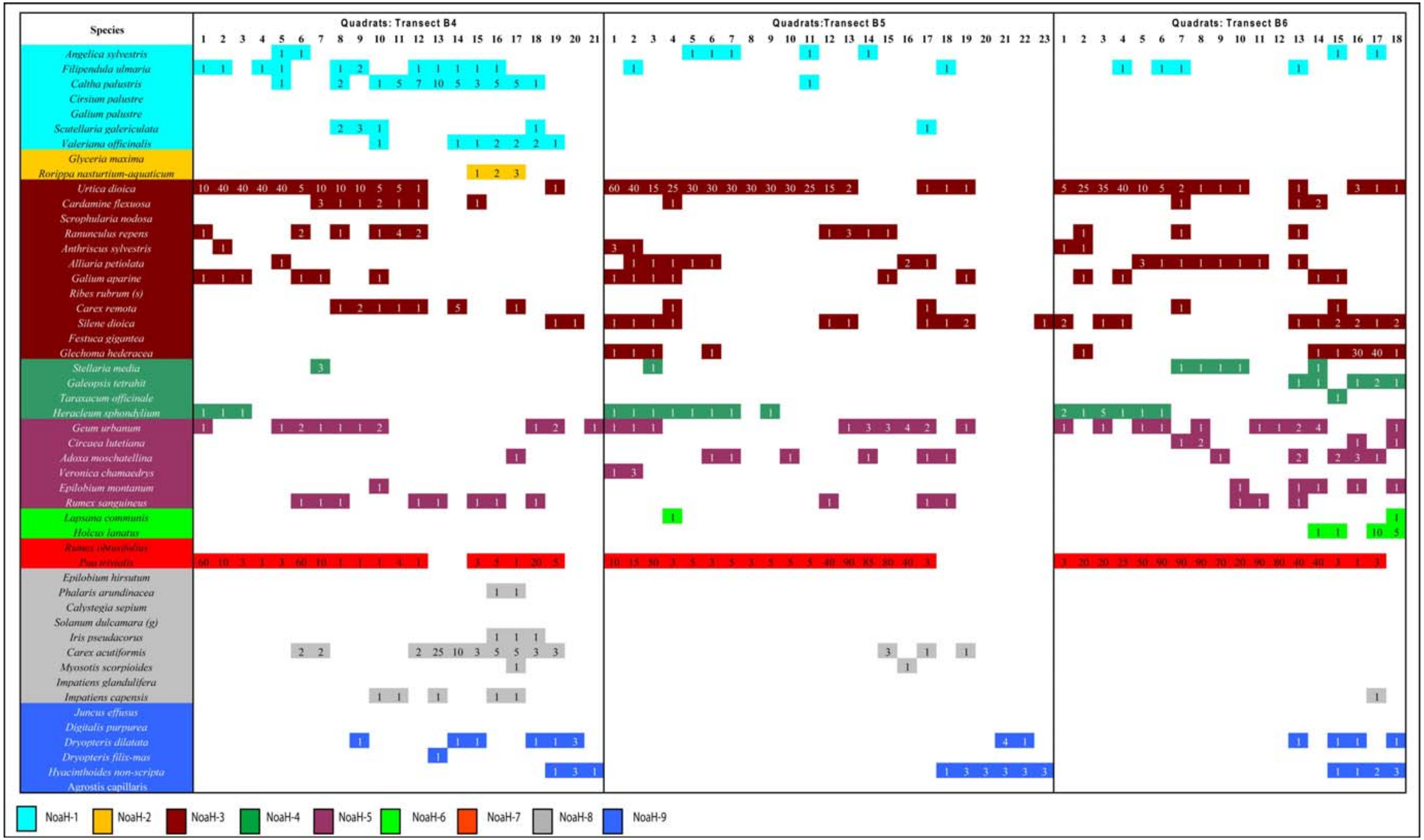


Fig. 7.14b Distribution & percentage cover of species in each quadrat along transects (4-6) in Site B *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)

7.4 REVIEW OF THE ASSOCIATION ON THE GROUND OF SPECIES, IN LOWLAND *ALNUS GLUTINOSA* WOODLAND, WITH SIMILAR OPTIMAL ENVIRONMENTAL CONDITIONS

Section 7.2 detailed the results of analysing a species x quadrat (percentage cover) matrix of data collected from 278 quadrats across three *Alnus glutinosa* woodlands at Stonebridge in summer 2008. Two techniques were employed: TWINSPAN and DCA ordination, and both produced similar groupings of species, Figure 7.1. The first two axes of the DCA ordinations outputs produced following input of the species x quadrat matrix, were considered the only ones worth investigating further on account of their Eigen values being greater then 0.3; axis 1 0.510 and axis 2 0.343 (Table 7.2).

Figures 7.3 to 7.7 show how the species in the TWINSPAN and DCA groups corresponded to the CoaHs defined in Section 5.2. Both the TWINSPAN and DCA analysis primarily differentiated species groups by light and soil conditions more than CSR-strategies. In each CoaH type (CSR, light and soil moisture, acidity and fertility) species of the same CoaH were generally in the same or closely related group determined by TWINSPAN and DCA ordination. However, the CSR-strategies were less consistently separated in both TWINSPAN groups and DCA ordination space. Table 7.1 showed all TWINSPAN groups comprised predominately CSR-strategists but with a bias towards competitors, competitive-ruderals or ruderals. Although there is broad separation of strategists, Figure 7.3 shows much overlap between strategies across ordination space. The similar grouping of species by both analyses (although weaker with CSR-strategies) shows that species with similar preferences for a given environmental condition do grow in close proximity on the ground. However, there are exceptions and species are also likely to co-exist with species from different CoaHs of the same condition, e.g. well lit (CoaH-J) species occur with semi-shade (CoaH-I) species. Such situations are discussed below in Sections 7.4.1 to 7.4.5.

7.4.1 Life-history strategies of groundflora species in *Alnus glutinosa* woodlands at Stonebridge

Although species with the same CoaH-CSR are at least loosely grouped in DCA ordination space and several species are represented in the same TWINSPAN groups, there are overlaps and sub-divisions (Figure 7.3). The less clear separation of CSR-strategies in the TWINSPAN and DCA analyses, compared to the light and soil conditions, may reflect the plants' abilities to grow in different situations (e.g. stressed, competitive or disturbed) but subsequently have weaker growth outside conditions suited for their main trait. For example, a competitor may be able to survive in a reduced/less productive form in situations where stress-tolerators thrive. Another reason is that there are different factors causing the species to be grouped and that the over-riding factor determining the presence of a particular species may vary from one species to another. For example, if CoaH-B (stress-tolerant) is considered, the three species are widely distributed in ordination space on axes 1and 2 and occur in three separate TWINSPAN groups (Figure 7.3); Table 7.5 considers these species in relation to their optimal growing conditions as described by their Ellenberg indicator values. The characteristics detailed in Table 7.5 suggests that the following factors have a stronger influence than stress or disturbance and are illustrated graphically in Figure 7.15:

- *Geum urbanum* - light and fertility (*Potentilla* and *Caltha* both have similar soil fertility and light optima)
- *Caltha palustris* - soil moisture (*Potentilla* and *Geum* both have similar soil moisture optimums)
- *Potentilla erecta* - soil acidity (*Caltha* and *Geum* both have similar soil acidity optimums).

Table 7.5 Ellenberg indicator values (Hill *et al.*, 2004) of three stress tolerant species in three separate TWINSPAN groups that are also separated in DCA ordination space (see Figure 7.2)

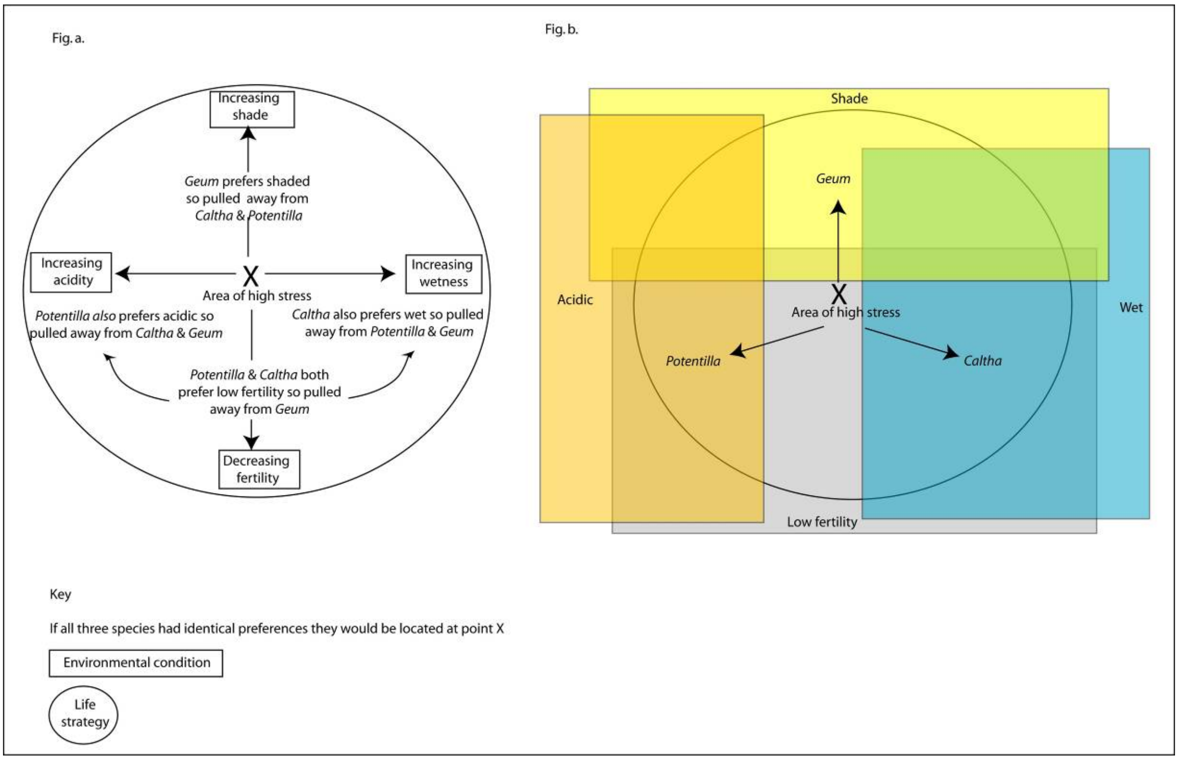


Fig. 7.15 Abstract graphical representation of the environmental influences on *Geum*, *Caltha* and *Potentilla* (all in the same CoaH-CSR) resulting in the three species occurring in different TWINSPAN groups and dispersed across DCA ordinations space (see Fig. 7.3). Fig. a shows the direction of pull each species has away from the others. Fig. b shows the subsequent separation of species in response to environmental conditions

In contrast to the species in Table 7.5, those detailed in Table 7.6 are all ruderals, closely clustered in ordination space and occur in the same TWINSPAN group (1110) (Figure 7.3). While the optimal light and soil conditions for these three species are broadly similar, there are a couple of dissimilarities:

- *Cerastium fontanum* – low fertility (*Senecio* and *Juncus* both have an intermediate soil fertility optimum)
- *Senecio jacobaea* – drier soils (*Cerastium* and *Juncus* have a wetter soil optimum).

This suggests these specie's ability to exploit ruderal situations has greater influence on their locations within the environment than soil and light conditions or that they are less influenced by soil and light. Alternatively they have the advantage over other species with the same light and soil preferences in disturbed areas.

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Table 7.6 Ellenberg indicator values (Hill *et al.*, 2004) of three ruderal species in the same TWINSPAN group and in close proximity in DCA ordination space (see Figure 7.2)

7.4.2 Preferred light conditions of groundflora species in *Alnus glutinosa* woodlands at Stonebridge

Although species with different optimal light conditions occur together in ordination space, there is a dominance of either well lit, or semi-shaded, in the TWINSPAN groups (Figure 7.4), and species at the opposite end of the light scale are absent from the group. For example groups dominated by species associated with well lit conditions do not include species associated with shaded conditions, but do include those of very well lit conditions. Similarly, groups dominated by semi-shade species include shade but not well lit species. This shows that species at opposing ends of the light gradation are less likely to grow in close proximity on the ground.

Table 7.7 reviews the anomalous species in each TWINSPAN group and shows that generally species with a preference for conditions outside the dominant condition have a light tolerance of such conditions and therefore their inclusion in the group is not unexpected. As a consequence management of high and low light conditions will have a greater influence on species composition than intermediate light conditions. So if management is for high light conditions, it is likely species associated with intermediate conditions will come in, but not those favouring shaded conditions.

TWINSPAN species group	Dominant condition (% of species in group)	Explanation of anomalies - derived from Grime *et al.* (2007) unless otherwise stated	Over-riding CoaH
01	Well lit (57)	Semi-shade: *Conopodium majus* occurs in shaded and unshaded conditions, but in the latter generally north facing aspect. Vernal so cycle over before canopy closes creating shade. *Dryopteris filix-mas* occurs in both woodland and skeletal habitats indicating tolerance for both shade and well lit conditions. *Silene dioica* primarily of shaded environments but occurs in deep shade in a non-flowering state. Also occurs in open habitats and is prominent during the open phase of the coppice cycle.	All anomalies tolerant of well lit conditions in certain circumstances so ‘Well lit’ CoaH is considered acceptable
0000	Well lit (80)	Semi-shade: It is noted (p.180) that *Cardamine flexuosa* “*exploit damp, shaded microsites in a wide range of habitats,*” suggesting that it can occur in situations that are generally well lit if there is localised shade. *Ribes rubrum* occurs in light to deep shade[1] *Valeriana officinalis* primarily occurs in open habitats indicating association with well lit conditions	
0001	Well lit (66)	Semi-shade: *Impatiens glandulifera* is also found in more open habitats	
0010	Semi-shade (50)	Shade: *Adoxa moschatellina* occurs in none to light shade[1] Well lit: although predominately a plant of open habitats *Heracleum sphondylium* also occurs in partially shaded situations. *Taraxacum officinalis* occurs in a range of habitats suggesting tolerance for a variety of conditions. Very well lit: *Ranunculus sceleratus* does not occur in shade[1]	Only *Ranunculus sceleratus* appears to have a very low tolerance of any shade, therefore ‘Semi-shade’ CoaH is considered acceptable
0011	Semi-shade (50)	Shade: *Geum urbanum* shows greatest flower and seed set in unshaded conditions and “*perhaps regarded as a ‘semi-shade’ species”* (p.332)– suggests wide tolerance of light conditions. Well lit: *Arrhenatherum elatius* occurs in a “*wide range of unshaded or lightly shaded habitats*” (p.132) *Senecio vulgaris* is “*rarely found in shaded habitats*”	Only *Senecio vulgaris* appears less tolerant of a more shaded environment therefore ‘Semi-shade’ CoaH is considered acceptable

Table 7.7 Dominant light conditions of each TWINSPAN group (based on the component species) and anomalies along their degree of tolerance to a range of light conditions. Summer 2008 data-Stonebridge *Alnus glutinosa* woodlands (Table continues).

TWINSPAN species group	Dominant condition (% of species in group)	Explanation of anomalies - derived from Grime *et al.* (2007) unless otherwise stated	Over-riding CoaH
10	Semi-shade (57)	Shade: *Circaea lutetiana* "*is almost totally confined to moist shaded habitats*" (p.220) Well lit: *Galeopsis tetrahit* also occurs in shaded situations, notably when soils are moist. *Persicaria hydropiper* does not occur in shade[1]	*Circaea lutetiana* and *Persicaria hydropiper* appear to have a narrow range of light tolerance and perhaps unexpected in 'Semi-shade' CoaH
110	Semi-shade (100)	None	-
1110	Well lit (69)	Semi-shade: *Scrophularia nodosa* occurs in none to light shade[1] Although it is noted that *Digitalis purpurea* is "*mainly restricted to disturbed shaded habitats*" (p.252), it is frequently noted in clearfell areas which are exposed to high light levels. *Epilobium montanum* occurs in open habitats, suggesting tolerance to well lit conditions. *Holcus mollis* occurs in both shaded and open habitats.	All species show some degree of tolerance to lighter conditions therefore 'Well lit' CoaH is considered acceptable
1111	Well lit (69)	Semi-shade: *Agrostis capillaris* occurs in a wide range of habitats, including amenity and grazed grassland, suggesting tolerance of higher light conditions than semi-shade. *Cardamine amara* frequently occurs in both shaded and unshaded situations. Also a vernal, completing flowering before canopy closes. *Deschampsia cespitosa* occurs in both open and shaded habitats. Very well lit: *Viola arvensis* does not occur in shade[1]	

Notes
1. Data from Fitter and Peat (1994)

Table 7.7 cont. Dominant light conditions of each TWINSPAN group (based on the component species) and anomalies along their degree of tolerance to a range of light conditions. Summer 2008 data-Stonebridge *Alnus glutinosa* woodlands.

7.4.3 Preferred soil moisture conditions of groundflora species in *Alnus glutinosa* woodlands at Stonebridge

The distribution of optimal soil moisture conditions across ordination space and within the TWINSPAN groups (Figure 7.5) shows a similar pattern to that of light conditions, i.e. one condition will dominate but will include species associated with other conditions, but not those at the opposite ends of the soil moisture gradient. However, there are a few anomalies (Group 0010, 1110 and 1111) which although dominated by species associated with drier to moist soils (75%, 85% and 77% species respectively) also include species associated with wetter conditions. The following species show preferences for wetter conditions as demonstrated by their Ellenberg F values:

- Wet
  - *Cardamine amara* - F9 (group 1111)
  - *Carex remota* - F8 (group 0010)
  - *Cirsium palustre* - F8 (group 1111)
  - *Ranunculus flammula* - F9 (group 1110)
  - *Ranunculus sceleratus* - F8 (group 0010)
- Very wet
  - *Callitriche stagnalis* - F10 (group 1110)
  - *Glyceria fluitans* - F10 (group 1111)
  - *Glyceria notata* - F10 (group 0010)

Ellenberg value F8 is intermediate between value 7 (constantly moist to damp soils) and 9 (water saturated soils) (Hill *et al.*, 2004) suggesting that species in this group can potentially be associated with both relatively drier and wetter soils. The species listed above are considered in relation to the range of conditions where they can grow, i.e. outside their optimal:

- *Cardamine amara* is a species of wetland and semi-aquatic habitats (Grime *et al.*, 2007) indicating that it has potential to occur with species of both moist and wet optimals.
- *Carex remota* is a species of damp soils, notably peat or clay and where water collects in winter (Rose, 1989) so could potentially occur on moist soils as well as wet soils.
- *Cirsium palustre* occurs on a wide range of soil moisture conditions, although is more frequent on those that remain moist in summer (Grime *et al.*, 2007) and, therefore, it can equally be associated with species of moist as well as wet conditions.

- *Ranunculus flammula* shows a tolerance to wetland conditions, generally occurring on wet soils without standing water in both marginal, and non-marginal, to open water situations. Although not an aquatic species, it may be temporally submerged (Grime *et al.*, 2007).
- *Ranunculus sceleratus*, an annual, is primarily associated with wet soils, but not surface water, in marginal, and non-marginal, to open water situations although has also been recorded where surface water is less then 100 mm (Grime *et al.*, 2007). Also found as "*an impermanent colonist of moist soil heaps and sewage spoil* (Grime *et al.*, 2007, p.514).
- Grime *et al.* (2007) made the following observations in relation to *Callitriche stagnalis*:
    - although more frequently found in hydrological conditions of 100-250 mm water depth, it also occurs where there is no surface water and at margins of open water.
    - can also occur in very localised areas of wet ground and is resilient to major disturbance or water table fluctuations.
- Although predominately a wetland plant, *Glyceria fluitans* may occur on moist conditions and has a high tolerance of extreme annual water fluctuations, i.e. it is similar to *Callitriche stagnalis* in that it occurs both in conditions where there is no surface water and where surface water is over 250 mm (Grime *et al.*, 2007).
- *Glyceria notata* occurs in similar habitats to *G. fluitans* (Stace, 2001).

As a result of their characteristics, it is considered possible that, although generally associated with wet or very wet conditions, the species considered above could potentially be associated with species with an optimal for moist or drier conditions. Similarly species may occur in very localised situations of wetter conditions and subsequently appear to co-exist, e.g. in transition from open water which dries up for part of the year. The scale of such localisation of conditions may not be captured within a quadrat and subsequently species of dry and very wet conditions may not be separated out in the analysis. For example, Figure 7.16 shows a situation that could occur within a single quadrat where plants of saturated soils occur adjacent to plants of moist soils.

Fig. 7.16 Example where plants with drier soil preferences may co-exist with plants of very wet soils. *Caltha palustris* and *Carex acutiformis* (F9-saturated soils) in the foreground and *Ranunculus ficaria* and *Poa trivialis* (F6-moist soils) above the water on the root base. Stonebridge Site B 22/04/08 (H S Miller)

These examples show that generally species at opposing ends of the soil moisture gradation are unlikely to grow in close proximity on the ground, however, there are certain situations that break this trend. Therefore, management for high and low soil moisture conditions will have greater influence on species composition than intermediate moisture conditions, but very localised management could encourage species at the extremes.

7.4.4 Preferred soil acidity conditions of groundflora species in *Alnus glutinosa* woodlands at Stonebridge

Although species with different optimal soil acidity conditions occur together in ordination space, there is a dominance of species with a preference for either acidic or near neutral in the TWINSPAN groups (Figure 7.6). An exception is TWINSPAN group 1110 which includes almost equal proportions of species associated with acidic (46%) and near neutral soils (54%). When the species comprising this group are considered in more detail in relation to their Ellenberg acidity (R) indicator values, the range of values is 3 to 7 with the majority (77%) being $^{+}/-$ 1 of the mean of the group (5.1). The following species have optimal soil acidity at the two extremes of this range:

- Acidic (R3)
    - *Holcus mollis* - R3
    - *Potentilla erecta* - R3
- Least acidic (R7)
    - *Scrophularia nodosa* - R7

These species are considered in relation to the range of conditions where they can grow, i.e. outside their optimal:

- *Holcus mollis* occurs on acidic to near neutral soils but never calcareous (Grime *et al.,* 2007). This species has a clonal habit and as such has the potential to establish on localised, more acidic, soils in an area that generally has neutral soils. *Holcus mollis* is also a competitor (C/CSR) so may out-compete other species.
- *Potentilla erecta* occurs on soils ranging from acidic to neutral but is more frequent on acidic; may occur in calcareous situations where soil moisture is high (Grime *et al.,* 2007).
- The Ecoflora (Fitter and Peat, 2004) notes that *Scrophularia nodosa* has been recorded at pH extremes of 4.6 and 8 but the typical maximum pH that it occurs at is 6.4. This falls within the descriptions of Hill *et al.* (2004) for Ellenberg values 5-6, i.e. moderately acidic to near neutral.

The above shows that although the species are generally more frequent on acidic or base-rich soils, they will also occur in near neutral soils, and as such there is potential for them to be associated with a range of species. *Potentilla erecta* is in TWINSPAN group 1110 which is dominated by species with a moist-damp soil optimal, suggesting that *Potentilla erecta* at Stonebridge may occur at the less acidic end of its range.

7.4.5 Preferred soil fertility conditions of groundflora species in *Alnus glutinosa* woodlands at Stonebridge

Unlike the other soil conditions and light discussed above, the species in each TWINSPAN group (Figure 7.7) do not show a dominance of a particular level of fertility, rather there is a bias towards either high or low fertility, i.e. the groups either comprised species associated with intermediate and high fertility or intermediate and low fertility. Generally species of low fertility are not in groups with species of high fertility, although there are three anomalies:

- Group 1111 (predominately intermediate and low fertility species) includes *Alopecurus pratensis* – Ellenberg value N7.
- Group 01 (predominately intermediate and high fertility species) includes *Galium palustre* - N4. Grime *et al.* (2007) note that this species is most frequent where there is some disturbance on fertile sites.

- Group 0000 (predominately intermediate and high fertility species) includes *Caltha palustris* – N4. Grime *et al.* (2007) suggest this species is also associated with moderately fertile soils.

The observations of Grime *et al.* (2007) show that there are situations when *Galium palustre* and *Caltha palustris* occur outside the optimal conditions indicated by their Ellenberg value (Hill *et al.*, 2004). Therefore, it is not such an unexpected anomaly in the groupings. *Alopecurus pratensis*, however, does not appear to be associated with infertile conditions, e.g. Grime (2007) and Cope and Gray (2009). This species is also not normally recorded in woodland habitats so it's presence is likely to be a consequence of edge effect and the influence of the adjacent habitats. On review of the raw data, this species was only recorded in one quadrat (A1.13 at the woodland edge) at only 1% cover and therefore could be considered as a transient species that has not established nor shows strong growth in the habitat or situation in which it occurred.

7.5 Review of the Association of Species, in *Alnus glutinosa* Woodlands, in Relation to the NoaHs in Which They Occur

Section 7.4 reviewed the association of species on the ground in relation to single environmental conditions, i.e. CoaHs. This section reviews the association of species when each CoaH is considered simultaneously, i.e. NoaHs.

Although, as shown in Figure 7.8, there is overlap between constituent species of NoaHs and sub-divisions of others, at least some species within the same NoaH occur together in TWINSPAN groups and ordination space. This shows that constituent species of NoaHs, defined by combining species Ellenberg values (Hill *et al.*, 2004) and CSR-strategies (Hunt, 2007b), do occur together in a real situation. However, the sub-divisions of NoaHs show that some species have a higher probability of growing together than others and there are other factors that dictate the association of species that have not been captured in the process of defining the current NoaHs. Such division of groupings more closely reflects the complexity and interactions between different environmental conditions in nature. Such complexities were also illustrated in the discussion in Sections 7.4.1 – 7.4.5 on the CoaHs, in that it was shown that in certain situations some species grow beyond their optimal conditions if another condition changes: e.g. *Potentilla erecta* is normally associated with acidic soils, but can grow in more calcareous conditions when combined with high soil moisture (Grime *et al.*, 2007).

As an example of species in different NoaHs overlapping, three species are considered:

- *Caltha palustris* – NoaH-1
- *Carex acutiformis* – NoaH-8
- *Rorippa nasturtium* – NoaH-2.

These three species are located in the same TWINSPAN group (0000) and closely clustered in ordination space (high axis 1, low axis 2 scores) indicating that they occur in close proximity on the ground; this is observed to be the case in Site B (see Figures 5.1 and 5.2). However, as shown in Figure 7.8 they occur in three separate NoaHs despite initial observations, both from the statistical analysis and in the field, suggesting they should occur in the same one. When the specific preferences of each species are considered, i.e. CoaHs, there are subtle differences which help explain their association at Stonebridge; these are detailed in Table 7.8 and discussed below.

Preferences	***Caltha***	***Carex***	***Rorippa***
CSR-strategy	CoaH-B: Stress tolerators Avoids high disturbance and low productivity sites (Grime *et al.*, 2007)	CoaH-A: Competitor Sites of low disturbance and moderate to high productivity (Grime *et al.*, 2007)	CoaH-D: Competitive ruderal Occurs in productive, moderately disturbed sites and is absent form unproductive areas (Grime *et al.*, 2007)
Light	CoaH-J: Well lit		
Soil moisture	CoaH-N: Wet Shallow water but not permanently flooded (Grime *et al.*, 2007)	CoaH-N: Wet Although does occur in shallow water in such circumstances part of the colony is on drier land (Grime *et al.*, 2007)	CoaH-O: Very wet Occurs as a marginal or in shallow water but has a preference for flowing, rather than stagnant water (Grime *et al.*, 2007)
Soil acidity	CoaH-Q: Near neutral		
Soil fertility	CoaH-S: Intermediate	CoaH-S: Intermediate Has the advantage over other potential dominates in low fertile conditions (Grime *et al.*, 2007)	CoaH-T: High

Table 7.8 Specific preferences of three species found to grow together at Stonebridge Area B but assigned to different NoaHs

On closer examination of the species distribution at Stonebridge, Site B, it is noted that *Rorippa* is concentrated in an area which remains wet and has surface water for the majority of the year, *Caltha* and *Carex* are more abundant where the soil remains wet but has limited surface water during the summer. However, even here it can be seen that *Caltha* dominates the central area (generally slightly lower ground level and wetter for longer periods of time than the edges) while *Carex* is more dominant and has stronger growth at the periphery. This separation is most likely to be attributed to an observation noted by Grime *et al.* (2007) that *Caltha* is able to dominate where conditions, such as winter floods, restrict other potential dominants, e.g. *Carex*, see Figure 7.17. The three plants co-exist in the transitional zones of these various conditions. These subtleties in species distribution described here were not clear from the quadrat data because it was not possible to survey the entire wood which was consequently sampled (see Section 3.5.4). Although transects allowed trends to be identified (that would not necessarily have been encountered if random quadrats were used unless a high sampling density was employed) full confirmation of the reasoning for subtle separation of species would need further, more specific study.

Fig. 7.17 Example of *Caltha*-*Carex* transitional zone in *Alnus glutinosa* woodland Site B, Stonebridge, 22/04/08 (H S Miller)

This example has shown that while it is possible for the three NoaHs to exist within a single woodland, the actual practicalities of managing them are low. It is, therefore, concluded that while NoaHs exist within a site, other than providing an indication of conditions, they cannot be used to inform specific management operations on account of the subtle, small scale transitions between them.

7.6 Review of the Spatial Distribution of Species in CoaHs and NoaHs in *Alnus glutinosa* Woodland

Sections 7.4 and 7.5 reviewed the association of species on the ground in terms of C/NoaHs using multivariate analysis. Section 7.6.1 reviews the spatial distribution and relationship of species in C/NoaHs, focusing on Site B, Stonebridge, illustrated in Section 7.3. Section 7.6.2 details an indicative review of the spatial distribution of C/NoaHs to provide an example of a real situation and interpretation of a site. It is, therefore, descriptive and has not been subjected to detailed data collection of environmental variables or statistical analysis.

7.6.1 Review of distribution of C/NoaHs data using quantitative data from Stonebridge, Warwickshire

Figures 7.9 to 7.14 in Section 7.3 (also Figures A15.1 to A15.12 illustrating the species distribution across transects at Site A and C, Appendix 15), show that species in the same CoaHs and NoaHs do generally occur in discrete clusters along different transects, and therefore show that plants/groups of species do represent intra-site variation based on their preferred growing conditions and life strategies. However, species also occur with species from different CoaHs/NoaHs and as such CoaHs/NoaHs cannot be used to guide specific management for intra-site conditions. The following provides examples of the six situations listed in Section 3.6.2 describing intra-site variation using the distribution and association of species found within a site.

<u>Situation 1: Species is ubiquitous across the site</u>

Poa trivialis and *Urtica dioica* occurred in the majority of quadrats along all transects in Sites B and C. *Geum urbanum* was also fairly ubiquitous at Site C, although at a lower abundance than *Poa* and *Urtica*. At Site A, *Poa trivialis, Holcus lanatus* and *Agrostis canina* show ubiquity across the woodland. Field observations noted that these species did dominate the majority of the ground cover at each respective site, see Figure 7.18 for an example at Site B.

Fig. 7.18 *Alnus glutinosa* woodland Site B, Stonebridge, showing ubiquity of *Poa trivialis* and *Urtica dioica*. 22/04/08 (H S Miller)

Situation 2: Species occurs in discrete localities across the site

Hyacinthoides non-scripta occurred in a number of consecutive quadrats at the southern end of all transects in Site B. Field observation noted that this species was locally dominant where the ground rose away from the floodplain and the soils were drier, see Figure 7.19. *Deschampsia cespitosa* and *Carex remota* show similar distribution patterns in Site A and Site C respectively.

Fig. 7.19 Localised area of *Hyacinthoides non-scripta* in *Alnus glutinosa* woodland, Site B, Stonebridge, where the ground rose away from the floodplain and soils were sandier/drier than the wetter/peaty soils at the foot of the slope. 10/05/08 (H S Miller)

Situation 3: Species occurs sporadically across the site

Cerastium fontanum, Ranunculus repens and *Rumex sanguinea* generally occurred in non-consecutive quadrats or those in close proximity at Sites A, B and C respectively.

Situation 4: No specific/distinct condition

When CoaH-fertility is considered, Quadrat B1.16 (Figure 7.12a) shows three species in each of high and low fertility and five species of intermediate fertility. The adjacent quadrat (B1.17) shows a similar pattern. Similar patterns can be seen in other CoaHs and at Sites A and C. For example Quadrats A4.1 and A4.2 (Site A, Figure A15.2) comprises species from different soil moisture CoaHs while Quadrats C3.19-29 (Site C, Figure A15.7c) comprises species from all three light CoaHs.

Situation 5: Localised intra-site variation of particular conditions

When CoaH-moisture is considered, Quadrat B6.18 (Figure 7.10b), it is seen that the majority of species are in CoaH-M (moist) with a few in CoaH-L (drier) and none in CoaH-N or O (wetter soils). Similar patterns are seen in Quadrats B6.14 – B6.17, although

B6.15 and B6.16 have one or two CoaH-N species. In contrast, Quadrats B1.4 to B1.7 predominately comprised CoaH-N, a few –M, but no –L species (Figure 7.10a). These examples indicate that the lower end of Transect 1 is wetter than Transect 6; this can be confirmed by field observation, see Figures 7.20 and 7.21. Similar patterns of quadrats dominated by a single CoaH can also be seen in other CoaHs and at both Sites A and C. For example, Quadrat A4.13 (Figure A15.2) comprises entirely species of moist soils, CoaH-M, and Quadrat C4.2 (Figure A15.7b) comprises species of semi-shade (CoaH-I) and only one species, at low abundance, from CoaH-H (shade).

Fig. 7.20 Example of wetter quadrats, north end of Transect B1, *Alnus glutinosa* woodland Site B, Stonebridge, 10/05/08. (H S Miller)

Fig. 7.21 Example of drier quadrats, south end of Transect B6, *Alnus glutinosa* woodland Site B, Stonebridge, 25/05/09 (H S Miller)

<u>Situation 6: Indication of intra-site variation</u>

When CoaH-fertility is considered, Quadrats B4.4 to B4.8 are seen to be dominated by CoaH-T (richly fertile) species, while the next set of Quadrats, B4.9 to B4.12, are dominated by CoaH-S (intermediate fertility) species (Figure 7.13b). Figure A15.8a shows that Quadrats C1.1 to C1.5 are dominated by species of CoaH-M (moist soils) with a few, low abundance species of CoaH-L (drier soils) while the next quadrats (C1.6 to C1.10) comprise species of moist to wet CoaHs (M and N respectively) with few/no species (those present occur only at low abundances) associated with drier soils (CoaH-L). This indicates an area of wetter soils in the vicinity of Quadrats C1.6-C1.10; on the ground these quadrats corresponded with a broad, shallow, drain across the site which retains water after periods of flood/rainfall. Figure 7.22 illustrates distinct intra-site variation in Site B, Stonebridge.

As can be seen in Figure 7.14, several of the NoaHs are represented by only a few species and as such it is concluded that they cannot be used to categorically say that the intra-site variation described by those particular NoaHs occurs within the site. Therefore, other than the NoaHs represented by the majority of species, NoaHs are less useful than CoaHs simply on account of fewer species being represented.

7.6.2 Qualitative example of C/NoaHs occurring in lowland *Alnus glutinosa* woodland: River Rother, Hampshire

To illustrate how C/NoaHs, identified from a site species list, can be used to describe a woodland and reflect the conditions on the ground, a qualitative study of a site at Liss, Hampshire, which comprises four separate sites is discussed. The approach used to collect the data is detailed in Section 3.6.3 but, in brief, entailed a systematic walk across each site at different times of year between 2004 and 2007 to record all plants observed. Figure 5.17 shows a schematic map of the four sites (A-D) in relation to each other and key habitat features. The C/NoaHs for these sites were identified in Section 5.4; here they are related to visual ground observations.

Sites A and B are located on the banks of the River Rother and are very similar on the ground despite noticeable differences in topography. Site A rises from the river and has a number of hollows, while Site B has a more consistently flat topography. Both Sites A and B are flooded during winter flood events. The similarities between the two sites are shown in the respective pie charts (b. and c.) in Figure 5.16 of these Sites.

Site D is located further from the river and although adjacent to Site B is separated by the route of a slightly embanked disused railway, now used as a public footpath. Site C is further still from the river and is located adjacent to Site D along the location of an old railway siding and, therefore, is significantly raised above the riverbank level. However, Site C includes a wet, stagnant ditch. Site D includes an iron-rich stream and damp hollows of stagnant water as well as raised drier areas. Neither Site C nor D experiences flooding, even during the highest winter floods, although the water table of Site D can rise after prolonged rain, particularly around the stream and hollows.

Fig. 7.22 Example of distinct intra-site variation in *Alnus glutinosa* woodland Site B, Stonebridge. Key species visible: Foreground *Poa trivialis* and *Urtica dioica;* middle ground *Caltha palustris* and *Carex acutiformis;* background *Hyacinthoides non-scripta.* 22/04/08 (H S Miller)

The canopy of Sites C and D are significantly darker than Sites A and B with the canopy trees being much closer spaced and, particularly in Site C, are very etiolated. Both Sites A and B, although more so in B as a result of overhead cables, have noticeable gaps in the canopy.

Tables 7.9 and 7.10 summarise the predicted C/NoaH conditions from consideration of the component species and those actually observed on site. These Tables show that, although not 100% accurate, C/NoaHs identified from a simple species list describe the dominant conditions within woodland. They also provide an indication of the variability, if not specific, intra-site variation.

Area	Predicted conditions (see Fig. 5.16)	Actual conditions (from personal observation)
A	Low stress, moderate disturbance	Disturbance will occur along the riverbank as a result of flood events.
	Semi-shade with areas of shade and well lit	Generally a closed canopy with lighter areas along the river edge and glades.
	Moist/damp with areas of wet soils	Generally moist soils but drier away from the river where the ground rises and wetter soils occur in hollows.
	Near neutral with areas of acidic soils	Soils are primarily of greensand origin and as such naturally acidic but also include Gault clay overlain with gravel deposits.
	Intermediate to richly fertile	Areas of higher fertility will occur in hollows and along the riverbank, indicated by high dominance of *Urtica dioica*
B	Low stress, moderate disturbance	Disturbance will occur along the riverbank as a result of flood events.
	Semi-shade with areas of shade and well lit	Generally a closed canopy with lighter areas along the river edge and under the power cable wayleave.
	Moist/damp with areas of wet soils	Generally moist soils with wetter soils in hollows.
	Near neutral with areas of acidic soils	Soils are primarily of greensand origin and as such naturally acidic but also include Gault clay overlain with gravel deposits.
	Intermediate to richly fertile	Areas of higher fertility will occur in hollows and along the riverbank, indicated by high dominance of *Urtica dioica*
C	Moderate stress, moderate disturbance	Stress likely to relate to the dense canopy while disturbance likely to relate to changes in water level of the stream.
	Semi-shade with areas of shade; minimal well lit areas	A dense closed canopy cast more shade than Sites A, B and D. Slightly lighter adjacent to the field.
	Limited variation, predominately moist/damp	Generally moist soils with wet areas along the stream.
	Near neutral with areas of acidic soils	Soils are primarily of greensand origin and as such naturally acidic but also include Gault clay overlain with gravel deposits.
	Intermediate to richly fertile	Areas of higher fertility along the stream adjacent to improved grassland field

Table 7.9 Comparison of predicted CoaHs and actual conditions observed on site in the four woodland sites along the River Rother, Liss, Hampshire (Table continues)

Area	Predicted conditions (see Fig. 5.16)	Actual conditions (from personal observation)
D	Moderate stress, high disturbance	Stress likely to relate to the dense canopy while disturbance likely to relate to changes in water level of the stream.
	Semi-shade with areas of shade and well lit	Although there are gaps in the canopy, the etiolated trees of adjacent Site C restrict light penetration.
	Moist/damp with areas of wet soils	Generally moist soils but with significant wet areas around the stream and wet seepage. Drier areas where ground is raised.
	Near neutral with areas of acidic soils	Soils are primarily of greensand origin and as such naturally acidic but also include Gault clay overlain with gravel deposits.
	Intermediate with areas of low and high fertility	Areas of higher fertility will occur around the stream/seepages and lower fertile on the raised areas, notably old railway siding embankment

Table 7.9 cont. Comparison of predicted CoaHs and actual conditions observed on site in the four woodland sites along the River Rother, Liss, Hampshire

NoaH characteristics	Predicted occurrence of condition (see Fig. 5.21)	Actual conditions
NoaH-1 Non-extreme stress and disturbance. Well lit, wet, near neutral and low fertility	Minor in all sites	Limited well lit, wet areas within A-D, such areas primarily restricted to the periphery/damp hollows.
NoaH-2 Low stress and moderate disturbance well lit environment. Shallow water on neutral soils of intermediate to rich fertility	Minor in Site A and D, not in B or C	Sites A & D both include areas of standing water: A: small wet ditch/seepage into the river (less than 5 m in length and free flowing. D: a wet, stagnant hollow towards the edge of the area and has low canopy cover
NoaH-3 Low stress with moderate disturbance in semi-shaded conditions on constantly moist, neutral, intermediate to richly fertile soils	Dominant condition in Site A, B & D. Co-dominant in Site C	Sites A & B: Much of these sites are at least partially shaded with disturbance and increased fertility resulting from seasonal flood events. Further away from the river edge than NoaH-7, where the ground is slightly lower so likely to retain silt deposits following flood events. Site C: Field/ditch edge of the site is lighter and wetter than the rest of the site. Site D: Limited well lit areas due to shading from adjacent Site C and B. Much of the site is low lying with soils that are at least damp for much of the year.
NoAH-4 Low stress, moderate to high disturbance in well lit conditions on drier, near neutral intermediate to high fertility soils	Minor in Sites A - C Not found in Site D	There are limited areas of high disturbance in well lit and drier conditions in any of the Sites.

Table 7.10 Comparison of predicted NoaHs and actual conditions observed on site in the four woodland sites along the River Rother, Liss, Hampshire (Table continues)

NoaH characteristics	Predicted occurrence of condition (see Fig. 5.21)	Actual conditions
NoaH-5 Moderate to high stress with low disturbance in shaded conditions. Drier, near neutral, intermediate fertile soils.	Second most significant in Sites A, B & D. Co-dominant in Site C	Much of Site C is densely shaded, drier on shallower soils as it is perched above the floodplain on the old railway platform. Furthest from the river in Sites A & B the ground is drier, less disturbed from seasonal flood events and more shaded. The part of Site D, adjacent to Site C is more shaded (from the etiolated trees of Site C) and on slightly higher, sloped (& therefore drier) ground.
NoaH-6 Moderate stress with moderate-high disturbance in semi-shade, although with a light bias, conditions. Drier, near neutral, low-intermediate fertile soils.	Minor in A - D	Areas of higher disturbance are generally in lighter, wetter areas in all Sites.
NoaH-7 Low stress, moderate-high disturbance in well lit conditions on constantly moist, near neutral, intermediate fertile soils	Third most significant in Sites A & B. Not found in Site C. Minor in Site D.	River edge in Sites A & B.
NoaH-8 A low stress, low disturbance environment in well lit conditions on wet, near neutral soils of intermediate to high fertility	Minor in Site A, B & D. Not in Site C.	Wetter areas in Sites A & B generally experience disturbance. Site D includes a wet hollow with lower canopy cover.
NoaH-9 Moderate stress, low disturbance in semi-shade. Constantly moist, acidic soils of low fertility	Minor in Sites A-C. Third most significant in Site D.	A & B: adjacent to path. C: Edge of ditch where etiolated trees cast shade. D: Boundary with Site C where there is higher shade cast by the etiolated trees but lower ground which remains damp.
NoaH-10 Moderate stress, low disturbance in semi-shade. wet, acidic soils of low fertility	Minor in Sites A & B. Not found in Sites C & D.	Such conditions occur on the edge of wet hollows

Table 7.10 cont. Comparison of predicted NoaHs and actual conditions observed on site in the four woodland sites along the River Rother, Liss, Hampshire

7.7 Validity of the Occurrence of C/NoaHs in Lowland *Alnus glutinosa* Woodland

It has been shown in the literature that species with the same, or similar, Ellenberg indicator values, or CSR-strategies, grow together in a site or habitat (see Section 3.3.4). Sections 3.3.4 and 3.4 demonstrated that there are few studies that have shown that species with the same values occur together at a more refined scale within a site or habitat. The search of the literature did not find any examples where these techniques have been used in *Alnus glutinosa* woodland.

This chapter has confirmed that CSR-strategies and Ellenberg values are also valid at an intra-site scale to illustrate variation of conditions when mean and species abundance are taken into consideration. However, when individual species are considered, although there is a tendency for those with the same preferred conditions to grow together, they will also grow with species outside their preferred condition. Generally, species with similar optimal requirements for their environmental conditions do occur together on the ground, but there are also interlopers/overlaps of species with dissimilar groups. This demonstrates that while species have an optimal requirement for growth in relation to the different environmental conditions, they will occur across a range with different degrees of tolerance and some are more tolerant while others are much more specific for a given, or combination of, environmental condition. Therefore, while CSR-strategies and Ellenberg values (and therefore C/NoaHs) are of value, it is also necessary to consider the range of conditions that the species are associated with to fully understand the intra-site variation.

At site level, C/NoaHs are useful to describe the dominant characteristics and degree of environmental variation, but appear to be less useful at the more intricate level of detail of the different vegetation patterns where generalisations become more difficult. Despite this, CoaHs can be used to guide management as diversity of CoaHs gives an indication of the complexity of conditions and biases within a site. A finer, more complex scale of diversity is illustrated by NoaHs. It is considered that presence/absence lists are sufficient to identify C/NoaHs within a site to guide management as well as looking at the overall character of a woodland and then its potential variation. Additionally, the requirement to collect detailed quadrat data of a site, before determining management, defeats the aim of the research to develop a straight forward method to allow site managers to interpret their site based on the species present. Given time, financial and knowledge constraints, it is unlikely that any management guidance requiring detailed quadrat surveys will be of any practical use. As a result of the complexities and variation within the natural environment, no generic management tool can be applied without knowledge of the site.

The results presented in Sections 7.2 and 7.3 and discussed in Sections 7.4 – 7.6 have shown that while species with the same preferred environmental conditions do occur together on the ground, they also occur with species with preferences for other conditions.

The same conclusions emerge if only one variable is considered at a time, i.e. CoaHs (Section 7.4), or when all the variables included in the current research are considered simultaneously, i.e. NoaHs (Section 7.5). A number of examples providing an explanation were discussed and it can be concluded that, while preferred conditions of constituent species can provide an indication of the general characteristics and degree of intra-site variation of a woodland, they cannot be used to categorically describe and identify the specific intra-site variation within a site.

The qualitative example of the Rother sites (Hampshire) and the quantitative example of Stonebridge (Warwickshire) do show, however, that different sites have different characteristics in terms of light and soil variables and CSR-strategies that can be described following the determination of the CoaHs and NoaHs from the component species. Therefore, Chapter 8 will consider the compatibility of different management techniques with the characteristics of each CoaH as defined in Chapter 5 and illustrated in a real situation on the ground in this chapter. Subsequently management guidance for lowland *Alnus glutinosa* woodlands will be developed.

8. MANAGING LOWLAND *ALNUS GLUTINOSA* WOODLAND

8.1 INTRODUCTION AND AIMS OF CHAPTER

Chapter 4 defined lowland *Alnus glutinosa* woodland as a habitat within the landscape, while Chapter 5 identified the theoretical and potential variation within the habitat (C/NoaHs). The theoretical C/NoaHs were subsequently reviewed in Chapter 7, using quantitative and qualitative data from actual sites, and concluded that C/NoaHs do occur on the ground and can be identified from a site species list. Although, NoaHs described the finer and more complex detail of intra-site variation, they were found to be less robust and consistent than CoaHs. This was primarily as a result of the complex interactions of environmental conditions determining the occurrence and distribution of species in any given space. Therefore, in determining appropriate management, only CoaHs are considered in this chapter. However, NoaHs can be used to give an indication of the relative diversity and complexity of a site. From a list of component species of a woodland, the characteristic C/NoaHs, and degree of variation within a site, can be identified and subsequently used to guide appropriate management.

Section 2.6 discussed the effects and implications that management can have on a woodland's character and species composition. Utilising data from a number of sources (particularly those detailed in Section 2.6 and Buglife, 2006; Corney *et al.,* 2006; Decocq *et al.,* 2004; Dzwonko & Gawronski, 2002; Grime *et al.,* 2007; Hannerz & Hånell, 1997; Latham & Blackstock, 1998; Mayle, 1999; McVean, 1953; Parker and Whitbread, 1993; personal observation, H S Miller; Prieditis, 1997; Rodwell, 1991; Wohgemuth *et al.*, 2002), Table 8.1 has been compiled to provide a summary of some specific examples as to how management, of relevance to lowland *Alnus glutinosa* woodlands, can alter conditions and the subsequent species response. For clarity the Table has been split into two: a. management of tree component and b. management of features and off-site management.

Management that can result in change of condition	Potential change in condition in lowland *Alnus glutinosa* woodland	Examples of response of species found in lowland *Alnus glutinosa* woodland
Felling canopy trees combined with creation of drains	Increased light and reduced soil moisture	Increased *Acer pseudoplatanus* regeneration
Felling canopy trees Coppice	Increased light	Increased growth of: *Betula* spp., *Ilex aquifolium* Increased regeneration of: *Fraxinus excelsior, Sambucus nigra, Fagus sylvatica, Clematis vitalba, Acer pseudoplatanus* *Alnus glutinosa* more likely to successfully regenerate Increase in *Rubus fruticosus, Silene dioica, Digitalis purpurea* during open phase Increase followed by a decline as the canopy closes of *Holcus mollis* In coppice systems *Geum urbanum* shows shade tolerance comparable with *Cirsium palustre*
Coppice Wind-blow (artificial) Felling and ground preparation Selective fell Clear-fell	Increased light and soil disturbance	Increase in ruderal species (until canopy closes) Increased dominance of *Chamerion angustifolium, Digitalis purpurea, Blechnum spicant, Cirsium arvense, Filipendula ulmaria* Abundant and vigorous growth of *Fraxinus excelsior* and *F. excelsior* regeneration; *Sambucus nigra, Rubus fruticosus, Clematis vitalba* and *Acer pseudoplatanus* regeneration Decrease in occurrence of old forest species, e.g. *Dryopteris carthusiana*
Clear-fell	Increased exposure to frost & wind	Decrease/loss of *Rubus idaeus*
Clear-fell Felling and ground preparation	Increased disturbance/exposed soils as a result of disturbance	Increased species richness in the groundflora Increased *Digitalis purpurea*
Artificial wind-blow Selective felling	Increased 3D-structure	Many species, including *Alnus glutinosa*, will regenerate from prostrate stems created through artificial wind-blow
Artificial wind-blow Selective felling	Increased 3D-structure	Increased flora diversity
Selective felling Clear-fell followed by natural regeneration Grazing – especially larger grazers	Increase micro-topographic conditions, e.g. • bare ground (hoof prints), • fertility (latrines), • standing water (hoof prints, wheel ruts)	Increase invasive species, e.g. • *Rumex obtusifolius* (bare soils), • *Urtica dioica* (latrine sites) Greater overall diversity through provision of different niches and disruption to seed-bank

Table 8.1a Examples where management (of tree component) can bring about changes in conditions and the subsequent response of species found in lowland *Alnus glutinosa* woodland (Table continues)

Management that can result in change of condition	**Potential change in condition in lowland *Alnus glutinosa* woodland**	**Examples of response of species found in lowland *Alnus glutinosa* woodland**
Grazing (general)	Regeneration & young trees	High grazing density results in reduced regeneration
		Reduced grazing density from formerly grazed site: a) increase, especially *Fraxinus excelsior* & *Sorbus aucuparia* b) increase in vigorous, competitive species, e.g. *Rubus fruticosus*
Winter grazing	Increased structure and diversity - tussocky sward but short sward if high grazing pressure Deep litter layers broken up (especially by cattle)	Increased spring growth Unfavourable for grasses
Grazing by horse/pony	Increased structure and diversity - varied/patchy sward structure, i.e. tussock and short grazed areas	Unfavourable for *Festuca* spp., *Agrostis* spp. *Carex* spp. and *Juncus* spp. ferns in late spring/summer
	Open, herb-rich swards if native breeds used	
Grazing by sheep	Increased structure and diversity - short sward	Unfavourable for grasses, *Rubus fruticosus* (winter grazing), *Fraxinus excelsior*, *Ilex aquifolium* and *Betula* spp. (summer grazing)
	Reduce regeneration as a result of seedling and sapling predation and sheep congregation	
Grazing by goats	Increased structure and diversity - uneven, tussocky swards	Unfavourable for grasses, *Carex* spp. and *Juncus* spp. (summer grazing), *Rubus fruticosus* and other spinose species Bark stripped from woody species in winter
	Much reduced regeneration as browse seedlings and saplings (more than cattle & sheep)	
Repeated cutting of groundflora	Increased disturbance	Reduced dominance of *Urtica dioica*
Shelterwood	Maintained moisture	Favours species with preferences for moist conditions
	Maintained shade	Favours species with preferences for shaded
Non-intervention	Increased shade	Decrease in vigour and increased susceptibility to fungal attack of *Holcus mollis*

Table 8.1a cont. Examples where management (of tree component) can bring about changes in conditions and the subsequent response of species found in lowland *Alnus glutinosa* woodland

Management that can result in change of condition	**Potential change in condition in lowland *Alnus glutinosa* woodland**	**Examples of response of species found in lowland *Alnus glutinosa* woodland**
Flood defence banks adjacent to site River control upstream, restricting water flow	Reduced wetness through reduced inundation Water table reduced/not recharged by flood events	Succession towards drier woodlands, e.g. *Quercus* spp. Reduced competitive advantage for *Alnus glutinosa* Loss of wetland species
	Less disturbance/exposed soils as a result of reduced disturbance following flood events	Reduced species richness in the groundflora
Clearance/creation of drains	Lowered water table i.e. drier soils	Increase in *Urtica dioica* and *Rubus fruticosus*
	Localised standing water	Increase in *Glyceria fluitans*
Control of water flow through drains within the site	Minor changes in timing of water table changes	Variable
	Seasonal soil wetness, e.g. high water table in winter, lower during summer months	Good growth of *Alnus glutinosa*
All of the above	Drier soils April – June; less than 20-30 days of constantly moist soils	Reduced success of *Alnus glutinosa* seedling establishment
Reduced flood defences causing increased flood events	Wetter conditions with water table near ground surface for most of the year	Abundant *Alnus glutinosa* regeneration but poor growth of existing specimens
Blocking existing drains/reduced maintenance		
River control upstream, increasing water flow/level		

Table 8.1b Examples where management (of features or off-site) can bring about changes in conditions and the subsequence response of species found in lowland *Alnus glutinosa* woodland

Using the knowledge gained and developed in the preceding chapters, this chapter relates the management options and subsequent effects (Sections 2.6 and 2.7) to the ecology specific to lowland *Alnus glutinosa* woodland as defined in this research (Chapters 4-7). The aims of Chapter 8 are therefore to:

1. Identify appropriate management for the nature conservation of lowland *Alnus glutinosa* woodland
2. Develop a mechanism by which appropriate management can be guided from a species list and key characteristics of the woodland.

Chapter 8 therefore, reviews management options that may be compatible with these woodlands in general (as defined in Chapter 4) before considering how CoaHs can be employed to guide management to facilitate the maintenance and/or creation of specific conditions.

8.2 Proposed Guiding Principles for Managing Lowland *Alnus glutinosa* Woodland for Nature Conservation

Chapters 2 to 7 have reviewed the literature and defined and documented an ecological and management understanding of lowland *Alnus glutinosa* woodland. This section subsequently proposes principles for the nature conservation management of these woodlands. Although not specifically proposed for the target habitat of this research, the principles of Lindenmayer *et al.* (2006) listed in Section 2.4, particularly those aimed at stand level (as stands in mesic woodlands are likely to equate, at least in size, to small lowland *Alnus glutinosa* woodlands) are of high relevance to lowland *Alnus glutinosa* woodlands. Based on the knowledge gained during the course of the current research, it is proposed that such principles could be applied to UK lowland *Alnus glutinosa* woodlands, although considered on two-tiers:

1. landscape level;
2. site specific level.

It is also emphasised that principles and strategies identified at regional and national level, such as in the BAPs and Lawton Review (see Section 2.2.3), should be taken into consideration before determining appropriate management for a site. While the five guiding principles (of Lindenmayer *et al.*, 2006; Section 2.4) focused on maintaining various features (such as connectivity and heterogeneity), it is considered that the active creation of such features should not be discounted, particularly in light of the importance of the habitat in Britain (as demonstrated by the UK BAP). Using ideas put forward by Lindenmayer *et al.* (2006), but adapted as a result of the findings of the current research, Table 8.2 details the proposed management principles and associated strategies for UK lowland *Alnus glutinosa* woodland. This Table includes strategies for both landscape and site scales, although landscape strategies will be harder to implement unless land beyond the woodland boundary is under the control of the owner or co-operation is agreed with neighbours. The principles and strategies have been developed under the same themes as the discussion on factors influencing the management of wet woodlands for nature conservation (Section 2.5).

<table>
<tr><th>Principle</th><th>Strategy – Landscape level</th><th>Strategy – Site level</th></tr>
<tr><td colspan="3">History & temporal dynamics</td></tr>
<tr><td rowspan="3">Consideration of the site’s history (both management and ecological) and temporal dynamics</td><td colspan="2">If appropriate, re-instate past management regimes</td></tr>
<tr><td colspan="2">Allow for natural change and temporal cycling of the ecosystem</td></tr>
<tr><td colspan="2">Implement management at a timescale that complements the natural dynamics of the woodland</td></tr>
<tr><td colspan="3">Diversity of species & structure</td></tr>
<tr><td rowspan="2">Consideration of soil moisture and wetland habitats</td><td>Protect, maintain and restore river systems and associated wetland habitats, e.g. ponds, swamp, mire, wet grassland</td><td>Protect watercourse banks, areas of standing water, seepages

Maintain drainage systems appropriate to the site but this is unlikely to include creation of drains

If appropriate create aquatic systems, e.g. open water, swamp, wet grassland</td></tr>
<tr><td colspan="2">Maintenance of buffer zones/habitats</td></tr>
<tr><td rowspan="2">Maintenance/creation of spatial and structure complexity, i.e. inter- and intra-variation</td><td><u>Landscape (inter-site) heterogeneity</u>
Creation of landscape/regional management plans based along the riparian corridors

Retain and protect areas that reflect different types and ages of lowland Alnus glutinosa woodland and associated habitats

Implement different management systems within the landscape</td><td><u>Intra-site heterogeneity</u>
Maintain and where appropriate create a diversity of conditions, e.g. open glades (open canopy), water (see soil moisture & wetland habitats), standing deadwood (ring-bark)

Long rotation management

Retain mature trees allowing natural aging and decay (assuming conditions allow), i.e. retain structural diversity during harvesting operations if the woodland is used for economic return from timber

Encourage the development of diverse woodland structure through appropriate management, e.g. selective fell/coppice systems/artificial wind-blow

Maintenance (and if appropriate creation) of specific habitats, e.g. dry embankments, deadwood, seepages</td></tr>
<tr><td colspan="2">Avoid monocultural management</td></tr>
<tr><td rowspan="3">Appreciation of notable/protected species</td><td>Provision of dispersal routes across the landscape</td><td>Niches may be natural or artificial (e.g. nest boxes) until natural resources develop</td></tr>
<tr><td colspan="2">Distribution and habitat use of notable and/or protected species, both flora and fauna, to be determined and taken into consideration prior to any management</td></tr>
<tr><td colspan="2">Provision of particular niches to support known or potential species in the locality</td></tr>
<tr><td rowspan="3">Control of non-native species</td><td colspan="2">Minimise risk of spread through implementation of current legislation/policy and guidance</td></tr>
<tr><td colspan="2">Follow current guidance, e.g. Environment Agency (2010) for Fallopia japonica, Impatiens glandulifera</td></tr>
<tr><td colspan="2">Favour native species during any felling operations. Acer pseudoplatanus should be considered on a site-by-site basis</td></tr>
</table>

Table 8.2 Management principles and strategies for lowland *Alnus glutinosa* woodland using current research and adapting ideas of Lindenmayer *et al.* (2006) for the management of woodland for nature conservation (Table continues)

Principle	Strategy – Landscape level	Strategy – Site level
Landscape setting and habitat continuum		
Maintenance/creation of habitat continuum	To be focused along riparian corridors Consideration of associated habitats, e.g. swamp, wet grassland, wetlands Maintenance/creation/restoration of a network of habitats to act as species sinks, for example, protected sites such as SSSI, county wildlife sites and local wildlife sites Can be continuous or 'stepping-stone'	Avoidance of widespread management, i.e. ensure a range of conditions remain within a site, such as achieved through rotation coppice compared with clear-fell Consideration of adjacent habitats
Operations		
Use of low impact management systems	Avoid intensive management	Reduction of high forest management Long rotation coppice Selective fell Avoidance of operations, including product removal from the site following harvesting, that will result in damage to the soil structure Implement management at an appropriate time of year (dependant on site conditions) to minimise harm to abiotic and biotic features of the site
Use of natural processes to guide management	Allow natural flooding where constraints allow, i.e. periodic, temporary inundation	Allow woodlands to flood, i.e. periodically be inundated with water If appropriate, sensitive use of grazing
	Avoid monocultural management	
Economics		
Economic return	Some sites/areas within larger forests used solely for timber production while others set-a-side for nature conservation	Strategy will be site specific dependant on local conditions, e.g. wetness, size, accessibility
	Use/identify local markets for products and resources	

Table 8.2 cont. Management principles and strategies for lowland *Alnus glutinosa* woodland using current research and adapting ideas of Lindenmayer *et al.* (2006) for the management of woodland for nature conservation

While it is not feasible (as a result of the natural variability within the natural environment at both landscape and site scales) to provide specific details on the implementation of the principles and strategies detailed in Table 8.2, it is possible to provide some general recommendations and examples of specific situations.

8.3 Recommendations for Nature Conservation Management of Lowland *Alnus glutinosa* Woodland

This section reviews specific situations and makes general recommendations in respect to the principles and strategies detailed in Table 8.2. It draws upon the discussions in Sections 2.5 and 2.6 on factors influencing nature conservation management decisions and how management may affect the character of the woodland.

8.3.1 History and temporal dynamics

The current or historic management will have significant bearing on the floristics of the woodland, however reinstating historic management may not be physically, or economically, feasible or ecologically appropriate. Therefore, it is recommended that historic and current management is reviewed in relation to the physical, economic and ecological constraints. Since ecosystems are dynamic, any management should reflect the changing nature of the system, either to sustain, promote or (if appropriate) arrest it, depending on the nature, influence and interaction of the wider landscape. For example, if an *Alnus glutinosa* woodland was drying out and *Fraxinus excelsior* was replacing *Alnus glutinosa* as the canopy tree, it may be considered appropriate to implement management that arrests such succession. This would be more significant if there are few/no other *Alnus glutinosa* woodlands in the local area.

8.3.2 Diversity of species and structure

To promote species and structural diversity, the following are recommended:

- management should:
  - be aimed at promoting 3D-structural and localised intra-site variation of the woodland habitat (e.g. deadwood, ponds, glades) so that it can subsequently support a diverse faunal community;
  - encourage a varied age structure, preferably mixed together, but for ease of implementation could be done in blocks provided connectivity is retained, e.g. groups of 30–40 trees of the same species (Everard *et al.*, undated, Ratcliffe, 1996). However, the practicalities of such management will be dependant on the size of the woodland;
- native trees (defined here as species naturally occurring within a region/country) should be favoured, e.g. for retention during restoration of non-native woodlands and planting;

- specific relevance of species nativeness/suitability, e.g. local provenance, to the site to be considered;
- removal of non-native:
    - invasive species, e.g. *Rhododendron* spp., *Heracleum mantegazzianum*, *Fallopia japonica*, *Symphoricarpos* spp., can be achieved by cutting and herbicide application as appropriate;
    - canopy or shrub layer species should be through gradual thinning processes so as to avoid sudden changes that could impact upon the current conditions while enhancing the woodland's naturalness. However, in some situations it may be beneficial to remove all in one go, e.g. if conditions are created through the partial removal process that then enable the invasive species to increase;
- any management, whether the removal of non-native (non-invasive) or native species, should not be 'clean management', i.e. retain at least some brash, standing and fallen deadwood, age variation, understorey;
- retain character trees/mature habitat, e.g. distorted, moribund, veteran trees;
- natural regeneration is preferable for the replacement of non-native species or canopy species;
- control level of grazing, both wild and stock animals, as appropriate for the site.

8.3.3 Landscape setting and habitat continuum

As discussed in Section 2.5.3, maintenance of habitat continuum at both site and landscape scale are important for the survival of *Alnus glutinosa* woodlands. Therefore, the following are recommended for retention:

- 60% canopy cover of mother/seed trees to provide a seed source for regeneration (Everard *et al.*, undated);
- (encourage) old growth which is particularly important for shade tolerant species and invertebrates;
- past management where appropriate (e.g. coppice; see Section 8.3.1); create new coppices but retain some to over-mature to maintain habitat continuum and provide new habitats/structure;
- the succession range, e.g. early colonisation to mature woodland to maintain habitat continuum and provide intra-variation of conditions.

Buffer zones around sites of high nature conservation interest help ensure the long-term survival of the nature conservation assets. Everard *et al.* (undated) suggest in sites specifically managed for nature conservation, e.g. SSSI, coupes should be 0.5 ha and separated by about 30 m of unfelled trees. However, even these relatively small areas with 30 m buffers may not be compatible with the small spatial extant of many lowland *Alnus glutinosa* woodlands.

8.3.4 Operations

The often small size and isolated position in the landscape of lowland *Alnus glutinosa* woodlands can be significant constraints to management operations. Section 2.5.3 identified a number of considerations in relation to operational activities of managing wet woodlands. The following recommendations are made to minimise any resultant negative impacts on the habitat:

- to minimise soil damage:
    - use light-on-the-ground, low impact equipment (e.g. hand, horse, cable crane, tractors with low ground pressures);
    - use brash mats;
    - choose access/extraction routes with the minimum impact, e.g. established rides, drier routes, floatation down rivers;
    - stack extracted timber on drier ground;
    - undertake works in dry weather or when the ground is frozen.
- herbicide use:
    - to be avoided if possible, but where it is necessary (e.g. control of non-native species) it should be applied by spot application and follow current best practice;
    - avoid work near water to reduce potential pollution incidents.
- to minimise damage to watercourse banks avoid works near/on the banks where possible. Where felling is necessary at the water's edge it should be directed away from the bank.

8.3.5 Economics

As a result of the small size, isolation and low marketable products obtainable from lowland *Alnus glutinosa* woodland, management needs to be cost-effective, easily implemented and with low intensive input.

The Forestry Commission (2003) recommends the following in terms of timber management of wet woodlands:

- thinning is rarely worth while unless favouring *Fraxinus excelsior* standards, then hand-held machinery is preferred to minimise damage to the ecosystem;.
- weeding should be confined to immediate competition to maintain and enhance diversity;
- longer coppice/felling rotations, e.g. 50 years, are more beneficial to nature conservation.

Unless it is desirable and economical to manage a lowland *Alnus glutinosa* woodland for timber production it is unlikely that operations, such as thinning to favour *Fraxinus excelsior* and weeding, will be implemented in such woodlands.

8.4 Specific Management Aims Appropriate for Lowland *Alnus glutinosa* Woodland

Based on the current research's results of the literature review, data analysis and the preceding sections here, recommendations can be made with regard to specific situations which may occur in lowland *Alnus glutinosa* woodlands. Table 8.3 expands and adapts the considerations discussed in Section 8.2 and 8.3, incorporating the current research, to identify specific aims and objectives for the management of lowland *Alnus glutinosa* woodland with the focus on nature conservation. The Table also details the conditions required to meet these aims/objectives and management which would result in the conditions being achieved.

Aim/objective	Conditions required to achieve aim/objective and suitable management
Avoiding dominance which can result in reduced floristic diversity	
Acer pseudoplatanus	No sudden light increase Selective felling, continuous cover management, i.e. avoidance of suddenly opening up the canopy
	Reducing seed set Coppice on short rotation so that the trees do not mature and produce seed Ring bark individual trees
	Restricted growth Grazing – *Acer pseudoplatanus* is more susceptible (when within reach of grazers) to grazing than other species such as *Betula* spp., *Quercus* spp. and *Crataegus monogyna* (Mayle, 1999) Protect desirable species
	Maintain water table Avoid clearing drains within the site that would take water off-site Divert drains adjacent to site to encourage water onto site
Rubus fruticosus	Avoid opening the canopy/increasing light reaching the ground Continuous cover and selective felling/coppicing will minimise the amount of light reaching the ground. Personal observation suggests that this species is more aggressive in drier and high light situations and as such there is a lower probability of it becoming dominant in wetter *Alnus glutinosa* woodlands than in drier woodlands.
Reducing dominance/exclusion of woodland species	
Urtica dioica and *Rubus fruticosus*	Increased soil moisture If drains/streams are present within the site which are causing a drying of the soils, such features could be reduced or course altered to encourage water to be retained on site
	Reduction of competitive advantage Frequent cutting (*Urtica*); grazing (*Rubus*)
	Maintain shaded conditions Continuous cover management
Aggressive herbs, e.g. *Urtica dioica, Poa trivialis, Galium aparine*	Increase water level and shade Block drains and avoid group felling Orzcewska (2010) found that these species noticeably avoided areas of high water table and poor light
Rhododendron spp.	Reduce the extent and eradicate from site Pig sows will use *Rhododendron* spp. as bedding litter. They must be provided with a full diet to reduce their tendency for rooting which may have a negative affect on desired species (Mayle, 1999) Cutting and appropriate herbicide treatment of the stumps
Encourage natural regeneration	
Alnus glutinosa specific	Provide gaps in the canopy or at woodland edges Mason *et al.* (1984) found that regeneration was prolific along riparian zones where there was only a single row of parent trees Group fell, especially at the woodland edge if there is no opportunity for expansion into adjacent habitats
	Appropriate levels of grazing Mayle (1999) noted that moderate grazing benefited *Alnus glutinosa* regeneration while high or no grazing prevented it Mason *et al.* (1984) found that the presence of spiny shrubs (*Crataegus monogyna, Prunus spinosa, Ilex aquifolium*) protected *Alnus glutinosa* seedlings from grazing stock. Therefore dead hedging with spiny shrubs may be appropriate Stock exclusion/management
	Water table near the surface throughout the year Control water retention on site

Table 8.3 Aims and objectives, conditions and management for situations specific to lowland *Alnus glutinosa* woodland derived from a literature review and data analysis during the current research (Table continues)

Aim/objective	Conditions required to achieve aim/objective and suitable management
General	Low/no grazing pressure Remove domestic stock grazing if present; control of wild grazers if feasible. Enclose newly felled areas/glades or use appropriate tree guards (Mayle, 1999) on regenerating trees Stock exclusion/management
	Reduce dominance of understory and create bare ground patches Use of pigs, cattle or ponies at relatively high densities for a short period of time (Mayle, 1999)
Timber	
Fraxinus excelsior, e.g. if a more productive woodland is desired. NB this species has the potential to replace *Alnus glutinosa* if it gains the competitive advantage	Light conditions If the species is already present, opening up the canopy is likely to encourage regeneration, therefore, coppice or selective/group fell existing canopy trees
Alnus glutinosa	Low summer water table Control site drainage Control flood waters, e.g. drain summer flood water off site but retain on site in winter floods
Diversity in general	
Creation of seed bed	Bare ground and no dense groundflora restricting seeds reaching the ground Graze – hoof prints break up the vegetation and create localised areas of bare ground (Mayle, 1999) Rooting behaviour of pigs can create seed-beds Reduce dominant species, e.g. *Urtica dioica*, grasses (see above) Allow woodlands to flood at times of high river flow
High diversity/increase groundflora diversity	No particular species group to dominate If a site is dominated by C, CR or CS strategists, management needs to be implemented to reduce their dominance and allow other groups, i.e. sub-ordinate (R, S, SR, R/CR, S/CS, CR/CSR) & transient species to establish Management will be dependant upon other dominating factors and conditions Vary the season at which cutting/grazing takes place each year
	Accessible bare ground and reduce dominant species Removal of bulk of old coarse grasses through mowing followed by extensive grazing, i.e. continuous at low density (Mayle, 1999) Reduction/clearance of dense ground vegetation, e.g. *Pteridium aquilinum*, *Elytrigia repens*, *Rubus fruticosus*, *Rosa* spp., by grazing pigs, although may reduce regeneration (unless snout is ringed) due to rooting behaviour Where there is a dense grass ground layer – graze on rotation and seasonal, e.g. early or late to create 'openings' and vary the grazing season each year to avoid certain groups becoming dominant and other species being lost
Increase shrub cover	Low/no grazing pressure Reduce grazing levels. If woodland is grazed then avoid sheep or goats, i.e. cattle or ponies preferred (Mayle, 1999)

Table 8.3 cont. Aims and objectives, conditions and management for situations specific to lowland *Alnus glutinosa* woodland derived from a literature review and data analysis during the current research (Table continues)

Aim/objective	Conditions required to achieve aim/objective and suitable management
Varied structure and groundflora	Low/no grazing pressure Very low grazing density for the first 5 years or exclude grazers until re-growth is above the browse height (Mayle, 1999) Introduce coppice management
	Coppice Mayle (1999) recommended the following management for ASNW wet woodlands (W1-7): For coppice regeneration over 5-40 years graze ≤ 0.07 cattle or ≤ 0.5 sheep ha^{-1} in the first 5-10 years For improving groundflora and structure graze ≤ 0.1 cattle or ≤ 0.7 sheep ha^{-1} in the 10 years onwards
Increase natural character through removal of non-invasive, non-natives	Variable Direct removal, e.g. ring bark, herbicide application, fell and remove
Alter conditions	
Increase wetness	Control water flow within the site Reduce flood defences Block existing drains
Decrease wetness	Create flood defences to reduce flood water entering the site Control river flow upstream to reduce flood events Clear/create drains
Increase light	Removal of canopy species, e.g. clearfell, coppice, selective fell Grazing
Decrease light	Retain canopy, e.g. continuous cover, non-intervention

Table 8.3 cont. Aims and objectives, conditions and management for situations specific to lowland *Alnus glutinosa* woodland derived from a literature review and data analysis during the current research

8.5 Compatibility of Different Management Techniques with Conditions Found in Lowland *Alnus glutinosa* Woodland

This section considers the compatibility of management techniques, identified and discussed in Section 2.7, with conditions that may dominate or occur within lowland *Alnus glutinosa* woodland (Chapters 5-7). Initially each of the general characteristics identified in Chapter 4 are considered, i.e. size, location, then each possible condition that may either dominate or occur within woodland are considered, i.e. CoaHs (Chapter 5). Key considerations identified in Sections 8.3 and 8.4 are also taken into account.

The following management techniques are in contradiction with the guiding principles set out in Section 8.2 and as such are not considered further:

- High Forest

- Short rotation coppice (creates heavy shade and therefore reduces overall biodiversity, Nisbit *et al*., 2011)
- Extensive clearfell & restock – except perhaps if the woodland is large and contains a high proportion of non-native species, i.e. requires restoration to native woodland
- Non-intervention, unless part of a wider landscape managed for nature conservation.

8.5.1 Size and location of lowland *Alnus glutinosa* woodland

<u>Size</u>

Lowland *Alnus glutinosa* woodlands have been defined as being generally small, i.e. less than 4 ha. The literature (Everard *et al.* undated) suggests that coupes should be 0.5 to 1 ha and for nature conservation management be 0.5 ha with a 30 m buffer of mature trees. Such suggestions, for nature conservation management will, therefore require a minimum of *c.* 1 ha per coupe. Given the small, irregular size of lowland *Alnus glutinosa* woodland (generally < 4 ha) this would only allow for about three coupes within a woodland and as such a gradient of conditions from cut to maturity is not feasible, although it is noted that a fully mature coupe would not be necessary on account of the buffer zones. Although current guidance (e.g. FC, 2003) recommends coppice rotations of 10-25 years are appropriate for wet woodlands, longer rotation, e.g. 50 year, have been suggested to be better for general woodland nature conservation; longer cycles are more likely to retain a woodland groundflora. However, rotations of this length may be disadvantageous to woodland of a ruderal/pioneer nature (see Section 8.5.2). As a rule of thumb, Watkins (1990) stated that, traditionally, the area of woodland to be coppiced each year is the total woodland area divided by the length of rotation. In small woodlands this could result in less than a tree being coppiced each year; in such cases coppicing should take place every other year or more, rather than annually. Coupe sizes of 0.5 ha, in conjunction with the longer rotation of up to 50 years, would be inappropriate for lowland *Alnus glutinosa* woodland on account of their size and successional nature.

<u>Location in the landscape</u>

Lowland *Alnus glutinosa* woodlands may be prominent features on the landscape if they occur as small blocks in a flat floodplain. Therefore management that creates a noticeable change of canopy cover, e.g. coppicing or group felling, would have a significant visual impact on the landscape. In contrast, techniques that maintain continuity of cover, e.g. continuous cover forestry and selective felling, would minimise visual impacts and be more appropriate in situations where the woodland is an isolated feature on the landscape. As well as being more visually acceptable, such techniques will also maintain temporal habitat continuity so reducing species loss and further fragmentation and isolation. Isolation will also have implications on the machinery and product extraction (if applicable) and as such low intensity management is likely to be more appropriate. Woodlands in the urban environment will have similar restrictions to those encountered in isolated woodlands.

In contrast to isolated woodlands, *Alnus glutinosa* woodland that forms part of larger mesic woodland is likely to be more accessible but, if small, not viable to manage differently from the adjacent stands. Woodlands in these situations lend themselves to minimal/non-intervention management as broad habitat connectivity and diversity is maintained in the adjacent woodland.

Lowland *Alnus glutinosa* woodlands generally occur adjacent or in close proximity to watercourses, and as such management operations that have potential to pollute, or disturb the banks of, the watercourse would be inappropriate. For example, herbicide application as part of the removal of non-native species would have to be undertaken with caution. Grazing is an option for woodlands that form part of a grazed grassland floodplain.

8.5.2 Age and history

Although the woodlands may have a long history, most comprise young to mature stands, i.e. 20 – 100 years old. Depending on the situation, different management options are likely to be more appropriate, for example:

- if there is evidence of recent coppice management, re-introduction of coppicing is a viable option;
- if there are indications (field and/or historic data) that a site, currently dominated by non-natives, was lowland *Alnus glutinosa* woodland, restoration management may be appropriate. Precise management options and techniques will be dependant upon the specific situations;
- recent and young woodlands can be managed to suit their particular situation, i.e. a ‘blank-canvas’ within any other constraints;
- if a well established and balanced ecosystem exists, a precautionary approach is recommended, e.g. minimal intervention and gradually bring the site back into management with regular and frequent monitoring.

8.5.3 Species composition and structure

Non-native species

Invasive non-native species should be removed using the most appropriate technique and following current best practice, particularly as new techniques regularly become available. However, generally removal of such species is likely to involve cutting and herbicide application and as such precautions in relation to watercourses (see Section 8.5.1) must be taken into consideration.

Clear fell and restock may be appropriate, depending on the size of the woodland, if there is the need for the removal of non-native canopy species. If there are only a few non-native canopy species selective felling or ring-barking are alternatives. Selective felling would also be more appropriate for small woodlands and those that are a visual landscape feature (see Section 8.5.1).

Structural and species diversity

Non-intervention relies on natural events and therefore cannot be guaranteed to promote variation in structure in an existing uniform woodland. Artificial 'windblow', natural regeneration, coppice/coppice-with-standards and selective felling are all appropriate to promote structural and species diversity in structurally poor woodland.

8.5.4 Degree of disturbance and stress

Stressed conditions can arise from a number of factors (e.g. lack of light, water and/or nutrients, sub-optimal temperatures or too much water) and the effects will vary from species to species. However, plants are more susceptible to disease when under stress. *Phytophthora* disease of *Alnus* affects all species of *Alnus* found in the UK but *A. glutinosa* is the most susceptible (Webber *et al.,* 2004). Research has indicated that the occurrence of *Phytophthora alni* subspecies *alni* may increase following flood events or disturbance (Webber *et al.*, 2004), therefore management that creates disturbance should be avoided if the disease is known to occur on site. Since it has been shown that the disease begins with bark death at the base of the stem, rather than the roots, it has been suggested that coppicing, at 0.2-0.3 m from ground level, is an appropriate method that helps in disease management (Webber, *et al.,* 2004). If *Phytophthora* is present within a site it is recommended that current best practice is followed for its control.

As with stressed conditions, disturbance can also be a result of different factors, e.g. grazing (herbivory and trampling), harvesting, wind damage, erosion and fire. Figure 8.1 illustrates management options compatible with different degrees and combinations of stress and disturbance which formed the origin of the CSR-triangle (see Section 2.3.1) and subsequently CoaHs-A-F. Any form of management that does not create extreme conditions will be appropriate for sites dominated by CoaH-G, e.g. continuous cover which aims at maintaining a continuity of conditions. However, in woodlands dominated by stressed characteristics (e.g. CoaH-B) it is essential to understand the cause of stress creating the conditions of the particular woodland. This can, at least in part, be determined by the review of the species contribution to environmental CoaHs, i.e. light (CoaH-H-K) and soils conditions (CoaH-L-T).

Disturbance \ **Stress**	**Low**	**Moderate**	**High**
Low	**CoaH-A** Grazing – see text below Minimal intervention Late phase coppice High productivity	**CoaH-E** Grazing – see text below Moderate productivity	**CoaH-B** Non-intervention - light stress Site drainage - water & potentially nutrient (leaching) stress Low productivity
Moderate	**CoaH-D** Grazing by domestic fowl – see text below Continuous cover – localised disturbance and stress Coppice Moderate productivity	**CoaH-F** Flooding – high water stress & periodic disturbance Low productivity	
High	**CoaH-C** Use of machinery Grazing Artificial wind-blow (localised disturbance) Felling canopy trees Low productivity		

Fig. 8.1 Management options compatible with CoaHs-A-F

Grazing can have either positive or negative effects on competitive species (i.e. those that describe CoaH-A) depending on the intensity and grazers involved. Under grazing allows competitors to outcompete less vigorous species. Over grazing can also promote invasive weed growth, e.g. *Rumex obtusifolius,* many of which are competitors. However, the trampling of cattle can also reduce coarse vegetation and break up dense stands so is less beneficial to competitors.

Grazing can also create conditions suitable for species that comprise CoaH-C, i.e. R-based strategists. However, it would be species dependant, for example pigs are likely to create more widespread ground disturbance than other grazing animals as a result of their rooting behaviour. Animals, such as cattle, habitually rest in particular locations and as such these areas receive regular and frequent disturbance, so creating conditions suitable for CoaH-C.

Grazing by domesticated fowl is likely to create conditions suitable for species of CoaH-D (i.e. competitive-ruderal based strategists) as a result of their scarifying and fertilising behaviour.

Decocq *et al.* (2004) suggested that cutting intervals which are shorter than recovery times resulted in early successional floristic communities being retained. Therefore, since lowland *Alnus glutinosa* woodlands are typically pioneer communities, such management may be appropriate. However, the specific recovery time for lowland *Alnus glutinosa* woodlands would need to be determined through further, more detailed, research and consider factors such as seed bank longevity. It has also already been indicated that short rotation coppice is incompatible with a number of the guiding principles for the target habitat, suggesting that a compromise may need to be sought.

8.5.5 Light conditions

Continuous cover and shelterwood forestry techniques would create shaded and semi-shaded conditions but are less likely to result in high light conditions. Therefore this technique is compatible with CoaH-H and -I (shaded and semi-shade) but not CoaH-J and -K (well to very well lit).

A well designed coppice system will benefit species of all light-CoaHs; early phase coppice will have CoaH-L and -K, while late phase coppice will favour CoaH-H. Species of CoaH-I are likely to occur during mid-phase and along the coupe edges. Coppice systems also provide localised conditions, e.g. coppice stools, small paths, large stumps and dry ditches (see Corney *et al.*, 2006). Similarly coppice-with-standards will also benefit species from all light conditions, although is likely to be more favourable for semi-shade, i.e. CoaH-H.

Management that maintains a closed canopy will favour species associated with shade conditions (CoaH-H), e.g. non- and minimal intervention, continuous cover, shelterwood.

Techniques, such as selective felling and low-moderate level grazing, that allow some light be penetrate the canopy will favour semi-shade species (CoaH-I). In contrast, techniques that result in an extensive opening up of the canopy are appropriate for species of lighter conditions (CoaH-J and -K). High grazing densities, especially deer, are likely to result in a browse line allowing more light to penetrate the woodland, particularly at the woodland edge. Clear-fell and group fell will also favour species preferring high light conditions; at least until the canopy closes again.

8.5.6 Soil conditions

<u>Soil moisture (CoaH-L-O)</u>

Soil moisture levels, notably constantly moist (CoaH-M), are less readily managed by on-site management. These conditions are more affected by wider-scale management, such as river flow and flood events. However, where a site has localised, or wide-spread wet conditions (e.g. CoaH-N or -O), they can be maintained through avoidance of operations that would cause such conditions to dry out, e.g. the creation of drains. Equally, in some cases, it may be feasible to encourage wet conditions if there are features within the site that promote dry conditions. For example, existing drains could be blocked, or flood bunds removed, to allow more frequent flood inundations of the site, however, there will clearly be need for serious consideration of the wider ranging implications of such operations.

Relatively drier conditions (appropriate for CoaH-L) can be created through, for example, locally raising the ground, e.g. creation of mounds, or bunds, creating or altering the course of drains or creating flood defence bunds.

However, some techniques that involve the management of trees, as opposed to physical features within or off-site, can alter the soil moisture. For example, techniques involving large machinery can create locally wet conditions through soil compaction and wheel ruts. Artificial windblow can create a localised pool at the base of the rootplate.

Extensive canopy tree removal can result in increased evaporation of the soils and so having a drying effect, but simultaneously the water table rises, as a result of less water uptake from canopy trees, so can result in overall wetter soils.

Soil acidity (CoaH-P and -Q) and Soil fertility (CoaH-R to -T)

Soil acidity and fertility are less directly manageable and predominately dependant upon natural conditions; enforced changes, such as lime application, are likely to be uneconomical or sustainable in the long-term. However, they can be influenced by altering the soil moisture. For example, the creation of more stagnant conditions following the reduction of efficiency of existing drains may increase acidity through creation of anaerobic conditions. Soil fertility can be influenced through the frequency of flood events and subsequent silt deposits. Coppice management can result in subtle soil acidity and fertility gradients during the coppice cycle as a result of changes and amounts of organic matter decay (Peterken, 1993).

Uncontrolled localised increases in soil fertility occur with grazing, i.e. localised increases at animals rest and latrine sites.

8.5.7 Summary of compatibility of different management techniques with characteristics found in lowland *Alnus glutinosa* woodlands and a proposed, novel, hybrid technique

Sections 8.5.1 to 8.5.6 discussed various management techniques, identified in Section 2.7, and their compatibility with the characteristics defining lowland *Alnus glutinosa* woodland. Although in the majority of cases the different management options are compatible with many of the possible situations and characters of lowland *Alnus glutinosa* woodland, there are cases with clear incompatibility. For example, clearfell is not appropriate for isolated sites as a result of visual impact, and non-intervention is not appropriate where invasive species are present. Therefore, by considering the overall character of the site, as opposed to just considering one aspect, some management options will be ruled out. In many respects it is the incompatibility/unsuitable management options which are more significant in terms of guiding management, and form a key part of the Management Decision Tool detailed later in Section 8.6.

However, when considered at a generic level for typical lowland *Alnus glutinosa* woodlands (based on conditions detailed in Chapter 4), the most appropriate management options for lowland *Alnus glutinosa* woodland are coppice/coppice-with-standards. However, although the general principle of coppice management is appropriate to create suitable conditions within a woodland that would retain or promote the general conditions that describe lowland *Alnus glutinosa* woodland, the size of the woodlands and visual impacts also need to be taken into consideration (Section 8.1). Since the majority of lowland *Alnus glutinosa* woodlands are too small to implement a full series of coppice coupes, such management techniques are likely to be deemed incompatible in the majority of cases despite the clear appropriateness for the overall nature conservation of the habitat. It is, therefore, proposed that a hybrid management system, of coppice-with-standards and continuous cover and selective fell forestry, is appropriate for lowland *Alnus glutinosa* woodland. Such a system would follow the principles of continuous cover, by maintaining a continuum of conditions across the site, but also the localised, high disturbance and opening of the canopy achieved during coppicing. Coppicing is also appropriate if *Phytophthora* disease is present. The retention of standards within the woodland would provide more shaded conditions and a stable environment. Such a system would allow movement of species to more favourable conditions when the area that they occupy becomes unfavourable following management, while at the same time maintaining a diverse structure across the site. It is suggested that rather than felling the canopy trees, as in continuous cover, they should be coppiced singularly or in small groups (similar to selective fell) to encourage the development of a varied structure and creation of high light conditions (assuming *Rubus fruticosus* is not abundant). The number of trees to be coppiced should follow, as far as practical, that of traditional coppicing with a rotation appropriate to the age structure of the woodland when this hybrid form of management is put into place.

To minimise the impacts of browsing, stools may require or protecting depending on the species and density of grazer that has access to the woodland. To maintain genetic diversity of canopy trees, it is suggested that the edge trees be felled on longer rotation to create conditions that would promote natural regeneration of *Alnus glutinosa.*

Additionally grazing should be considered if the groundflora is fairly uniform. The species, timing and length of grazing will be dictated by local conditions.

8.6 Proposed Management Decision Tool for Lowland *Alnus glutinosa* Woodlands

Section 8.5 has shown that conditions likely to occur within lowland *Alnus glutinosa* woodland can be maintained, or promoted, through different management techniques. It has proposed a novel, hybrid, management technique that could be appropriate for most lowland *Alnus glutinosa* woodlands. However, all sites are unique and may have specific situations, such as those described in Table 8.3, that require an alternative management regime to maintain, or if appropriate, promote variation. There are three key questions to consider when deciding on appropriate management for woodlands:

1. What are the physical constraints that cannot be altered?
2. What are the existing, desired (in the case of enhancement) or potential (in the case of creation) environmental conditions?
3. What are the management aims of the woodland?

Each of the questions above have been considered, in the preceding sections, in relation to different management options. This section considers these questions further, in conjunction with CoaHs, to develop and describe a tool to guide management in individual woodlands. Section 8.6.1 describes the approach, which can be used by anyone with basic plant identification skills and knowledge of the site, to evaluate and determine appropriate specific management for a site. Section 8.6.2 works through an example, applying this process using qualitative data from Stonebridge.

8.6.1 Management decision process

The management decision tool (MDT), devised and developed as a result of the research detailed in Chapters 3 to 7 and described in this section, can be applied to achieve different objectives for a woodland:

MDT Objective 1: Maintain existing conditions

MDT Objective 2: Enhance/alter existing conditions

MDT Objective 3: Create/promote conditions in newly planted woodland.

Figure 8.2 outlines the process involved for each of the scenarios listed above and is described in detail below. Table 8.4 summarises the steps for each MDT Objective.

MDT Objective	Order of steps in Figure 8.2
1: Maintain existing conditions	1, 2, 3.1, 3.2, 4.1, 5 – 7.1
2: Enhance/alter existing conditions	1, 2, 3.3, 4.1, 5 – 7.1
3: Create/promote conditions	1, 2, 5, 6, 7.2, 3.4, 4.2, 8

Table 8.4 Steps to follow in Figure 8.2 to apply each of MDT Objectives

In the MDT, reference to grazing primarily refers to domestic and large wild grazers (principally deer) but can also include rodents and herbivorous small mammals. The level of grazing has been split into three options: low, moderate and high. These are broadly defined as follows, but a relative judgement will have to made as to the circumstances of individual woodlands:

- low – no apparent affect/damage to trees and regeneration
- moderate – between low and high
- high – obvious damage to trees and regeneration success, e.g. gnawed regeneration shoots and bark damage.

Control and management of invasive species is included as restoration management. Specific details have not been provided as best practice and control of different species is continually being updated and revised. Therefore, the user of the MDT is advised to consult current best practice at the time of management.

Steps 1 and 2: Identifying fixed characteristics and constraints of a woodland and compatible management options

Identify constraints that cannot readily be altered or have a significant bearing on operations. Such characteristics and their compatibility with different management options are detailed in Table 8.5. For clarity the table is split into two a: management of tree component and b: management of features and regeneration.

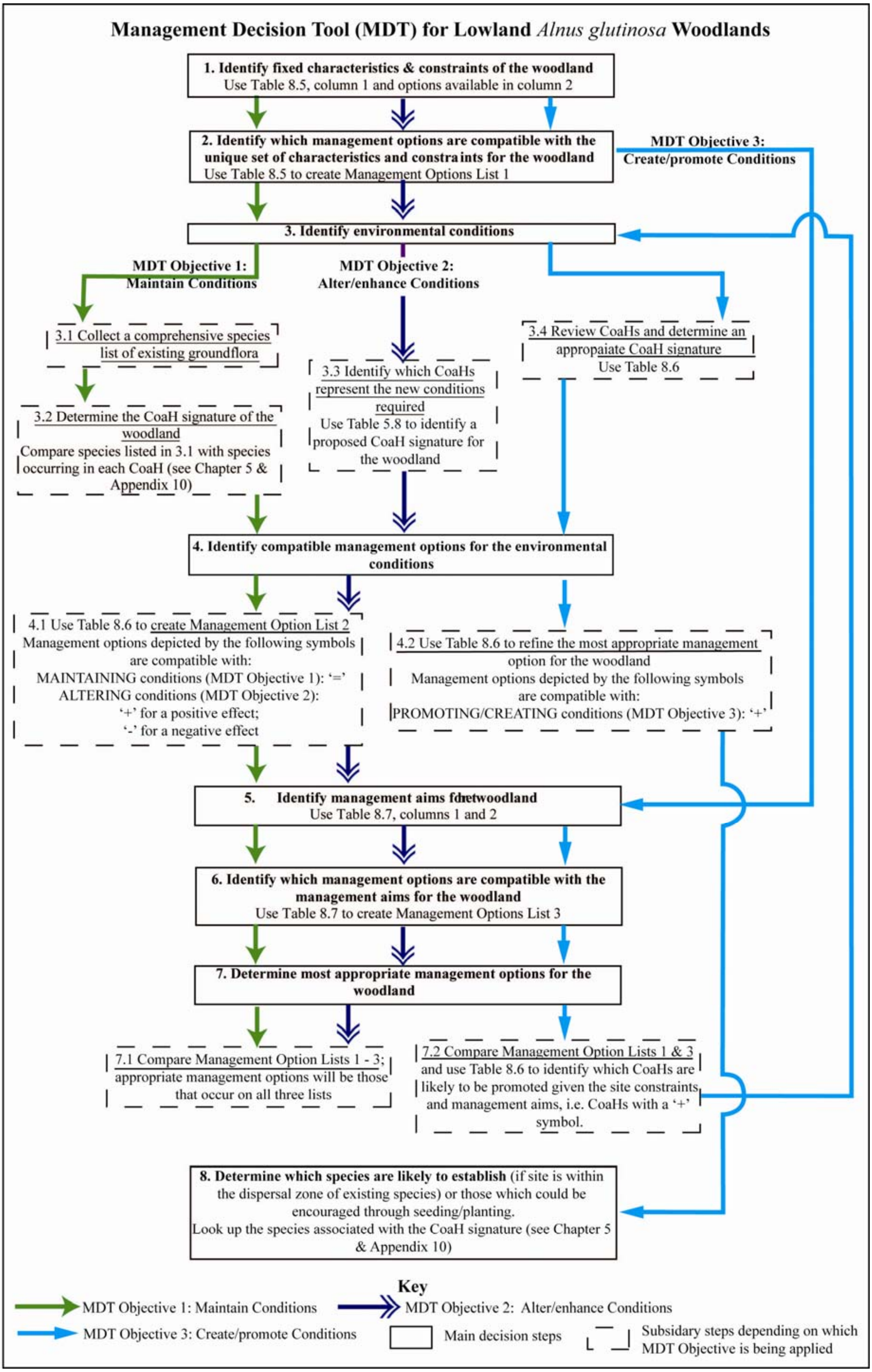

Fig. 8.2 Management Decision Tool for different scenarios of lowland *Alnus glutinosa* woodland management

Character		Intensive: Clearfell/ re-stock	Intensive: Selective felling	Traditional: Coppice	Traditional: Coppice + standards	Sensitive/mimic: Grazed	Sensitive/mimic: Uniform shelterwood	Sensitive/mimic: Continuous cover	Sensitive/mimic: Artificial windblow	None/limited: Non-intervention	None/limited: Minimal intervention	Hybrid
Isolated in the landscape	**yes**		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	no	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Confined by urbanisation	**yes**		✓	✓	✓		✓	✓	✓		✓	✓
	no	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Labour source available	**yes**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	no		✓				✓	✓	✓	✓	✓	✓
Market for products available	**yes**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	no		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Main adjacent habitats	**urban/amenity**		✓	✓	✓		✓	✓	✓		✓	✓
	woodland	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
	grassland/heath (grazable, i.e. not amenity)		✓	✓	✓	✓	✓	✓	✓		✓	✓
	arable		✓	✓	✓		✓	✓	✓		✓	✓
Naturalness state	**invasive species present**	✓	✓	✓	✓	✓	✓	✓	✓			✓
	high proportion non-natives in canopy	✓	✓	✓	✓	✓			✓			✓
	predominately semi-natural & appropriate species		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	**old**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	young	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
History	**Ancient**		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	recent	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Time lapse since last management	**<50 years**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	> 50 years	✓	✓			✓	✓	✓	✓	✓	✓	✓
Size	**< 4 ha**		✓			✓	✓	✓	✓	✓	✓	✓
	> 4 ha	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grasses dominate groundflora	**yes**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	no	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Current grazing level	**low**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	moderate	✓	✓				✓	✓	✓	✓	✓	✓
	high						✓	✓	✓	✓	✓	

Table 8.5a Summary of compatibility of different management techniques for the general situations, conditions and constraints of lowland *Alnus glutinosa* woodland – tree management

CoaH / Management		Natural regeneration	Restoration	Flood defence banks adjacent to site	River control upstream	Clearance/ creation of drains	Control of water flow through drains within site	Reduced flood defences so increased flood events	Blocking existing drains
Isolated in the landscape	**yes**	✓	✓	✓	✓	✓	✓	✓	✓
	no	✓	✓	✓	✓	✓	✓	✓	✓
Confined by urbanisation	**yes**	✓	✓	✓	✓	✓	✓		✓
	no	✓	✓	✓	✓	✓	✓	✓	✓
Labour source available	**yes**	✓	✓	✓	✓	✓	✓	✓	✓
	no	✓		✓	✓	✓	✓	✓	✓
Market for products available	**yes**	✓	✓	✓	✓	✓	✓		
	no	✓	✓	✓	✓	✓	✓	✓	✓
Main adjacent habitats	**urban/amenity**	✓	✓	✓	✓	✓	✓		
	woodland	✓	✓	✓	✓	✓	✓	✓	✓
	grassland/heath (grazable, i.e. not amenity)	✓	✓	✓	✓	✓	✓	✓	✓
	arable	✓	✓	✓	✓	✓	✓		
Naturalness state	**invasive species present**	✓	✓	✓	✓	✓	✓	✓	✓
	high proportion non-natives in canopy	✓	✓	✓	✓	✓	✓	✓	✓
	predominately semi-natural & appropriate species	✓		✓	✓	✓	✓	✓	✓
Age	**old**	✓	✓	✓	✓	✓	✓	✓	✓
	young	✓	✓	✓	✓	✓	✓	✓	✓
History	**Ancient**	✓	✓	✓	✓	✓	✓	✓	✓
	recent	✓	✓	✓	✓	✓	✓	✓	✓
Time lapse since last management	**<50 years**	✓	✓	✓	✓	✓	✓	✓	✓
	> 50 years	✓	✓	✓	✓	✓	✓	✓	✓
Size	**< 4 ha**	✓	✓	✓	✓	✓	✓	✓	✓
	> 4 ha	✓	✓	✓	✓	✓	✓	✓	✓
Grasses dominate groundflora	**yes**	✓	✓	✓	✓	✓	✓	✓	✓
	no	✓	✓	✓	✓	✓	✓	✓	✓
Current grazing level	**low**	✓	✓	✓	✓	✓	✓	✓	✓
	moderate		✓	✓	✓	✓	✓		
	high		✓	✓	✓	✓	✓		

Table 8.5b Summary of compatibility of different management techniques for the general situations, conditions and constraints of lowland *Alnus glutinosa* woodland – feature and regeneration management

Step 3.1 and 3.2: Identifying existing environmental conditions

Existing environmental conditions can be determined following identification of CoaHs occurring within the woodland. Using a list of groundflora species occurring in the woodland, it is possible to identify the dominant, sub-dominant and diversity of CoaHs within a given site. The optimal time of year to gather these data, if only a single visit is feasible, is between April and July. If time and resources allow, it is recommended that site visits are conducted in February, April, June and September to capture vernals and summer species.

To identify if there is any strong bias towards a particular environmental condition (e.g. very wet or very shaded) compare the species list created (Step 3.1, Figure 8.2) for the site with the species listed in each of the CoaHs determined in Chapter 5 (see Appendix 10). Each species is assigned to the appropriate CoaH for CSR-strategy, light, soil moisture, acidity and fertility. Therefore, each species will be assigned to five different environmental CoaHs (see Table 5.8) giving a CoaH-signature for the site, i.e.

1. CSR-strategy
    - A. Competitors – low disturbed/low stressed environment
    - B. Stress-tolerators – stressed environment
    - C. Ruderals – disturbed environment
    - D. Competitive ruderals
    - E. Stress-tolerant competitors
    - F. Stress-tolerant ruderals
    - G. Non-extreme environment
2. Light
    - H. Shade
    - I. Semi-shade
    - J. Well lit
    - K. Very well lit
3. Soil moisture
    - L. Drier/moist
    - M. Constantly damp
    - N. Wet
    - O. Very/permanently wet

4. Soil acidity

- P. Acidic
- Q. Moderately acidic/more or less neutral

5. Soil fertility

- R. More or less infertile
- S. Intermediate fertility
- T. Richly fertile.

Each of the five environmental conditions will include a CoaH which will contain the majority of species from the site. These CoaHs are indicative of the predominant conditions of the site in relation to single environmental conditions. For example, if a large number of species can be assigned to CoaH-H (shaded) and the remaining species occur in CoaH-I and K, the site will be predominantly heavily shaded with localised areas of semi-shade and very well-lit conditions. In some cases, more than one CoaH may be equally represented, in which case there will be primary and secondary CoaH-signatures.

Where the number of species associated with particular CoaHs is low, it could be considered unlikely that the group of species represents specific localised intra-site variation. However, it must be taken into consideration that such groups may comprise strong competitors, have a clonal habit or be locally dominant in a particular season, and therefore create a monocultural stand. For example, *Mercurialis perennis* may be the only species representing CoaH-D, H, M, Q and/or T, so conditions described by these CoaHs may be dismissed as not occurring across much extant on site. However, *Mercurialis perennis* can form extensive stands and, therefore, the conditions can be significant to the woodland. As discussed in previous Chapters, Ellenberg indictor values (from which CoaHs are derived) are for the species optimum conditions, but plants can also occur in conditions outside their optimum indicator value type condition. Therefore some species in the groups are likely to occur in transitional conditions or in sub-optimal conditions along the environmental gradient.

<u>Step 3.3: Identifying potential new environmental conditions</u>

CoaHs can also be used to describe potential conditions within a woodland. In this situation, rather than using the species to determine the CoaHs present, the characteristics that the CoaHs represent are used. It can then, theoretically, be possible to predict which species may establish within a woodland (assuming, all other factors influencing plant occurrence, e.g. seed source, are correct/available) if existing conditions are altered to the new conditions.

Step 3.4: Reviewing potential environmental conditions

When creating new woodland, the MDT may identify a number of feasible management options that subsequently identify a choice of CoaH signatures with contrasting conditions, for example, options may be available for both infertile and fertile soils. If such situations arise, further site investigation may be necessary to determine which CoaHs would be more appropriate, e.g. in terms of situation or economics; it is unlikely to be cost effective to create a low fertility woodland in a floodplain which regularly receives fertile silt deposits.

Step 4.1 and 4.2: Identifying compatible management for the environmental conditions

Table 8.6 (as in Table 8.5, split into two for clarity) lists each CoaH that has potential to occur within a woodland, and management options which will either promote or have a negative affect on such conditions, or are neither promoting, nor degrading, to the condition. If a condition is to be maintained, management options that have neither a promoting, nor a negative effect, are considered most appropriate. However, if a condition is to be enhanced or created, then management options that have a positive impact on the condition are more appropriate.

MDT Objective 1: In this situation CoaHs are used to describe the existing conditions of a woodland (Step 3.1 and 3.2). Therefore, there is a need to look at management options which retain such conditions, not necessarily those which promote them. For example, if a site is already wet, although blocking drains is indicated as being compatible with wet sites, making the site wetter by blocking drains may result in the loss of the current conditions and species.

MDT Objective 2: There may be situations where it would be appropriate to implement management that changes the current conditions. If there are very few different CoaHs within the site and the management aim is to increase diversity, management that results in different conditions could be implemented. For example, although continuous cover may be compatible with woodland dominated by CoaH-H (shade), by implementing selective felling (counterproductive for shaded conditions) could increase the diversity by creating conditions suitable for species of CoaH-J (well lit). In these situations, rather than using the groundflora occurring in the woodland to identify CoaHs, one would look at the conditions that the CoaHs describe, e.g. well lit or wet, and look for the management options (Table 8.6) that promote such conditions. If at least some species associated with the desired CoaH occur either within the woodland already or, within the dispersal zone for such species, it could be expected that such species will increase, or colonise, the new conditions created as a result of the management.

MDT Objective 3: In this situation, the conditions represented by the CoaHs are used rather than using the component species to identify the CoaHs and Table 8.6 is used to review the management options determined in Step 7.2.

Management / CoaH	Intensive		Traditional		Sensitive/mimic				None/limited		Hybrid
	Clearfell/ re-stock	Selective felling	Coppice	Coppice + standards	Grazed	Uniform shelterwood	Continuous cover	Artificial windblow	Non-intervention	Minimal intervention	
Competition/disturbance											
CoaH-A	=	=	=	=	+/-	=	=	=	+	=	=
CoaH-B	=	=	=	=	+/-	=	=	=	=	=	=
CoaH-C	+	+	+	+	+	-	-	+	-	-	+
CoaH-D	+	+	+	+	+	+	+	+	-	-	+
CoaH-E	-	=	=	=	+	=	=	+	+	+	=
CoaH-F	+	+	+	+	+/-	=	=	+	-	-	+
CoaH-G	-	=	-	-	-	+	+	-	=	=	=
Light											
CoaH-H	-	-	+	+	-	+	+	-	+	+	+
CoaH-I	-	=	+	+	=	+	+	=	+	+	+
CoaH-J	=	+	+	+	+	-	-	+	-	-	+
CoaH-K	+	=	+	+	=	-	-	=	-	-	+
Soil moisture											
CoaH-L	=	=	+	+	=	=	=	=	=	=	+
CoaH-M	=	=	=	=	=	=	=	=	=	=	=
CoaH-N	+	+	+	+	+	=	=	=	=	=	+
CoaH-O	+	+	+	+	+	=	=	+	=	=	+
Soil acidity											
CoaH-P	=	=	+	+	=	=	=	=	=	=	+
CoaH-Q	=	=	=	=	=	=	=	=	=	=	=
Soil fertility											
CoaH-R	=	=	=	=	-	=	=	=	=	=	=
CoaH-S	=	=	+	+	+	=	=	=	=	=	+
CoaH-T	=	=	=	=	+	=	=	=	=	=	=

Table 8.6a Summary of compatibility of different management techniques that are appropriate for lowland *Alnus glutinosa* woodland. '+' indicates a positive affect, '-' indicates a negative effect, '=' indicates the effects are neither strong promoting nor detrimental of the CoaH conditions – tree management

Management / CoaH	Natural regeneration	Restoration	Flood defence banks adjacent to site	River control upstream	Clearance/ creation of drains	Control of water flow through drains within site	Reduced flood defences so increased flood events	Blocking existing drains
Competition/disturbance								
CoaH-A	+	-	+	+	-	+/-	-	-
CoaH-B	-	+/-	+	+	+	+/-	+	+
CoaH-C	-	+	-	-	=	+/-	+	=
CoaH-D	=	=	=	=	=	=	+	=
CoaH-E	=	=	=	=	=	=	-	=
CoaH-F	=	=	=	=	=	=	+	=
CoaH-G	+	-	+	+	-	=	-	-
Light								
CoaH-H	=	-	=	=	=	=	=	=
CoaH-I	+	+	=	=	=	=	=	=
CoaH-J	-	+	=	=	=	=	=	=
CoaH-K	-	+/-	=	=	=	=	=	=
Soil moisture								
CoaH-L	=	+/-	+	+	+	+/-	-	-
CoaH-M	=	+/-	=	=	=	+/-	=	+
CoaH-N	=	+/-	-	-	-	+/-	+	+
CoaH-O	=	+/-	-	-	+	+/-	+	+
Soil acidity								
CoaH-P	=	=	=	=	=	=	=	+
CoaH-Q	=	=	=	=	=	=	=	=
Soil fertility								
CoaH-R	=	=	=	=	+	+/=	-	-
CoaH-S	=	=	=	=	=	=	=	=
CoaH-T	=	=	+	-	-	+/-	+	+

Table 8.6b Summary of compatibility of different management techniques that are appropriate for lowland *Alnus glutinosa* woodland. '+' indicates a positive affect, '-' indicates a negative effect, '=' indicates the effects are neither strong promoting nor detrimental of the CoaH conditions – feature and regeneration management

Steps 5 and 6: Identifying management aims and compatible management options

A number of aims, specific to situations that may occur in lowland *Alnus glutinosa* woodland, and compatibility of different management techniques are detailed in Table 8.7 (as in Table 8.5, split into two for clarity). This Table is not exhaustive but provides a starting point when considering management aims of lowland *Alnus glutinosa* woodland.

Management aim \ Management option		Intensive		Traditional		Sensitive/ mimic				None/ limited		
		Clearfell/ re-stock	Selective felling	Coppice	Coppice + standards	Grazed[1]	Uniform shelterwood	Continuous cover	Artificial windblow	Non-intervention	Minimal intervention	Hybrid
Avoiding dominance	*Acer pseudoplatanus*		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Rubus fruticosus		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reducing dominance/ competitive exclusion of woodland species	*Rubus fruticosus*		✓	✓	✓	✓	✓	✓		✓	✓	✓
	Urtica dioica		✓	✓	✓	✓	✓	✓		✓	✓	✓
	Rhododendron spp.	✓	✓	✓	✓	✓	✓	✓	✓			✓
	Aggressive herbs, e.g. *Urtica dioica, Poa trivialis, Galium aparine*		✓	✓	✓	✓	✓	✓		✓	✓	✓
	Invasive non-native spp.	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Encouraging natural regeneration	*Alnus glutinosa*		✓			✓			✓			✓
	General		✓			✓	✓	✓	✓	✓	✓	✓
Timber	*Alnus glutinosa*	✓	✓	✓	✓	✓	✓	✓	✓			✓
	Fraxinus excelsior	✓	✓	✓	✓	✓	✓		✓			✓
Diversity in general	Creation of seed bed	✓	✓			✓			✓			✓
	High diversity/ increase groundflora diversity	✓	✓	✓	✓	✓	✓	✓	✓			✓
	Increase shrub cover	✓	✓	✓	✓		✓	✓	✓			✓
	Varied structure & groundflora		✓	✓	✓	✓		✓	✓			✓
	Increase natural character through removal of non-natives (non-invasive)	✓	✓									✓
Alter conditions	Increase wetness											
	Decrease wetness											
	Increase light	✓	✓	✓	✓	✓			✓			✓
	Decrease light						✓	✓		✓	✓	

Table 8.7a Summary of compatibility of different management techniques for specific management aims (see Table 8.3) for lowland *Alnus glutinosa* woodland – tree management

Management aim	Management option	Natural regeneration	Restoration	Flood defence banks adjacent to site	River control upstream	Clearance/ creation of drains	Control of water flow through drains within site	Reduced flood defences so increased flood events	Blocking existing drains
Avoiding dominance	*Acer pseudoplatanus*		✓				✓	✓	✓
	Rubus fruticosus		✓				✓	✓	✓
Reducing dominance/ competitive exclusion of woodland species	*Rubus fruticosus*		✓				✓	✓	✓
	Urtica dioica		✓				✓	✓	✓
	Rhododendron spp.		✓				✓	✓	✓
	Aggressive herbs, e.g. *Urtica dioica, Poa trivialis, Galium aparine*		✓				✓	✓	✓
	Invasive non-native spp.		✓	Species dependant					
Encouraging natural regeneration	*Alnus glutinosa*	✓	✓				✓	✓	✓
	General	✓	✓	✓	✓	✓	✓	✓	✓
Timber	*Alnus glutinosa*	✓	✓				✓	✓	✓
	Fraxinus excelsior	✓	✓	✓	✓	✓	✓	✓	✓
Diversity in general	Creation of seed bed	✓	✓				✓	✓	✓
	High diversity/ increase groundflora diversity	✓	✓	✓	✓	✓	✓	✓	✓
	Increase shrub cover	✓	✓	✓	✓	✓	✓	✓	✓
	Varied structure & groundflora	✓	✓	✓	✓	✓	✓	✓	✓
	Increase natural character through removal of non-natives (non-invasive)	✓	✓				✓	✓	
Alter conditions	Increase wetness	✓	✓				✓	✓	✓
	Decrease wetness	✓	✓	✓	✓	✓	✓	✓	
	Increase light	✓	✓	✓	✓	✓	✓	✓	✓
	Decrease light	✓	✓	✓	✓	✓	✓	✓	✓

Table 8.7b Summary of compatibility of different management techniques for specific management aims (see Table 8.3) for lowland *Alnus glutinosa* woodland – feature and regeneration management

Step 7.1: Determining the most appropriate management – existing woodland

For existing woodlands, the final management options most appropriate for any given woodland will be compatible with the answers to all of the key questions posed at the start of this section, i.e.

1. What are the physical constraints that cannot be altered? (Steps 1 and 2, Figure 8.2)
2. What are the existing (MDT Objective 1) or desired (in the case of enhancement: MDT Objective 2) environmental conditions? (Steps 3 and 4, Figure 8.2)
3. What are the management aims of the woodland? (Steps 5 and 6, Figure 8.2).

If a situation occurs where there is not a management technique which is compatible with all three questions, a compromise may need to be made or the management aims of the woodland reviewed. Alternatively it may be appropriate to implement different management options in stages. Where non-native invasive species are present, appropriate restoration techniques are likely to be necessary regardless of the compatibility of other conditions within the site.

<u>Step 7.2: Determining the most appropriate management – creating woodland</u>

When creating new woodlands the three questions posed at the start of this section are considered in a different order:

1. What are the physical constraints that cannot be altered? (Steps 1 and 2, Figure 8.2) (Question 1)
2. What are the management aims of the woodland? (Steps 5 and 6, Figure 8.2) (Question 3)
3. What are the potential environmental conditions? (Step 3, Figure 8.2) (Question 2).

The management options most appropriate for any given woodland will be compatible with the answers to key questions 1 and 3.

<u>Step 8: Determining which species may establish</u>

Once appropriate management and likely environmental conditions have been determined it is possible to use the CoaHs to identify which species would be suited to the targeted creation conditions. It would be expected that species, either planted/seeded, or naturally occurring, within the dispersal zone, would colonise the conditions created. However, further investigation would be needed as other factors need to be taken into consideration that are not necessarily readily, or economically, created by implementation of management considered in the current research, e.g. existing soil conditions, seed sources.

8.6.2 Management decision process: Stonebridge

The eight step process described in Section 8.6.1 and illustrated in Figure 8.2 is demonstrated for the case of maintaining conditions (MDT Objective 1) in this section using the three lowland *Alnus glutinosa* woodlands at Stonebridge (see Chapter 6):

Step 1: Table 8.8 details the general characteristics and constraints of each site.

Step 2: Table 8.10 details management options compatible with the constraints and character of each site (Management Option List 1).

Step 3: Figure 8.3 illustrates the environmental conditions of each site, based on the presence of species (Appendix 13). The CoaH-signatures for each site are:

- Site A: 1^0 CoaH-DJMQS; 2^0 CoaH-CIL
- Site B: 1^0 CoaH-DJMQS; 2^0 CoaH-AINT
- Site C: 1^0 CoaH-DJMQS; 2^0 CoaH-CILT.

Step 4: Table 8.10 details management options compatible with these environmental characteristics (Management Option List 2).

Step 5: Table 8.9 details the specific situations/appropriate management aims for each of the woodlands.

Step 6: Table 8.10 details management options compatible with the management aims of each site (Management Option List 3).

Step 7: Table 8.10 details the final list of management options appropriate for each site.

Step 8: NA because step relates to creation/promotion which is not a current management aim at Stonebridge.

Table 8.10 shows that, based on the details provided in Tables 8.8 and 8.9 and Figure 8.3, the following management options are appropriate and least likely to have a negative impact on the existing conditions:

<u>Site A:</u> Hybrid (if re-growth is protected from current grazers), selective fell and artificial windblow. The site is predominately constantly moist, but has a significant proportion of species associated with drier conditions as well as some associated with wet conditions. Therefore, any alteration of drains and water on site would potentially shift this balance but is unlikely to be detrimental to the overall variety within the site. Grazing already takes place within the site and as such has not been identified as a management option for implementation. To maintain conditions, grazing should continue at the current level.

<u>Site B:</u> Hybrid and selective fell. Appropriate restoration techniques are necessary to control the invasive species, *Impatiens glandulifera*. The site is more, or less, equally dominated by species associated with constantly moist, drier and wetter conditions. Therefore, although altering the drainage and water within the site would potentially shift this balance it is unlikely to be detrimental to the overall variety within the site.

Site C: Hybrid, selective fell and grazing. Appropriate restoration techniques are necessary to control the invasive species, *Impatiens glandulifera*. The site is co-dominated by species associated with constantly moist and drier although there is a significant proportion of species associated with wetter conditions. Although unlikely to be detrimental to the overall variety within the site, any alteration of drains and water on site would potentially shift this balance.

Character	Option	Site A	Site B	Site C
Isolated in the landscape (choose 1)	**yes**			
	no	✓	✓	✓
Confined by urbanisation (choose 1)	**yes**			
	no	✓	✓	✓
Labour source available (choose 1)	**yes**	✓	✓	✓
	no			
Market for products available (choose 1)	**yes**			
	no	✓	✓	✓
Main adjacent habitats (choose all that apply)	**urban/amenity**			
	woodland			
	grassland/heath (grazable, i.e. not amenity)	✓	✓	✓
	arable			
Naturalness state (choose all that apply)	**invasive species present**		✓	✓
	high proportion non-natives in canopy			
	predominately semi-natural and appropriate species	✓	✓	✓
Age (choose 1)	**old**	✓	✓	✓
	young			
History (choose 1)	**Ancient**			
	Recent	✓	✓	✓
Time lapse since last management	**<50 years**	✓	✓	✓
	> 50 years			
Size	**< 4 ha**	✓	✓	✓
	> 4 ha			
Grasses dominate groundflora	**Yes**	✓		✓
	No		✓	
Current grazing level (choose 1)	**Low**		✓	✓
	Moderate	✓		
	High			

Table 8.8 General characteristics and constraints of lowland *Alnus glutinosa* woodlands at Stonebridge

Management aim		Site A	Site B	Site C
Avoiding dominance	*Acer pseudoplatanus*	NA		
	Rubus fruticosus	✓	✓	✓
Reducing dominance/ competitive exclusion of woodland species	*Rubus fruticosus*	NA		
	Urtica dioica	NA	✓	✓
	Rhododendron spp.	NA		
	Aggressive herbs, e.g. *Urtica dioica, Poa trivialis, Galium aparine*	NA	✓	✓
	Invasive non-native species	NA	✓	✓
Encouraging natural regeneration	*Alnus glutinosa*	✓	✓	✓
	General	✓	✓	✓
Timber	*Alnus glutinosa*	NA		
	Fraxinus excelsior			
Diversity in general	Creation of seed bed	✓	✓	✓
	High diversity/increase groundflora diversity	✓	✓	✓
	Increase shrub cover	✓	✓	✓
	Varied structure and groundflora	✓	✓	✓
	Increase natural character through removal of non-natives (non-invasive)	NA		
Alter conditions	Increase wetness	NA		
	Decrease wetness			
	Increase light			
	Decrease light			

Table 8.9 Specific management aims (see Table 8.3) that are appropriate for the lowland *Alnus glutinosa* woodlands at Stonebridge, based on their current conditions

Management Option Lists at each Site / Management Option (trees)		Site A			Site B			Site C		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Intensive	**Clearfell/re-stock**									
	Selective felling	✓	✓	✓	✓	✓	✓	✓	✓	✓
Traditional	**Coppice**		✓			✓			✓	
	Coppice + standards		✓			✓			✓	
Sensitive/ mimic	**Grazed**		✓	✓		✓	✓	✓	✓	✓
	Uniform shelterwood	✓			✓			✓		
	Continuous cover	✓			✓			✓		
	Artificial windblow	✓	✓	✓	✓	✓		✓	✓	
None/ limited	**Non-intervention**									
	Minimal intervention	✓								
Hybrid		✓	✓	✓	✓	✓	✓	✓	✓	✓
Management Option (features/regeneration)										
Natural regeneration					✓			✓		
Restoration			✓	✓	✓		✓		✓	✓
Flood defence banks adjacent to site		✓			✓			✓		
River control upstream		✓			✓			✓		
Clearance/creation of drains		✓			✓			✓		
Control of water flow through drains within site		✓	✓	✓	✓	✓	✓	✓	✓	✓
Reduced flood defences so increased flood events				✓	✓		✓	✓		✓
Blocking existing drains				✓	✓		✓	✓		✓

Table 8.10 Management Options Lists 1-3, determined from data provided in Tables 8.8 and 8.9 and Figure 8.3, for the lowland *Alnus glutinosa* woodlands at Stonebridge. Shaded cells indicate management options compatible with all three Management Options Lists

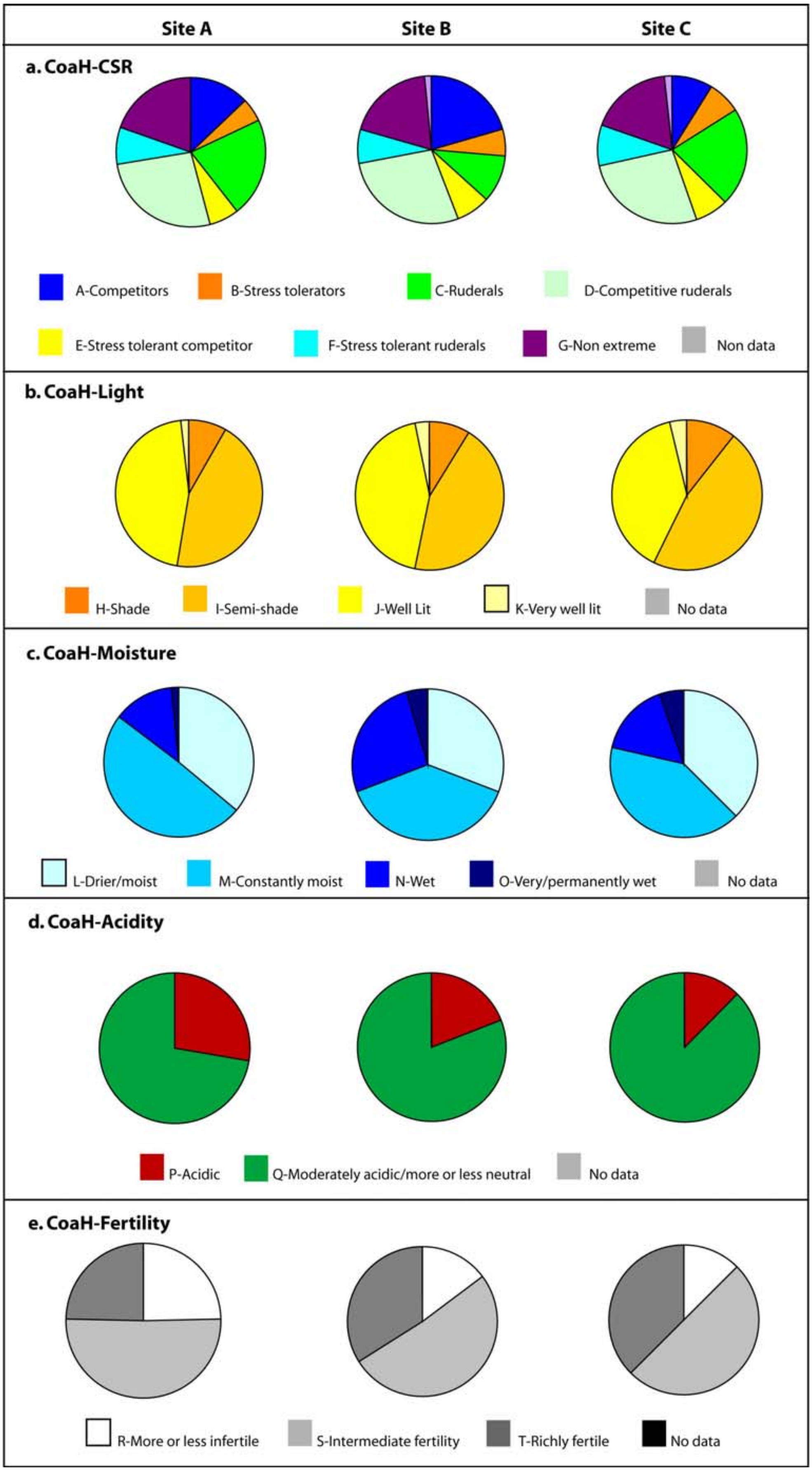

Fig. 8.3 Component CoaHs of the three distinct sites in Stonebridge - Sites A-C. Each pie chart comprises species associated with each CoaH based on presence/absence data collected during the current research (see Appendix 13)

8.7 CONCLUSIONS OF DETERMINING APPROPRIATE MANAGEMENT FOR LOWLAND *ALNUS GLUTINOSA* WOODLANDS

Traditionally wet woodlands, including *Alnus glutinosa*, were likely to have been managed, although at a low input management, because of their location and wet ground conditions. Where conditions allowed, these woodlands were most likely to have been managed on a coppice system or grazed as part of floodplain meadows. Despite this, the current view (e.g. Miller, 2003) is that these woodlands may be best left unmanaged. As a result of the current research, this school of thought is challenged in this thesis and it is proposed, that some degree of management is necessary for the following reasons:

- the mobile/transient nature of the habitat
- locations within the landscape
- adjacent land use pressure restricting natural expansion and contraction
- maintain and where appropriate promote biodiversity.

However, it is equally proposed that, given the small size, fragmented distribution and wet ground conditions of *Alnus glutinosa* woodlands, low intensity/sensitive management is most appropriate. As such, it is recommended that non-intervention management is inappropriate for most lowland *Alnus glutinosa* woodlands and they can fall into two categories in relation to management:

1. low impact/sensitive techniques;
2. coppice systems.

The observations discussed in the literature (Section 2.4) support the view that management of woodland should, given the constraints of location and woodland use, mimic natural processes if they are to remain as near to a self-regulating ecosystem as possible. The optimal light levels of species associated with lowland *Alnus glutinosa* woodland (i.e. Ellenberg indicator values 6 to 8: well lit to high light levels where relative illumination in summer is <40% (Hill *et al.*, 2004)) also indicate that management which results in dense shade is less appropriate. High light levels/opening in the canopy (or available adjacent land), in conjunction with moist soils and disturbance, are also necessary for natural regeneration of the main canopy species, i.e. *Alnus glutinosa* (e.g. McVean, 1953).

It has been shown that both the history and the dynamic nature of a habitat are material considerations when determining an appropriate management regime for a woodland.

Therefore it is proposed that lowland *Alnus glutinosa* woodlands should be managed for the present but with opportunities for the future, while taking the immediate past into consideration. Management should be flexible and allow for the natural cycles of the habitat wherever feasible. The approach for managing such woodlands should follow the same principles as landscape scale management/restoration, but at a scale appropriate for the mobile mosaic of conditions within a site.

However, it is noted that each woodland should be considered on an individual basis and its specific intra-site variation taken into account; as Lindenmayer *et al.* (2006. p.343), referring to woodlands in general, stated, there are no "*management "shortcuts" such as indicator species, focal species and threshold levels of vegetation cover may be of limited generic value*". Although short-cuts may be inappropriate, it is feasible to use features, such as those listed by Lindenmayer *et al.*, to guide management in the right direction.

Section 8.5 demonstrated that a number of management techniques are compatible with different conditions, described by CoaHs, found in lowland *Alnus glutinosa* woodlands. Section 8.6 subsequently confirmed that CoaHs can successfully be used to help determine appropriate management for lowland *Alnus glutinosa* woodlands for three separate situations:

1. Describing existing conditions
2. Identifying conditions which may be promoted or negatively impacted through management
3. Identifying/predicting species that are likely to occur if certain conditions are created.

Although, CoaHs (and NoaHs) can describe and demonstrate the variability within the woodland, the scale of variability may be such that it is not practical to manage individual areas of different conditions. For example, Site B at Stonebridge has at least 14 different CoaHs (and five different NoaHs) within an area of *c.* 10 x 40 m with only about six canopy trees; see Figure 7.22. Therefore, in terms of management, rather than identify techniques suitable for the different conditions and implementing them in small pockets of a site, it is perhaps more significant to avoid techniques that are counterproductive/non-compatible with existing, or desired, conditions described by the significant CoaHs. Techniques that are counterproductive to CoaHs represented by a few species that are gregarious and have the potential to form extensive stands on site should also be avoided. For example, if a site is currently wet it would not be advisable to clear out the drains, unless there was a clear over-riding reason to do so. In support of this, woodlands (generically) have not historically been micro-managed, yet they remain as diverse habitats.

In summary, management needs to be compatible with the range of conditions, which can be determined by the identification CoaHs and NoaHs, within the site.

9. CONCLUSIONS AND REVIEW OF THE RESEARCH PROJECT

9.1 Synopsis of the Research

This research project considered the plant ecology of lowland *Alnus glutinosa* woodland in the UK and the implications, on the management of a site, of species:

- composition,
- growth requirements and
- distribution within woodland.

A contract with Severn Trent Water and The National Forest (Miller, 2004) with which the author was involved (see Appendix 1), determined, despite wet woodlands being of high ecological interest, that there was, in relation to other woodland types, a comparatively low knowledge base with respect to their character and management. A scoping questionnaire was devised and distributed to approximately 30 woodland owners and managers of a range of woodland types, from nature reserves through to commercial forestry. The results of this questionnaire have provided supporting data to the literature searches and data analyses conducted for the current research project. The changing state of woodlands, with emphasis on wet and lowland *Alnus glutinosa* woodlands, within the UK and their importance to nature conservation was considered further in the literature review. The policy drivers for the value and management of woodland were also identified. This literature review (Chapter 2), focusing on the current known ecology and management of lowland *Alnus glutinosa* woodland, further guided the aims and objectives of the research.

Woodlands, particularly wet and *Alnus glutinosa* woodlands, were discussed in detail and the geographic and landscape context set for lowland *Alnus glutinosa* woodlands. As part of the discussion in Chapter 2, a number of abiotic and biotic factors were identified as having significant influences on the floristic composition of the habitat. The diversity of woodlands, notably those where *Alnus glutinosa* was a dominating feature, was discussed in relation to the most influential classifications of the last 100 years. The diversity and factors influencing floristic composition were also considered in relation to different woodland management techniques.

Chapter 3 described and provided justification of the development of the approaches taken during the research, in order to achieve the aims and objectives set out in Section 1.2. This chapter also discussed alternative options and explained why they were either not pursued or documented in detail in the current thesis.

Chapters 4 and 5 determined the dominating and potential intra-site variation of lowland *Alnus glutinosa* woodlands through detailed consideration and analysis of the optimal growing conditions (Ellenberg indictor values and CSR-strategies) of the species found to be associated with the habitat. The latter species were determined following a literature review and surveys of 64 sites across lowland Britain. In addition, the species were reviewed in relation to their association with other habitats (as described by the NVC) to illustrate the ubiquity of species and diversity of conditions associated with lowland *Alnus glutinosa* woodland. These chapters used qualitative data to provide a prediction of the character and intra-site variation of a woodland based on the groundflora component. While Chapter 4 determined and described the overall character of the target habitat, Chapter 5 considered the intra-site variation. The latter identified 20 Characteristics of a Habitat (CoaHs) and 10 Niches of a Habitat (NoaHs) that have the potential to occur within a lowland *Alnus glutinosa* woodland. The former considered a suit of conditions (disturbance, stress, light and soil moisture, acidity and fertility), described by CSR-strategies and Ellenberg indicator values, independently from one another. The NoaHs, are the result of considering all these conditions simultaneously, by multivariate analysis (TWINSPAN classification and DCA ordination). It is acknowledged while only five main factors affecting the floristic distribution and composition of lowland *Alnus glutinosa* woodland (stress/disturbance, light and soil moisture, acidity and fertility) have been considered in detail, there are an infinite number of other factors dictating the occurrence and association of plants.

Chapter 6 described three lowland *Alnus glutinosa* woodlands (Stonebridge Meadows, Warwickshire, UK) subsequently investigated, using quantitative data, in Chapter 7. These three woodlands, within about 500 m of each other, have very different characteristics as well as apparently different origins and former management:

1. Site A: Open, grazed woodland with no understory and grass dominated groundflora. Originated from meadow and unmanaged.
2. Site B: Closed woodland with understory, variety of intra-site variation of abiotic conditions and varied groundflora. Naturally established around wet seepages and unmanaged.
3. Site C: Closed woodland with minimal understorey and groundflora dominated by grasses; limited intra-site variation. Originally planted and managed for woodland products.

All sites are now managed for nature conservation.

Chapter 7, using the quantitative data gathered at the Stonebridge woodlands, verified the occurrence of CoaHs (as determined in Chapter 5) in an actual woodland. Using the same data, the NoaHs were also reviewed but required subsequent refinement to better describe conditions within real woodlands, rather than theoretical situations. Both CoaHs and NoaHs were also reviewed using qualitative data from four sites along the River Rother, Hampshire, surveyed during the course of the research when identifying species associated with lowland *Alnus glutinosa* woodland. The chapter concluded while overall characteristics of the woodland and the degree of variation, i.e. CoaHs, could fairly readily be predicted from the species occurring in woodland, specific conditions as described by NoaHs showed a greater degree of overlap. Although it was shown conditions described by NoaHs do occur in specific woodlands, as a result of the wide transition zones and species tolerances of conditions outside those described by the CSR-strategies and Ellenberg indicator values, they are of less use than the CoaHs in informing specific management decisions. Despite this, NoaHs do provide a more detailed illustration, than CoaHs, of the diversity of conditions within a specific woodland and would therefore potentially help inform management decisions.

Having identified the ecological characteristics and environmental factors driving the lowland *Alnus glutinosa* woodland ecosystem, appropriate management can be implemented. Chapter 8 brought the specific ecology and variation of such woodlands together with woodland management techniques, to identify appropriate principles, strategies and recommendations for managing lowland *Alnus glutinosa* woodland for nature conservation. Following a review of existing management techniques, a novel, hybrid technique was developed and discussed that could be appropriate for many lowland *Alnus glutinosa* woodlands. Within Chapter 8, a process, based on the CoaHs developed during the research, was described that would enable those with basic plant identification skills to determine both the dominant conditions within a woodland and the variation. Compatibility tables can then be used to determine which management techniques would be appropriate to maintain such conditions. Equally the compatibility tables could be used to look up which management techniques could best be used to alter the conditions and thereby potentially enhance the intra-site variation of existing and newly created woodland. By combining the use of CoaHs, to describe conditions, and the compatibility tables a management decision tool has been developed which can be applied to achieve one of three broad management objectives:

1. Maintain existing conditions
2. Enhance/alter existing conditions

3. Create/promote conditions in newly planted woodland.

The following section discusses how the techniques developed during this research project and the subsequent outcomes can be applied in practical terms by the landowner.

9.2 Application of the Research

9.2.1 Identifying intra- and inter-site variation

The CoaHs and NoaHs determined in Chapters 4 and 5 and refined in Chapter 7, can be used to identify the diversity of a woodland in terms of its groundflora composition and subsequently to identify variations within the environmental condition. Such variation can be considered either within a site or used to compare different sites. The CoaHs can subsequently be used in guiding appropriate management.

9.2.2 Woodland management

Although all woodlands are unique and management of a site will also be influenced by non-ecological issues, Chapter 8 developed a number of guiding principles and strategies to help managers understand their sites and implement appropriate management to the benefit of the nature conservation value. In addition, management recommendations have been made pertaining to specific situations and intra-site variation that can occur in lowland *Alnus glutinosa* woodland. These principles, strategies and recommendations focused on the ecological interest (notably flora) and value of the habitat and support the aims and objectives of national and local policy and guidelines, e.g. BAP (see Chapter 2).

Subsequently, the compatibility of different management options was reviewed and a management decision tool (MDT) developed for lowland *Alnus glutinosa* woodlands. A novel, hybrid management technique, suitable for nature conservation management for the majority of such woodlands, was developed. Although, it is acknowledged that generic management is inappropriate for the natural environment, it is hoped that this thesis, while providing some recommendations, will stimulate thought and debate for alternatives to the present attitude of ‘minimal/non-intervention’ for nature conservation, at least in wet woodlands. It is proposed (as discussed in this thesis) that such management is inappropriate for lowland *Alnus glutinosa* woodland given the spatial constraints and small size of the majority of this floodplain habitat. This is particularly the case for maintaining, as a minimum, the biodiversity value of the target habitat. Pryor and Peterken (2001) noted that for in perpetuity survival of broadleaf woodland biodiversity in general, woodlands need to have representatives of all age classes (i.e. young through mature to old) and that the smallest area, described by the "Minimum Dynamic Area" (MDA), within which all classes in the cycle can be represented is 50-100 ha. They suggest that the MDA can be reduced, e.g. to at least 20 ha, with appropriate management. Even 20 ha is much greater than the area typical of a lowland *Alnus glutinosa* woodland (4 ha), therefore as Pryor and Peterken noted for ancient woodlands (which are also typically small), long-term survival of high biodiversity is at considerable risk. Although careful and appropriate management, such as discussed in this thesis, may lower the risk of biodiversity loss, more needs to be done to retain lowland *Alnus glutinosa* woodlands, e.g. implementation of the concepts described by Lawton *et al.* (2010). This research, therefore, contributes one element to the long-term survival of the target habitat.

9.2.3 Habitat creation

The thesis has identified conditions occurring in lowland *Alnus glutinosa* woodland and how they can be managed to maintain intra-site variation. Such information can also be used to encourage the development of diverse future woodland ecosystems and guide the creation of new:

- conditions within an existing woodlands; and,
- lowland *Alnus glutinosa* woodland (one of the UK BAP targets for the habitat; see Chapter 2).

For example, it was discussed in Section 7.4.3 that micro-topography within a site provides floristic diversity by the creation of different conditions, notably relatively dry and wet areas, allowing plants with very different optimal water conditions to co-exist. Therefore, it is suggested by creating such micro-topography within a site which shows little variation, could provide opportunity for diversification, assuming a seed source is within natural dispersal distance.

The MDT developed and described in Chapter 8, includes processes for identifying management options for each of the creation situations listed above. CoaHs can be used to help identify which species are likely to colonise or, would to be appropriate to add to the groundflora, once the various environmental conditions of the site have been determined or created. It is considered that use of the MDT in woodland creation requires further development as it was not the focus of this research.

9.2.4 Monitoring change

Mountford and Chapman (1993) suggested mean Ellenberg F values can be used to detect the early stages of vegetation change, e.g. as a result of drainage. Therefore, by calculating the mean F value for a site, or part of a site, from the species present, the impacts of implementing a given management can be assessed/determined. However, there may be a delay, sometimes a significant period, in the response of species. For example, Mountford and Chapman (1993) reported that seven years following drainage, the mean F value only fell by 0.9 of a value in a meadow habitat. Similarly light, soil acidity and fertility can be monitored by changes in the species and subsequent mean Ellenberg indictor values of the site. Levels of disturbance and stress can be assessed through the mean CSR-strategy.

The techniques and methodology developed in this research for assessing the intra-site variation (C/NoaHs) can, therefore, also be used to monitor change as a result of management or natural change succession, including perhaps the effects of climate change.

9.2.5 Other habitats

It is suggested the methods developed for determining localised variation (C/NoaHs), and subsequent management, within lowland *Alnus glutinosa* woodlands can also be applied to other woodland types and potentially any other habitats, but further research would be necessary to confirm this.

9.3 Achievement and Critique of Project Aims and Objectives

This section considers the outcome of the research in relation to the aim and objectives set out in Section 1.2.

The research has shown that UK wet woodlands (including lowland *Alnus glutinosa* woodlands) are under-represented in the literature in terms of the floristic composition and management, either as a commercial commodity or for their nature conservation interest, when compared to other habitats, including woodlands. This is attributed to the fact they are generally of small spatial extent and of low commercial value, typically being managed in conjunction with adjacent habitats. Examples of the latter include: grazed if they occur in a floodplain meadow; either, neglected, or managed as adjacent timber crops within larger woodlands. It could therefore be considered a neglected resource. This balance needs to be redressed as these are important and not insignificant habitats, particularly for UK biodiversity (see UK BAP). However, being small and not economic to manage on a large scale, like the majority of woodlands, this research provides a straightforward approach to understanding the habitat and determining appropriate management to maintain and increase the value of the habitat, without necessarily high input of either time or money. The research, documented in this thesis, has collated and expanded on existing knowledge pertaining to the floristic ecology and management of a habitat highlighted as important by UK legislation, but until now largely under-represented in any specific management guidance, either for productivity or diversity.

9.3.1 Aim: develop a tool that enables appropriate management decisions to be made based on the flora and basic knowledge of a site

This aim has been met through the development of a MDT (Chapter 8), based on the following, for nature conservation management of lowland *Alnus glutinosa* woodland:

- general characteristics and constraints of the habitat/site (Chapter 4);
- groundflora component and associated environmental conditions (Chapter 5);
- guiding management principles and strategies (Section 8.2);
- recommendations and management aims for specific situations and intra-variation (Sections 8.3 and 8.4); and,
- compatibility of different management techniques (Section 8.5).

The MDT, summarised in Section 8.6, was developed following a detailed literature review, extensive data collection and data analysis using newly developed and adapted assessment methodologies (Chapters 2-7). Although the focus of this research was on the flora of the target habitat to guide management, it was found that it was also necessary to consider basic physical attributes of the site. For example, woodlands surrounded by urbanisation could not realistically be managed as non-intervention, on the grounds of health and safety, or be grazed by stock.

Given the natural variability of woodlands it is not practical, or appropriate, to provide definite management options or develop a tool based on generic principles. Therefore any tool developed would still require a certain amount of flexibility and interpretation from those managing the woodland and, therefore, the outputs of this research are considered to be a guide rather than to provide definite answers. However, such tools do provide a starting point based on sound ecological principles.

9.3.2 Objective 1: identify the general character and intra-site variation within lowland *Alnus glutinosa* woodland using, and then combining, existing tools (CSR & Ellenberg)

This objective has been met by applying the methods described in Section 3.3 and 3.4; the resultant outputs are detailed and discussed in Chapters 4 and 5. A study of the literature

(Section 3.3.4) concluded that both CSR-strategies and Ellenberg indicator values can be used:

- to describe the character of a habitat;
- to differentiate between different groups of species representing different conditions, e.g. recent and ancient woodlands;
- as substitutes for measuring environmental conditions.

For example, Orczewska (2010, p. 307) concluded that CSR-strategies and Ellenberg indicator values "*appeared to be effective in confirming differences in ecological behaviour of species from AAWS* [Ancient Alder Woodland Species] *and OAWS* [Other Ancient Woodland Species]". Orczewska (2010) for *Alnus* woodlands, and other authors for other habitats (e.g. Kirby *et al.*, unpublished), have shown these ecological species attributes can differentiate between two groups of species from similar habitats. Therefore, it is considered that they are also effective at identifying intra-site variation which would be represented by different groups of species. Although there was no evidence in the literature that CSR-strategies and Ellenberg values have been applied in this way to UK *Alnus glutinosa* woodlands, the current research was, in part, based on the assumptions listed above. The research subsequently has shown, through qualitative (four sites along the River Rother, Hampshire) and quantitative (three sites at Stonebridge, Warwickshire) data analysis (Chapters 6 and 7), that the use of both CSR-strategies and Ellenberg indicators to describe the character of a habitat and differentiate between groups of species growing in different situations, is valid for lowland *Alnus glutinosa* woodlands in the UK.

There was also no evidence in the literature that CSR-strategies and Ellenberg indicator values have been used simultaneously in any habitat. Several studies, including those on *Alnus* woodlands, have used both types of ecological attribute but not together. For example, Orczewska (2010) used both CSR-strategies and Ellenberg indicator values to review species colonisation rates in *Alnus glutinosa* woodlands in Poland. Although she detailed the species contributions to each CSR-strategy and Ellenberg value and compared *Alnus glutinosa* ancient woodland species with other ancient woodland species, she did not relate them to the character of the woodlands nor consider both simultaneously. Therefore the methods applied successfully in the current research could be seen as a pilot, and thus require further rigorous testing before the results could be accepted by the scientific community. Despite this, the simultaneous consideration of CSR-strategies and Ellenberg values (resulting in describing 10 NoaHs in lowland *Alnus glutinosa* woodlands) drew some meaningful conclusions which could be seen on the ground. However, further refinement and testing of the methodology is recommended as there was a certain degree of overlap of component species. This overlap has primarily been attributed to the fact the species will occur outside the conditions described by the CSR-strategies and Ellenberg value, which indicate the optimal conditions in which the species occur, rather than representing their tolerance ranges. As summarised above and discussed in further detail in Section 3.3.4, employing these attributes independently from one another has successfully been used by a number of authors for different habitats (see Tables 3.2 and 3.3). The current research also found that their independent use (CoaHs) was more successful, than simultaneous use (NoaHs), at describing dominant and intra-site variation of conditions.

9.3.3 Objective 2: relate the general character and intra-site variation to conditions created through management techniques

Chapters 4-7 identified and verified the use of CSR-strategies and Ellenberg indicators, both independently (i.e. CoaHs) and in combination (i.e. NoaHs), to describe the dominating character and degree of variation within a site. Combining CSR-strategies and Ellenberg indicators, and therefore using a combination of six variables that influence the composition and distribution of the groundflora communities, enabled groups of species, that occurred on the ground, to be grouped into 10 NoaHs. However, the level of detail and variability among the species (as a result of their tolerances of sub-optimal conditions) was inappropriate to guide management decisions. It was subsequently concluded that conditions determined through the use of the ecological attributes independently (i.e. CoaHs) were more consistent in different situations than when the attributes were considered simultaneously (NoaHs). Therefore, NoaHs were rejected when developing the MDT and CoaHs only were used. However, the NoaHs do give an indication of diversity, complexity and character of conditions within different sites. Therefore, the focus of Chapter 8, which relates the site's ecology to conditions created by management, was on the CoaHs rather than NoaHs.

The conditions created by various management techniques were determined through the literature review and surveying 64 sites during the course of the research. This was supplemented with the author's first hand experience gained through having carried out ecological surveys of over 300 woodlands for the Forestry Commission across England and Wales over a 3 year period and subsequent surveys in the course of ecological consultancy work. An alternative approach could have been to sample different woodlands managed in different ways, and measure the environmental variables or determine them through the use of CSR-strategies and Ellenberg values as described in Chapter 3. However, as discussed in Chapter 3, such opportunities were limited for lowland *Alnus glutinosa* woodlands.

Although, the use of NoaHs in helping to identify appropriate management was rejected, some management techniques show greater compatibility with certain CoaHs than others. For example, clear-fell techniques would create conditions better suited for light demanding species (CoaH-K) rather than those with preferences for shade (CoaH-H). It was concluded in Chapter 8 that different management techniques are compatible with different CoaHs, although some techniques may be compatible with several CoaHs of the same condition. For example, coppicing creates conditions for the whole light gradient, from well lit to shade, as result of the rotational nature of the management, i.e. recently coppiced through to mature coppice within the same woodland.

9.3.4 Objective 3: develop a tool that identifies the general character and intra-site variation using groundflora species

A process was described in Section 8.6 (Steps 3.1 and 3.2 in the MDT) that enables intra-site variation (C/NoaHs) of a site to be determined from a comprehensive list of the component groundflora species. Although, NoaHs are not subsequently used to guide management decisions, they do provide an additional layer of information describing the character and degree of variation of the site and can be identified using the same approach for the identification of CoaHs.

9.3.5 Alternative approaches to achieving the aims and objectives

In Chapter 3, a number of alternative approaches were discussed and subsequently dismissed. The most significant of which was to undertake habitat manipulation of sites, assess changes and take measurements of abiotic characteristics, e.g. light and soil conditions, rather than the theoretical approach adopted. The practicalities and feasibility of a direct approach were investigated at the beginning of the research, to determine whether sites could be found that could be manipulated/managed using different techniques and any subsequent changes in flora assessed. As discussed in Section 3.5.4 such sites were not available. Additionally, following further discussions with woodland practitioners and reviews of the literature for similar studies in other types of woodland, it was concluded that insufficient time was available during the course of a PhD to detect changes in woodland flora. However, personal observation at Stonebridge since the completion of the current research suggests that increased frequency and regularity of cutting the path along the river bank, over a two year period, has reduced the dominance of *Urtica dioica* and *Impatiens glandulifera*.

As direct manipulation and assessment was not a realistic option, sites with different management techniques were considered. To minimise other variables, such as geology and seed sources, such situations would preferably be within the same woodland or in close proximity. Again, primarily as a result of the small size of the target habitat, as well as the fact that most were not managed, it was difficult to identify sufficient sites meeting such criteria to allow replication. Stonebridge, with three sites with apparently different management histories, was the best that could be found that met these criteria. Subsequently, the more theoretical approach described in this thesis was taken to develop a tool to guide decisions regarding appropriate management.

9.4 Taking the Research Forward

It is inevitable that this research has identified areas where further knowledge would be beneficial. The following are possible lines of investigation which could take forward the understanding of the ecology and management of this under-investigated habitat:

1. Consideration of the effects of off-site management options, such as river flow control upstream.
2. Investigate the consistency of C/NoaHs in different sites.
3. Confirm the viability of using CoaHs in woodland creation.
4. Assessment of how lowland *Alnus glutinosa* woodland differs from equivalent upland habitat.

In addition, further research is required to investigate whether the methods developed here could be applied in other habitat types, to determine variation within sites and assist in management decisions.

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APPENDICES

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APPENDIX 1: PROOF OF AUTHORSHIP

MIDDLEMARCH ENVIRONMENTAL

Dr Peter Hedges
Aston University
Aston Triangle
Aston
Birmingham

5th February 2010 CO-MME-20789

Dear Peter,

Chapter 6, Management of Existing Wet Woodland - National Forest Wet Woodland Creation & Management Best Practice Report RT-MME-1050

Further to your recent request I am writing to confirm that Helen Miller (Principal Consultant, Middlemarch Environmental Ltd) was the sole author of Chapter 6 entitled Management of Existing Wet Woodland within this report written and compiled by Middlemarch Environmental Ltd.

If you have any further queries about Helen's role within the production of this report please do not hesitate to contact me.

Yours sincerely,
For and On Behalf of Middlemarch Environmental Ltd.

Phil Fermor

Dr Philip Fermor
Managing Director

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APPENDIX 2: QUESTIONNAIRE TO DETERMINE CURRENT UNDERSTANDING OF WET WOODLANDS

A2.1 SAMPLE LETTER

June 2003

Ref: WWBM03_Q06000

RE: The Response of the Biodiversity of Wet Woodlands to Differing Management Practices

Dear…

I am writing to you because I am hoping that you will be able to help with the above research project which is part of the PhD that I am undertaking at Aston University. The research is partially sponsored by Middlemarch Environmental Ltd (wholly owned subsidiary of Warwickshire Wildlife Trust), with additional support from the Wet Woodland Research Steering Group Committee (The National Forest, Severn Trent Water, Environment Agency, Forestry Commission, Hanson Aggregates and Cambridge University).

The aim of the research is to assess the biodiversity of wet woodlands in response to different management practices. This assessment will develop a methodology for predicting the outcome of management practices to obtain optimum degree of biodiversity in a given situation. It will also result in the development of guidelines for the appropriate management practice to use for a given outcome. This will aid all those involved with the management of such woodlands to understand and to conform with present and future legislation and best practice on biodiversity. This project is one of several research projects that Aston University are involved in covering many aspects of the ecology of wetland habitats.

Wet woodlands are a relatively small habitat resource in comparison to other habitats including woodlands but form an important part of larger integrated ecosystems and landscapes. Several types of wet woodland occur which can broadly be categorised into willow, alder or birch dominated woodlands. Physical characteristics such as water level, soil characteristics, pH and calcium will have key influences in determining the type of wet woodland in any one area. Wet woodlands can form under several differing situations, e.g. river corridors/floodplains, succession from fens and mires. These woodland types are summarised in Table 1 in relation to the National Vegetation Classification (NVC) (Rodwell 1991).

The Forest Authority *Forestry Practice Guide 8 The Management of Semi-Natural Woodlands: Wet Woodlands* provides a brief description of the types of semi-natural wet woodland i.e. NVC communities W1 through to W7 but for full descriptions please refer to *British Plant Communities Volume 1: Woodlands and Scrub* (Rodwell 1991).

NVC	Name/Dominant Species	Description
W1	**Willow** – bedstraw	Willow carr at edge of slow moving/standing water or in moist hollows on wet mineral soil.
W2	**Willow**-birch-reed	Willow-birch carr on peaty soils in flood plain and valley mires.
W3	**Willow**-sedge	Willow based woodland on peaty soils with base-rich/calcareous ground water forming a transition community between open water and drier land.
W4	**Birch** – purple moor grass	Birch woodland on moderately acidic peaty soils within wet hollows/seepages within acidic woodland types.
W5	**Alder**-sedge	Alder based woodland of waterlogged, base-rich and eutrophic soils. Classic swamp carr forming a transition community between open water and drier land.
W6	**Alder**-nettle	Alder dominated woodland on moist eutrophic soils in river valleys and the periphery of silting water bodies.
W7	**Alder**-ash-yellow pimpernel	Alder dominated woodland of moist to very wet, moderately base-rich and mesotrophic soils along stream valleys.

Table 1 Summary of Wet Woodland Types

They have had and still have important uses e.g. alder coppices for stakes, poplar woodlands for the matchsticks and bobbin industries and potentially have future uses, e.g. willow for biofuel, flood reduction, soil stabilisation on banks, water and sewage filtratration/purification.

Various environmental policies recognise that native woodlands are an irreplaceable resource, particularly for biodiversity. As a result the guidelines require and/or state that ecological knowledge and understanding of woodland systems is necessary in order for the polices to be implemented. A common theme through the environmental polices and guidelines and the uses of wet woodlands is restoration and sustainable or biodiversity management. In order to achieve the objectives there needs to be knowledge of how the wet woodland ecosystem functions, how biodiversity responds to management or otherwise and a method of monitoring change.

It is necessary therefore to identify knowledge and information on wet woodlands. The attached questionnaire is aimed at gaining an understanding of the current state of knowledge and use of wet woodland habitats in relation to their management. The questionnaire has been designed so that it is primarily a question of marking boxes, however the more information you can provide, particularly in the 'Any other comments' column the more meaningful the results and conclusions will be. It is not anticipated that the questionnaire will take more than about 15-30 minutes to complete. The results of the questionnaire will form a component of a paper that I am presenting at a Wetlands Conference at Borova Lada, Czech Republic in September 2003. I should be very pleased to provide a summary of these findings later in the year if you request it.

I look forward to your response and enclose a self-addressed envelope for your reply. If you would like an electronic copy please contact me at the address below.

Yours sincerely

Helen S Miller
E-mail: millerhs@aston.ac.uk
Address: C/O Middlemarch Environmental Ltd, Common Lane, Kenilworth, Warks, CV8 2EL

A2.2 QUESTIONNAIRE

Please mark appropriate boxes and indicate the NVC type if you are able, Table 1 provides a brief description of each NVC community listed

		Willow			Birch	Alder			Unknown NVC On Wet Woodland Site						Any Other Comments
		W1	W2	W3	W4	W5	W6	W7	Willow	Birch	Alder	Conifer	Native Broadleaf	Non- Native Broadleaf	(Please Specify Main Specie of unknown NVC woodland)
1	What types of wet woodland, if any, do you manage? (Please mark all which apply) If none, please complete as much of the questionnaire as possible as this information is also of value														
2	What size wet woodlands do you manage? (Please mark all which apply)														
	0-2 ha														
	2-4 ha														
	4-6 ha														
	6-8 ha														
	8-10 ha														
	10+ ha														
3	How do you currently manage your wet woodlands? (Please mark all which apply)														
	Non-intervention														
	Minimum intervention														
	Coppice														
	Coppice with standards														
	High forest														
	Selective thinning														
	Artificial ‘windblow'														
	Pollard														
	Restoration management, please provide details under ‘comments’														
	Other, please provide details under ‘comments’														

			Any Other Comments
4	What factors influence your choice of management? (Please rank in importance, 1 highest, 4 lowest etc)		
	Cost		
	Availability of guidance		
	Legislation/policy e.g. BAPs, HAPS etc		
	Access		
5	What methods/machinery do you use? (Please mark all which apply)		
	Big machinery e.g. forwarders, skidders, harvesters etc		
	Hand		
	Horse		
	Cable crane		
	Tractors		
	Other, please provide details under ‘comments’		
6	What do you manage your wet woodlands for? (Please mark all which apply)		
	Timber		
	Biodiversity/conservation		
	Specific species, please specify		
	Recreation		
	Landscape/amenity		
	Other, please provide details under ‘comments’		

			Any Other Comments
7	What ‘products ‘ do you get from your wet woodlands? (Please mark all which apply)		
	Timber (specify use e.g. logs, sold for pulp etc)		
	Firewood		
	Recreation		
	Biodiversity		
	Biofuel e.g. willow		
	Local crafts e.g. basketry, charcoal		
	Restoration		
	Others, please provide details under ‘comments’		
8	When do you carry out forestry operations in wet woodlands? (Please mark all which apply)		
	Winter		
	Spring		
	Summer		
	Autumn		
9	What constraints do you have on management of wet woodlands? (Please mark all which apply)		
	Access		
	Topography/slope		
	Size		
	Ground conditions		
	Biodiversity / conservation		
	Other, please provide details under ‘comments’		

			Any Other Comments
10	Is there financial benefit/incentive to you in wet woodlands? (Please mark all which apply)		
	Grants		
	Income		
	None		
	Other, please provide details under 'comments'		
11	Have any ecological/biological surveys been carried out? (Please mark all which apply)		
	Invertebrates		
	Birds		
	Mammals		
	Lower plants		
	Ground flora		
	Canopy		
	Understorey		
	Other, please provide details under 'comments'		
12	Can you suggest other sources of information in relation to biodiversity/ management/ management of wet woodlands?		
13	Can you suggest any one else that may be able to help with advice? Please provide details.		

			Any Other Comments
14	Are there any research opportunities within the sites that you own/manage?		
	e.g. conifer plantation returning to native broad-leaf		
	e.g. non-native broad-leaf returning to native broad-leaf		
	e.g. management trials		
	Other, please provide details under 'comments'		

May I contact you for further information? Y/N

Please feel free to forward a copy onto anyone that you think may be able to help.

Thank you for your time in responding to this questionnaire.

Helen S Miller

e-mail: millerhs@aston.ac.uk

A2.3 SUMMARY OF RESULTS OF QUESTIONNAIRE

In brief, biodiversity appears to be an important issue in relation to the management of wet woodlands.

1. What types of wet woodland, if any, do you manage?
The most frequent wet woodland type was alder based, forming about a third of the responses. Where NVC communities were identified these were mainly W6 *Alnus glutinosa-Urtica dioica.* The remaining two thirds were more or less equally split between willow, birch, conifer and native broadleaves. Only a small proportion consisted of non-native broadleaves.

2. What size wet woodlands do you manage?
The most common size range of wet woodlands was 0-4 ha. Larger woodlands were generally managed by larger companies/organisations. These woodlands were generally wet woodland sites occupied by non-native species, particularly conifers.

3. How do you currently manage your wet woodlands?
The most common current management of wet woodlands is with minimal intervention.

4. What factors influence your choice of management?
Legislation and policy was recorded as the highest influencing factor affecting the choice of management. The availability of guidance had the least influence on the choice of management.

5. What methods/machinery do you use?
The most frequent method of management was by hand. Where the woodlands formed a small pocket within a larger non-wet woodland, the wet woodland was managed in the same way as the adjacent non-wet woodland.

6. What do you manage your wet woodlands for?
Wet woodlands were most frequently managed for biodiversity and conservation and accounted for over 50% of all responses.

7. What 'products' do you get from your wet woodlands?
Biodiversity was the main 'product' obtained from wet woodlands, about a third of all responses. More traditional products, e.g. timber were less frequently obtained from the wet woodlands.

8. When do you carry out forestry operations in wet woodlands?
The usual timing for forestry operations being carried out in wet woodlands was winter/autumn and often dependant on when operations were being undertaken in the adjacent woodland.

9. What constraints do you have on management of wet woodlands?
The most frequently marked constraints were ground conditions and biodiversity/conservation.

10. Is there financial benefit/incentive to you in wet woodlands?
There is basically no financial benefit/incentive for managing wet woodlands. One comment stated that it was cheaper not to manage the wet woodland and another said that the only income was at the initial phase of restoration. Other benefits/incentives included education and BAPs/HAPs.

11. Have any ecological/biological surveys been carried out?
Various surveys have been carried out within wet woodlands, most notably vegetation.

APPENDIX 3: CHARACTERISTICS OF LOWLAND *ALNUS GLUTINOSA* WOODLANDS COMPARED TO WOODLAND CLASSIFICATIONS

Tables A3.1 to A3.3 summarise the characteristics of lowland *Alnus glutinosa* woodland compared to the characteristics of *Alnus glutinosa* woodland described by the most influential woodland classifications within the UK (see Section 2.3.2).

Classification	Location
Lowland *Alnus glutinosa* woodland	
Lowland *Alnus glutinosa* woodland	Lowland Britain, mainly adjacent, or in close proximity, to watercourses
Tansley	
Fen carr/swamp carr	Within other woodland types Periphery of marsh, water body or stream
Young carr	Fens
Valley fenwoods	Valley bottoms
Merlewood National Classifications	
Type 10	Throughout England and Wales
Type 12	Throughout England and Wales Steep valley sides
Type 14	Throughout England and Wales Valley floors
Type 15	Throughout England and Wales Moist, heavy conditions
Type 16	Throughout England and Wales Riverine locations
Type 31	Infrequent England and Wales
Peterken Stand Types	
7Aa	Valleys Shallow depressions, river terraces, margins of Type 7B Throughout Britain but rarely extensive
7Ab	Valleys Shallow depressions, river terraces, margins of Type 7B Mixed coppices inn England and Wales
7Ba	Depressions where water movement is vertical
7Bb	Springs, flushes and small streams Common in Weld, South-west England, East Anglia
7Bc	Springs, flushes and small streams Common on Wealden Sands
7C	Flat plateaus Undulating landscapes of East Anglia
7D	Middle and lower slopes where groundwater movement is below soil surface North-west Britain Fairly heavily grazed
7Ea	Shallow valley Norfolk
7Eb	Flat ground Uplands of Britain, except south-west

Table A3.1 Location characteristics of lowland *Alnus glutinosa* woodland compared to various habitat classifications (Table continues)

Classification	Location
NVC	
W5	Local but widespread, primarily of English lowlands, scattered examples in Scotland and Wales
W6	Widespread but local across British lowlands Along mature rivers and remnants of undrained floodplains and eutrophic mires
W7	Widespread but local throughout north-west upland fringes Occasionally in southern England
Rackham	
Fen	Low, level grounds of river and stream floodplains; often isolated from other woodlands
Valley	Fringes of streams, hillside flushes, springs; associated with other woodlands
Plateau	Level uplands
CVS	
VC36	Mainly in south-west England and occasionally other lowlands in England and marginal uplands
VC39	Mainly in central England with some outliers
VC46	South-west England, west Wales and the lowlands of northern Britain

Table A3.1 cont. Location characteristics of lowland *Alnus glutinosa* woodland compared to various habitat classifications

Classification	Canopy	Shrub layer	Groundflora
Lowland *Alnus glutinosa* woodland			
Lowland *Alnus glutinosa* woodland	34 species. *Alnus glutinosa*	30 species *Sambucus nigra*	269 species. *Arum maculatum*, *Dryopteris dilatata*. *Geum urbanum*, *Glechoma hederacea*, *Ranunculus ficaria*
Tansley			
Fen carr/swamp carr	Mixed but includes *Alnus glutinosa*	No data	*Urtica dioica* – prominent
Young carr	*Salix cinerea*	*Rhamnus catharicus*, *Frangula alnus*, *Viburnum opulus*	No data
Valley fenwoods	*Alnus glutinosa*, *Betula* spp., *Fraxinus excelsior*, *Salix* spp., *Populus* spp.	*Corylus avellana*, *Prunus spinosa*, *Crataegus* spp., *Salix* spp.	*Carex* spp. – notable feature
Merlewood National Classifications			
Type 10	*Fraxinus excelsior*, *Quercus* sp., *Acer pseudoplatanus*, *Betula* spp., *Salix* sp., *Alnus glutinosa*	No data	*Fraxinus excelsior*, *Rubus fruticosus*, *Dryopteris dilatata*, *Circaea lutetiana*, *Dryopteris filix-mas*
Type 12	*Fraxinus excelsior*, *Quercus* spp., *Acer*, *pseudoplatanus*, *Betula* spp., *Alnus glutinosa*	*Crataegus monogyna*	*Rubus fruticosus*, *Viola riviniana*, *Dryopteris filix-mas*; *Geum urbanum*, *Oxalis acetosella*, *Deschampsia cespitosa*
Type 14	*Fraxinus excelsior*, *Betula* spp., *Alnus glutinosa*, *Salix* spp.	*Corylus avellana*	*Chrysosplenium oppositifolium*, *Dryopteris dilatata*, *Silene dioica*, *Circaea lutetiana* , *Urtica dioica*
Type 15	*Quercus* spp. , *Fraxinus excelsior Alnus glutinosa*, *Salix* spp.	*Corylus avellana*	*Holcus lanatus*, *Cirsium palustre*, *Ranunculus repens*, *Rubus fruticosus*, *Epilobium montanum*, *Juncus effusus*, *Prunella vulgaris*
Type 16	*Fraxinus excelsior*, *Alnus glutinosa*	*Corylus avellana*	*Cirsium palustre*, *Viola riviniana*, *Athyrium filix-femina*, *Circaea lutetiana*, *Deschampsia cespitosa*, *Agrostis tenuis*, *Holcus lanatus*, *Lysimachia nemorum*
Type 32	*Betula* spp., *Alnus glutinosa*, *Salix* spp.	No data	*Angelica sylvestris*, *Filipendula ulmaria*, *Galium palustre*, *Juncus effusus*, *Salix* spp., *Epilobium palustre*, *Lychnis flos-cuculi*, *Mentha aquatica*

Table A3.2 Characteristic species of lowland *Alnus glutinosa* woodland compared to various habitat classifications (Table continues)

Classification	Canopy	Shrub layer	Groundflora
Peterken Stand Types			
7Aa	*Alnus glutinosa*, *Betula pubescens* Occasional standards: *Quercus robur*. Frequent: *Acer pseudoplatanus*, *Ilex aquifolium*, *Sambucus nigra*	Coppice: *Betula pubescens*, *Corylus avellana*, *Alnus glutinosa* *Salix cinerea*	*Lonicera periclymenum*, *Rubus fruticosus*, *Pteridium aquilinum*, *Dryopteris* spp. *Holcus* spp. abundant in grazed woods
7Ab	*Alnus glutinosa*, *Betula pubescens* Standards: *Quercus* spp., *F. excelsior*.	*Acer campestre*, *Rosa arvensis*, *Ulmus glabra* Coppice: *Alnus glutinosa*, *Corylus avellana*, *Fraxinus excelsior*	Generally rich although with few/no dominants. *Allium ursinum*, *Ajuga reptans*, *Anemone nemorosa*, *Arum maculatum*, *Athyrium filix-femina*, *Brachypodium sylvaticum*, *Cardamine flexuosa*, *Carex pendula*, *C. remota*, *C. sylvatica*
7Ba	*Alnus glutinosa*	No data	Shaded marsh vegetation
7Bb	*Alnus glutinosa*	No data	Shaded marsh vegetation *Cardamine amara*, *Carex acutiformis*, *C. strigosa*, *Chrysosplenium alternifolium*, *C. Oppositifolium*, *Valeriana dioica*
7Bc	*Alnus glutinosa*	No data	Shaded marsh vegetation *Carex laevigata*, *Chrysosplenium oppositifolium*, *Sphagnum palustre*
7C	*Alnus glutinosa*, *Betula pubescens*, *Fraxinus excelsior*, *Quercus robur* Standards: *Quercus* spp., *F. excelsior* or *Betula* spp.	*Corylus avellana*, *Acer campestre*, *Crataegus monogyna*, *Lonicera periclymenum*, *Salix cinerea* Coppice: *Alnus glutinosa*, *C avellana*, *F. excelsior* with some *Betula* spp., *Acer* spp., *Quercus* spp.	No data
7D	*Alnus glutinosa*, *Betula pubescens*	*Corylus avellana*, *Fraxinus excelsior*, *Prunus padus*, *Salix aurita*, *Sorbus aucuparia*, *Ulmus glabra* Coppice: *C. avellana*, *Alnus glutinosa*, *F. excelsior*, *Betula* spp.	Intimate mixture with few/no dominants

Table A3.2 cont. Characteristic species of lowland *Alnus glutinosa* woodland compared to various habitat classifications (Table continues)

Classification	Canopy	Shrub layer	Groundflora
7Ea	*Alnus glutinosa*, *Quercus* spp., *F. excelsior*, *Prunus padus*, *Betula pubescens*, *Sorbus aucuparia* Lacks *A. glutinosa* on drier ground.	*Corylus avellana*, *Lonicera periclymenum*, *Salix cinerea* Coppice: *A. glutinosa*, *P. padus*, *C. avellana*.	No data
7Eb	*Alnus glutinosa*, *Betula pendula*, *Fraxinus excelsior*	*Ulmus glabra* Coppice: *Alnus glutinosa*	No data
NVC			
W5	*Alnus glutinosa*, *Fraxinus excelsior*, *Salix cinerea*	No data	*Carex* spp., *Phragmites australis*, *Urtica dioica*, *Dryopteris* sp., *Athyrium filix-femina*
W6	*Alnus glutinosa*, *Salix* spp., *Betula* spp.	*Salix cinerea*, *Crataegus monogyna*	*Urtica dioica*
W7	*Alnus glutinosa*, *Fraxinus excelsior*, *Salix* spp. *Betula* spp.	*Corylus avellana*, *Salix* spp.	*Juncus* spp., grasses, *Carex* spp.
Rackham			
Fen	*Alnus glutinosa*	No data	*Chrysosplenium oppositifolium*, *Cardamine flexuosa*, *Adoxa moschatellina*
Valley	*Alnus glutinosa*	No data	*Carex pendula*, *Humulus lupulus*, *Solanum dulcamara*, *Calystegia sepium*, *Urtica dioica*, *Digitalis purpurea*
Plateau	*Alnus glutinosa*	No data	*Allium ursinum*, *Equisetum telmateia*
CVS			
VC36	*Alnus glutinosa*	No data	*Hedera helix*, *Rubus fruticosus*, *Geranium robertianum*, *Chrysosplenium oppositifolium* and *Phyllitis scolopendrium*
VC39	*Alnus glutinosa*, *Fraxinus excelsior*, *and Acer pseudoplatanus*	No data	*Mercurialis perennis*, *Circaea lutetiana*, *Veronica montana*, *Athyrium filix-femina* and *Allium ursinum*
VC46	*Alnus glutinosa*	No data	*Agrostis stolonifera*, *Rubus fruticosus*, *Urtica dioica*, *Oxalis acetosella*, *Geranium robertianum*, and *Chrysosplenium oppositifolium*

Table A3.2 cont. Characteristic species of lowland *Alnus glutinosa* woodland compared to various habitat classifications

Classification	Moisture	Acidity	Fertility
Lowland *Alnus glutinosa* woodland			
Lowland *Alnus glutinosa* woodland	Moist to wet	More or less neutral	Intermediate to richly fertile
Tansley			
Fen carr/swamp carr	Water logged peat	Moderately acidic	-
Young carr	No data	No data	No data
Valley fenwoods	Wet, peaty	No data	No data
Merlewood National Classifications			
Type 10	No data	Acidic	No data
Type 12	No data	Medium	No data
Type 14	Includes surface water	Medium	Eutrophic
Type 15	Moist	Medium	Likely to be rich – alluvium
Type 16	Flushed lateral movement	Medium	No data
Type 32	Some surface water	Medium	Likely to be rich – alluvium
Peterken Stand Types			
7Aa	Fairly dry At least seasonally moist	Acidic	No data
7Ab	Fairly dry Usually free-draining	Medium	Limited humus accumulation
7Ba	Water permanently or seasonally at surface	No data	No data
7Bb	Water permanently or seasonally at surface	Neutral to alkaline	No data
7Bc	Water permanently or seasonally at surface	Medium	No data
7C	Poorly drained with seasonally high water table	No data	No data
7D	No data	Acidic to neutral	Mull humus
7Ea	Free-draining	Acidic to neutral	Mull humus
7Eb	Permanently water logged	Neural	High proportion of organic matter
NVC			
W5	Wet/water logged	Base-rich	High
W6	Moist	No data	High
W7	Moist to very wet	Moderately base-rich	Low-moderate
Rackham			
Fen	Wet	Range	No data
Valley	Fairly dry	No data	No data
Plateau	No data	Moderately acidic	No data
CVS			
VC36	No data	No data	No data
VC39	No data	No data	High
VC46	No data	No data	No data

Table A3.3 Soil characteristics of lowland *Alnus glutinosa* woodland compared to various habitat classifications

APPENDIX 4: SITES SURVEYED TO DETERMINE SPECIES ASSOCIATED WITH *ALNUS GLUTINOSA* WOODLAND

Table A4.1 lists the sites where species were recorded to determine the species associated with lowland *Alnus glutinosa* woodland. Tables A4.2 to A4.36 lists the species recorded at each of the 64 sites surveyed during the course of this research (NB Stonebridge has been excluded and is provided in Appendix 13).

Site	County	Nearest settlement	Total No. species recorded	Survey dates
Berrington Pool 4	Herefordshire	Leominster	8	04/02/05
Berrington Pool 5	Herefordshire	Leominster	12	
Berrington Pool 6	Herefordshire	Leominster	10	
Blakemere	Herefordshire	Blakemere	32	08/02/05
Byton & Coombe Moors 4	Herefordshire	Byton	11	11/02/05
Cage Brook	Herefordshire	Clehonger	28	04/02/05; 08/02/05
Carvers Rock	Derbyshire	Swadlincote	80	02/08/04
Clowes A	Warwickshire	Foreshaw Heath	55	05/02/04; 23/02/04; 17/04/04; 30/08/04; 21/05/05; 28/03/05; 22/07/07
Clowes B	Warwickshire	Foreshaw Heath	21	
Clowes C	Warwickshire	Foreshaw Heath	60	
Cornerways	Warwickshire	Coventry	27	02/05/05
Coughton 4	Herefordshire	Coughton	15	08/02/05
Coughton 7	Herefordshire	Coughton	14	
Coughton 8	Herefordshire	Coughton	4	
Elmdon Park	Warwickshire	Solihull	34	07/07/04
Feckenham	Worcestershire	Feckenham	33	22/02/04; 09/05/04; 08/10/04; 21/01/05; 25/03/05
Godalming	Surrey	Godalming	51	04/06/04; 30/04/05; 27/10/05
Harmondsworth 19	Greater London	Harmondsworth	12	July 04
Harmondsworth 52	Greater London	Harmondsworth	25	
Hill Hole Dingle 1	Herefordshire	Risbury	5	10/02/05
Hill Hole Dingle 2	Herefordshire	Risbury	16	
Hill Hole Dingle 3	Herefordshire	Risbury	22	
Ipsley A	Worcestershire	Redditch	65	01/02/04;22/02/04; 09/05/04; 08/10/04; 21/01/05; 25/06/05; 22/07/07
Ipsley B	Worcestershire	Redditch	34	
Ipsley C	Worcestershire	Redditch	41	
Ipsley D	Worcestershire	Redditch	38	
Liphook	Hampshire	Liphook	23	30/04/04; 27/10/05
Longmoor	Hampshire	Liss Forest	26	04/06/04; 27/10/05
Shobden	Herefordshire	Shobden	29	18/02/05
Meriden Park	Warwickshire	Solihull	17	07/07/04
Narborough Bog	Leicestershire	Narborough	18	-
Olton Wet	Warwickshire	Solihull	47	07/07/04
Potteric Carr W1/2	South Yorkshire	Doncaster	32	01/07/04
Potteric Carr W6e	South Yorkshire	Doncaster	34	02/07/04
Rotherlands E	Hampshire	Petersfield	23	27/10/05
Rotherlands Pond	Hampshire	Petersfield	17	
Rother A	Hampshire	Liss	72	23/01/04; 24/04/04; 06/06/04; 05/01/05; 13/03/05; 30/04/05; 02/07/05; 30/07/07
Rother B	Hampshire	Liss	60	
Rother C	Hampshire	Liss	37	
Rother D	Hampshire	Liss	42	
Shadowbrook	Warwickshire	Hampton-in-Arden	37	24/04/04; 30/08/04; 02/12/04
Spring wood	Derbyshire/ Leicestershire	Calke	41	02/08/04

Table A4.1 Lowland *Alnus glutinosa* Sites (Table continues)

Site	County	Nearest settlement	Total No. species recorded	Survey dates
Stockton	Herefordshire	Stockton, Leominster	11	02/03/05
Tankerdale	Hampshire	Petersfield	33	05/06/04; 01/05/05; 27/10/05
The Flits 1	Herefordshire	Preston-on-Wye	21	04/02/05
The Flits 7	Herefordshire	Preston-on-Wye	14	
The Flits 8	Herefordshire	Preston-on-Wye	15	
The Flits 9	Herefordshire	Preston-on-Wye	9	
Titley Pool 2	Herefordshire	Titley	14	03/02/05
Titley Pool 6	Herefordshire	Titley	10	
Titley Pool 9	Herefordshire	Titley	6	
Upper Welson Marsh 5	Herefordshire	Upper Welson	13	03/03/05
Upper Welson Marsh 6	Herefordshire	Upper Welson	12	
Upper Welson Marsh 7&8	Herefordshire	Upper Welson	17	
Uxbridge 1	Greater London	Uxbridge	34	Aug 02
Uxbridge 2	Greater London	Uxbridge	16	
Uxbridge 3	Greater London	Uxbridge	16	
Whitacre	Warwickshire	Whitacre Heath	16	09/12/04
Wilden Marsh	Worcestershire	Wilden	68	11/07/07; 26/06/08; 04/07/08; 07/07/08; 10/07/08; 24/07/08; 25/07/08
Willowmead	Hertfordshire	Willowmead	82	Aug 02
Wychwood	Warwickshire	Solihull	45	11/06/04

Table A4.1 cont. Lowland *Alnus glutinosa* Sites

Species	Ref.	Berrington Pool 4	Berrington Pool 5	Berrington Pool 6
Acer pseudoplatanus	3002		✓	
Alnus glutinosa	3004	✓	✓	✓
Castanea sativa	3008		✓	
Corylus avellana	2005		✓	✓
Dryopteris dilatata	1084	✓		
Dryopteris filix-mas	1085			✓
Fagus sylvatica	3009		✓	
Fraxinus excelsior	3010		✓	
Geranium robertianum	1114		✓	
Geum urbanum	1116	✓		✓
Glechoma hederacea	1117			✓
Juncus effusus	1138			✓
Mercurialis perennis	1157	✓	✓	✓
Populus canescens	3015			✓
Rubus fruticosus agg.	2024	✓	✓	✓
Sambucus nigra	2025	✓	✓	
Silene dioica	1222	✓	✓	✓
Urtica dioica	1244	✓	✓	
TOTAL species		**8**	**12**	**10**

Table A4.2 Species recorded at Berrington Pool

Species	Ref.
Alnus glutinosa	3004
Arum maculatum	1022
Cerastium fontanum	1058
Crataegus monogyna	2007
Filipendula ulmaria	1105
Geranium robertianum	1114
Geum urbanum	1116
Ranunculus ficaria	1198
Rubus fruticosus agg.	2024
Salix viminalis	3031
Urtica dioica	1244
TOTAL species	**11**

Table A4.3 Species recorded at Byton and Coombe Moors 4

Species	Ref.	Species	Ref.
Ajuga reptans	1008	*Glechoma hederacea*	1117
Alnus glutinosa	3004	*Hedera helix*	1120
Arum maculatum	1022	*Heracleum sphondylium*	1122
Caltha palustris	1032	*Ilex aquifolium*	2010
Cardamine amara	1035	*Iris pseudacorus*	1134
Carex remota	1053	*Juncus effusus*	1138
Carex riparia	1054	*Mentha aquatica*	1156
Corylus avellana	2005	*Mercurialis perennis*	1157
Crataegus monogyna	2007	*Prunella vulgaris*	1193
Deschampsia cespitosa cespitosa	1077	*Ranunculus ficaria*	1198
Dryopteris dilatata	1084	*Rubus fruticosus* agg.	2024
Dryopteris filix-mas	1085	*Salix cinerea*	3026
Filipendula ulmaria	1105	*Salix fragilis*	3027
Fraxinus excelsior	3010	*Sambucus nigra*	2025
Geranium robertianum	1114	*Urtica dioica*	1244
Geum urbanum	1116	*Veronica montana*	1250
TOTAL species	**32**		

Table A4.4 Species recorded at Blakemere

Species	Ref.	Species	Ref.
Allium ursinum	1010	*Ranunculus ficaria*	1198
Alnus glutinosa	3004	*Ranunculus repens*	1201
Anthriscus sylvestris	1017	*Rubus fruticosus* agg.	2024
Corylus avellana	2005	*Rumex sanguineus*	1212
Dryopteris dilatata	1084	*Salix fragilis*	3027
Filipendula ulmaria	1105	*Sambucus nigra*	2025
Fraxinus excelsior	3010	*Sanicula europaea*	1213
Galium aparine	1108	*Silene dioica*	1222
Geum urbanum	1116	*Sorbus aucuparia*	3035
Hedera helix	1120	*Stellaria media*	1232
Heracleum sphondylium	1122	*Urtica dioica*	1244
Hyacinthoides non-scripta	1127	*Veronica montana*	1250
Ilex aquifolium	2010	*Viburnum opulus*	2030
Mercurialis perennis	1157		
TOTAL species	**27**		

Table A4.5 Species recorded at Cornerways

Species	Ref.	Species	Ref.
Alnus glutinosa	3004	*Mercurialis perennis*	1157
Arum maculatum	1022	*Oenanthe crocata*	1165
Caltha palustris	1032	*Phyllitis scolopendrium*	1178
Cardamine amara	1035	*Picea abies*	3011
Chrysosplenium oppositifolium	1063	*Pinus nigra*	3012
Corylus avellana	2005	*Polypodium vulgare*	1184
Dryopteris dilatata	1084	*Ranunculus ficaria*	1198
Dryopteris filix-mas	1085	*Rubus fruticosus* agg.	2024
Eranthis hyemalis	1100	*Salix fragilis*	3027
Fagus sylvatica	3009	*Sambucus nigra*	2025
Fraxinus excelsior	3010	*Silene dioica*	1222
Geranium robertianum	1114	*Stachys officinalis*	1229
Geum urbanum	1116	*Symphytum officinale*	1235
Glechoma hederacea	1117	*Urtica dioica*	1244
TOTAL species	**28**		

Table A4.6 Species recorded at Cage Brook

Species	Ref.		
Alnus glutinosa	3004	*Lemna minor*	1145
Angelica sylvestris	1014	*Lonicera periclymenum*	2012
Anthoxanthum odoratum	1016	*Lotus pedunculatus*	1146
Arctium minus	1020	*Luzula multiflora*	1147
Athyrium filix-femina	1023	*Lycopus europaeus*	1150
Betula pendula	3006	*Molinia caerulea*	1158
Caltha palustris	1032	*Myosotis laxa caespitosa*	1161
Calystegia sepium	1033	*Persicaria hydropiper*	1171
Cardamine flexuosa	1036	*Persicaria maculosa*	1172
Cardamine pratensis	1038	*Potentilla erecta*	1189
Carex distans	1041	*Pteridium aquilinum*	1194
Carex nigra	1047	*Quercus petraea*	3020
Chamerion angustifolium	1060	*Ranunculus acris*	1196
Circaea lutetiana	1064	*Ranunculus flammula*	1199
Cirsium arvense	1065	*Ranunculus repens*	1201
Cirsium palustre	1066	*Rosa canina*	2023
Crataegus monogyna	2007	*Rubus fruticosus* agg.	2024
Deschampsia cespitosa cespitosa	1077	*Rubus idaeus*	1207
Digitalis purpurea	1079	*Rumex acetosa*	1208
Dryopteris carthusiana	1082	*Rumex obtusifolius*	1211
Dryopteris dilatata	1084	*Rumex sanguineus*	1212
Epilobium hirsutum	1086	*Salix caprea*	3025
Epilobium palustre	1089	*Salix cinerea*	3026
Equisetum fluviatile	1095	*Salix fragilis*	3027
Equisetum hyemale	1096	*Sambucus nigra*	2025
Filipendula ulmaria	1105	*Scutellaria galericulata*	1218
Frangula alnus	2009	*Silene dioica*	1222
Fraxinus excelsior	3010	*Solanum dulcamara*	1223
Galeopsis tetrahit	1107	*Sorbus aucuparia*	3035
Galium aparine	1108	*Sparganium erectum*	1227
Galium palustre	1110	*Stellaria holostea*	1231
Galium saxatile	1111	*Stellaria media*	1232
Heracleum sphondylium	1122	*Stellaria uliginosa*	1233
Holcus lanatus	1123	*Thelypteris palustris*	1240
Hydrocotyle vulgaris	1128	*Trifolium repens*	1241
Ilex aquifolium	2010	*Typha latifolia*	1243
Iris pseudacorus	1134	*Urtica dioica*	1244
Juncus acutiflorus	1135	*Valeriana officinalis*	1246
Juncus articulatus	1136	*Veronica beccabunga*	1247
Juncus bufonius	1137	*Viola palustris*	1258
Juncus effusus	1138	*Wahlenbergia hederacea*	1260
TOTAL species	**82**		

Table A4.7 Species recorded at Carvers Rock

Species	Ref.	Clowes A	Clowes B	Clowes C
Acer pseudoplatanus	3002			✓
Ajuga reptans	1008	✓		✓
Allium ursinum	1010		✓	✓
Alnus glutinosa	3004	✓	✓	✓
Anemone nemorosa	1013			✓
Angelica sylvestris	1014	✓		✓
Anthriscus sylvestris	1017			✓
Arum maculatum	1022		✓	✓
Athyrium filix-femina	1023	✓		
Betula pendula	3006	✓		✓
Caltha palustris	1032	✓	✓	✓
Carex paniculata	1050	✓		✓
Carex pendula	1051	✓		✓
Carex remota	1053	✓		✓
Chrysosplenium oppositifolium	1063	✓		✓
Circaea lutetiana	1064	✓		

Table A4.8 Species recorded at Clowes (Table continues)

Species	Ref.	Clowes A	Clowes B	Clowes C
Convallaria majalis	1071			✓
Corylus avellana	2005	✓	✓	✓
Crataegus monogyna	2007		✓	✓
Deschampsia cespitosa cespitosa	1077	✓		✓
Digitalis purpurea	1079			✓
Dryopteris dilatata	1084	✓		✓
Dryopteris filix-mas	1085			✓
Epilobium montanum	1087			✓
Equisetum sylvaticum	1098	✓		
Fagus sylvatica	3009	✓		
Filipendula ulmaria	1105	✓		✓
Frangula alnus	2009	✓		
Fraxinus excelsior	3010	✓	✓	✓
Galium aparine	1108	✓	✓	✓
Geranium robertianum	1114	✓		✓
Geum urbanum	1116	✓	✓	✓
Glechoma hederacea	1117	✓		✓
Hedera helix	1120	✓	✓	
Heracleum sphondylium	1122	✓		✓
Hyacinthoides non-scripta	1127	✓	✓	
Ilex aquifolium	2010	✓		
Impatiens glandulifera	1133	✓	✓	✓
Iris pseudacorus	1134	✓		
Lamiastrum galeobdolon	1141	✓		✓
Lonicera periclymenum	2012	✓		✓
Lycopus europaeus	1150	✓		
Lysimachia nemorum	1151	✓		
Lysimachia nummularia	1152	✓		
Mercurialis perennis	1157	✓		✓
Oxalis acetosella	1168	✓		✓
Phalaris arundinacea	1175	✓		✓
Phyllitis scolopendrium	1178			✓
Polypodium vulgare	1184			✓
Prunus cerasifera	2016	✓	✓	✓
Prunus spinosa	2020			✓
Quercus robur	3021	✓		✓
Ranunculus acris	1196			✓
Ranunculus ficaria	1198	✓	✓	✓
Ranunculus repens	1201	✓		✓
Ribes nigrum	1203	✓		✓
Rorippa nasturtium-aquaticum	1206	✓		
Rosa canina	2023	✓	✓	✓
Rubus fruticosus agg.	2024	✓	✓	✓
Rubus idaeus	1207			✓
Rumex obtusifolius	1211	✓	✓	✓
Rumex sanguineus	1212	✓	✓	
Salix fragilis	3027			✓
Sambucus nigra	2025	✓		✓
Silene dioica	1222	✓		✓
Solanum dulcamara	1223	✓		✓
Sorbus aucuparia	3035	✓		✓
Stachys officinalis	1229			✓
Stellaria holostea	1231	✓		✓
Taraxacum officinale	1237		✓	✓
Tussilago farfara	1242		✓	
Urtica dioica	1244	✓	✓	✓
Valeriana officinalis	1246	✓		
Veronica beccabunga	1247			✓
Veronica chamaedrys	1248			✓
Viburnum opulus	2030	✓		✓
TOTAL species		**55**	**21**	**60**

Table A4.8 cont. Species recorded at Clowes

Species	Ref.	Coughton 4	Coughton 7	Coughton 8
Alnus glutinosa	3004	✓	✓	✓
Arum maculatum	1022	✓	✓	
Corylus avellana	2005	✓	✓	
Crataegus monogyna	2007	✓	✓	✓
Dryopteris dilatata	1084	✓		
Fraxinus excelsior	3010	✓	✓	✓
Geum urbanum	1116		✓	
Glechoma hederacea	1117		✓	
Hedera helix	1120	✓	✓	✓
Heracleum sphondylium	1122		✓	
Hyacinthoides non-scripta	1127	✓		
Ilex aquifolium	2010	✓		
Ligustrum vulgare	2011	✓		
Mercurialis perennis	1157	✓	✓	
Primula vulgaris	1192	✓		
Rosa canina	2023		✓	
Rubus fruticosus agg.	2024	✓		
Salix caprea	3025		✓	
Salix cinerea	3026		✓	
Sambucus nigra	2025	✓		
Urtica dioica	1244	✓	✓	
TOTAL species		**15**	**14**	**4**

Table A4.9 Species recorded at Coughton

Species	Ref.	Species	Ref.
Acer platanoides	3001	*Hedera helix*	1120
Acer pseudoplatanus	3002	*Heracleum sphondylium*	1122
Alnus glutinosa	3004	*Hyacinthoides non-scripta*	1127
Betula pendula	3006	*Ilex aquifolium*	2010
Carex acutiformis	1039	*Lonicera periclymenum*	2012
Carex hirta	1045	*Oxalis acetosella*	1168
Carex remota	1053	*Pinus sylvestris*	3013
Corylus avellana	2005	*Quercus robur*	3021
Crataegus monogyna	2007	*Rhododendron ponticum*	2022
Digitalis purpurea	1079	*Ribes rubrum*	1204
Dryopteris dilatata	1084	*Rubus fruticosus* agg.	2024
Dryopteris filix-mas	1085	*Salix cinerea*	3026
Fraxinus excelsior	3010	*Sambucus nigra*	2025
Galium aparine	1108	*Stellaria media*	1232
Galium odoratum	1109	*Symphytum officinale*	1235
Geranium robertianum	1114	*Urtica dioica*	1244
Geum urbanum	1116	*Viburnum opulus*	2030
TOTAL species	**34**		

Table A4.10 Species recorded at Elmdon Park

Species	Ref.	Species	Ref.
Alliaria petiolata	1009	*Heracleum sphondylium*	1122
Alnus glutinosa	3004	*Lapsana communis*	1143
Angelica sylvestris	1014	*Ligustrum vulgare*	2011
Anthriscus sylvestris	1017	*Lonicera periclymenum*	2012
Arum maculatum	1022	*Phragmites australis*	1177
Calystegia sepium	1033	*Prunus cerasifera*	2016
Cirsium palustre	1066	*Quercus robur*	3021
Corylus avellana	2005	*Ranunculus ficaria*	1198
Crataegus monogyna	2007	*Ranunculus repens*	1201
Deschampsia cespitosa cespitosa	1077	*Rosa canina*	2023
Dryopteris dilatata	1084	*Rubus fruticosus* agg.	2024
Filipendula ulmaria	1105	*Sambucus nigra*	2025
Fraxinus excelsior	3010	*Silene dioica*	1222
Galium aparine	1108	*Stachys sylvatica*	1230
Geranium robertianum	1114	*Taraxacum officinale*	1237
Geum urbanum	1116	*Urtica dioica*	1244
Hedera helix	1120		
TOTAL species	**33**		

Table A4.11 Species recorded at Feckenham

Species	Ref.	Hill Hole Dingle 1	Hill Hole Dingle 2	Hill Hole Dingle 3
Allium ursinum	1010			✓
Alnus glutinosa	3004	✓	✓	✓
Arum maculatum	1022			✓
Betula pendula	3006		✓	✓
Caltha palustris	1032	✓	✓	✓
Chrysosplenium oppositifolium	1063	✓	✓	✓
Corylus avellana	2005		✓	✓
Crataegus monogyna	2007		✓	✓
Deschampsia cespitosa cespitosa	1077			✓
Dryopteris dilatata	1084			✓
Dryopteris filix-mas	1085			✓
Fraxinus excelsior	3010		✓	✓
Geranium robertianum	1114		✓	✓
Geum urbanum	1116			✓
Hedera helix	1120		✓	
Helleborus viridis	1121		✓	✓
Hyacinthoides non-scripta	1127			✓
Iris pseudacorus	1134		✓	
Mercurialis perennis	1157		✓	✓
Polystichum aculeatum	1185			✓
Primula vulgaris	1192		✓	
Ranunculus ficaria	1198		✓	✓
Rubus fruticosus agg.	2024			✓
Salix caprea	3025	✓	✓	✓
Urtica dioica	1244	✓	✓	✓
TOTAL species		**5**	**16**	**22**

Table A4.12 Species recorded at Hill Hole Dingle

Species	Ref.	Species	Ref.
Acer pseudoplatanus	3002	*Iris pseudacorus*	1134
Aconitum napellus	1002	*Lycopus europaeus*	1150
Aegopodium podagraria	1004	*Mentha aquatica*	1156
Aesculus hippocastanum	3003	*Oenanthe crocata*	1165
Alnus glutinosa	3004	*Phalaris arundinacea*	1175
Anthriscus sylvestris	1017	*Phragmites australis*	1177
Arrhenatherum elatius	1021	*Ranunculus acris*	1196
Caltha palustris	1032	*Ranunculus ficaria*	1198
Cardamine amara	1035	*Ranunculus repens*	1201
Cardamine flexuosa	1036	*Rosa canina*	2023
Carex pendula	1051	*Rubus fruticosus* agg.	2024
Carex riparia	1054	*Rumex obtusifolius*	1211
Cirsium palustre	1066	*Salix alba*	3023
Corylus avellana	2005	*Salix caprea*	3025
Crataegus monogyna	2007	*Salix cinerea*	3026
Dryopteris dilatata	1084	*Sambucus nigra*	2025
Epilobium hirsutum	1086	*Scirpus sylvaticus*	1215
Equisetum palustre	1097	*Silene dioica*	1222
Filipendula ulmaria	1105	*Solanum dulcamara*	1223
Galium aparine	1108	*Stellaria holostea*	1231
Galium palustre	1110	*Taraxacum officinale*	1237
Geranium robertianum	1114	*Typha latifolia*	1243
Hedera helix	1120	*Urtica dioica*	1244
Heracleum sphondylium	1122	*Veronica beccabunga*	1247
Ilex aquifolium	2010	*Viburnum opulus*	2030
Impatiens glandulifera	1133		
TOTAL species	**51**		

Table A4.13 Species recorded at Godalming

Species	Ref.	Harmondsworth 19	Harmondsworth 52
Alnus glutinosa	3004	✓	✓
Alnus incana	3005		✓
Arrhenatherum elatius	1021		✓
Carex hirsute	1045		✓
Cirsium palustre	1066		✓
Cornus sanguinea	2004	✓	✓
Crataegus monogyna	2007	✓	
Deschampsia cespitosa	1077		✓
Filipendula ulmaria	1105		✓
Frangula alnus	2009		✓
Fraxinus excelsior	3010		✓
Galium aparine	1108		✓
Holcus lanatus	1123		✓
Impatiens glandulifera	1132		✓
Iris pseudacorus	1134	✓	
Phalaris arundinacea	1175	✓	
Populus nigra ‘Italica’	3017		✓
Populus tremula	3018		✓
Potentilla anserina	1188		✓
Ranunculus acris	1196		✓
Ranunculus repens	1201	✓	
Rubus fruticosus	2024	✓	
Rumex sanguineus	1212	✓	
Salix alba	3023	✓	
Salix caprea	3025		✓
Salix cinerea	3026		✓
Salix fragilis	3027	✓	✓
Salix pentandra	3028		✓
Sambucus nigra	2025	✓	✓
Senecio vulgaris	1221		✓
Typha latifolia	1243		✓
Urtica dioica	1244	✓	
Viburnum opulus	2030		✓
TOTAL species		**12**	**25**

Table A4.14 Species recorded at Harmondsworth

Species	Ref.	Ipsley A	Ipsley B	Ipsley C	Ipsley D
Acer campestre	2001	✓		✓	✓
Acer platanoides	3001	✓			
Acer pseudoplatanus	3002	✓			✓
Aesculus hippocastanum	3003			✓	
Agrostis stolonifera	1007		✓		
Alliaria petiolata	1009	✓		✓	✓
Allium ursinum	1010	✓		✓	
Alnus glutinosa	3004	✓	✓	✓	✓
Alnus incana	3005	✓			
Angelica sylvestris	1014	✓			
Anthriscus sylvestris	1017	✓		✓	✓
Apium nodiflorum	1018	✓			
Arum maculatum	1022	✓		✓	✓
Athyrium filix-femina	1023			✓	
Bellis perennis	1024		✓		
Cardamine flexuosa	1036		✓		
Carex acutiformis	1039		✓		
Carex hirta	1045		✓		
Carex paniculata	1050	✓			
Carex pendula	1051	✓			
Carex remota	1053		✓		
Castanea sativa	3008				✓
Chamerion angustifolium	1060				✓
Circaea lutetiana	1064	✓			
Cirsium palustre	1066		✓		✓
Corylus avellana	2005	✓	✓	✓	✓
Crataegus monogyna	2007	✓	✓	✓	✓
Deschampsia cespitosa cespitosa	1077	✓	✓		✓
Dryopteris dilatata	1084	✓	✓	✓	✓
Dryopteris filix-mas	1085	✓		✓	✓
Epilobium hirsutum	1086				✓
Filipendula ulmaria	1105	✓	✓		
Fragaria vesca	1106	✓			
Fraxinus excelsior	3010	✓	✓	✓	✓
Galium aparine	1108	✓		✓	✓
Geranium robertianum	1114	✓	✓	✓	✓
Geum urbanum	1116	✓		✓	✓
Glechoma hederacea	1117	✓	✓	✓	✓
Hedera helix	1120	✓	✓	✓	✓
Heracleum sphondylium	1122	✓	✓	✓	✓
Holcus lanatus	1123	✓			✓
Hyacinthoides hispanica	1126	✓		✓	
Hyacinthoides non-scripta	1127	✓		✓	
Ilex aquifolium	2010	✓	✓	✓	✓
Juncus effusus	1138		✓		
Juncus inflexus	1139		✓		
Lamiastrum galeobdolon	1141	✓		✓	
Lamium album	1142	✓			
Lapsana communis	1143	✓			✓
Ligustrum vulgare	2011	✓	✓		✓
Lonicera periclymenum	2012	✓			
Luzula sylvatica	1148				✓
Malus sylvestris sens.lat.	2014	✓			
Melica uniflora	1155	✓			
Mercurialis perennis	1157	✓		✓	
Myosotis arvensis	1160			✓	
Picea abies	3011				✓
Pinus sylvestris	3013				✓
Plantago major	1180				✓
Poa trivialis	1183	✓			
Prunus avium	2015	✓		✓	

Table A4.15 Species recorded at Ipsley (Table continues)

Species	Ref.	Ipsley A	Ipsley B	Ipsley C	Ipsley D
Prunus cerasifera	2016	✓		✓	
Prunus laurocerasus	2017			✓	
Prunus spinosa	2020	✓	✓	✓	
Quercus robur	3021	✓		✓	✓
Ranunculus acris	1196	✓		✓	
Ranunculus bulbosus	1197	✓			
Ranunculus ficaria	1198	✓	✓		
Ranunculus repens	1201	✓	✓	✓	
Ribes nigrum	1203	✓			
Rosa canina	2023	✓	✓	✓	
Rubus fruticosus agg.	2024	✓	✓	✓	✓
Rumex obtusifolius	1211	✓			
Rumex sanguineus	1212		✓	✓	✓
Salix caprea	3025	✓		✓	
Salix cinerea	3026	✓		✓	
Salix fragilis	3027	✓			
Sambucus nigra	2025	✓		✓	✓
Silene dioica	1222	✓	✓		✓
Solanum dulcamara	1223		✓		
Stachys sylvatica	1230	✓		✓	✓
Stellaria holostea	1231	✓			
Stellaria media	1232	✓	✓		
Taraxacum officinale	1237	✓	✓	✓	
Ulmus procera	2029	✓			
Urtica dioica	1244	✓	✓	✓	✓
Veronica beccabunga	1247		✓		
Viburnum opulus	2030	✓			
Viola odorata	1257				✓
TOTAL species		**65**	**34**	**41**	**38**

Table A4.15 cont. Species recorded at Ipsley

Species	Ref.	Species	Ref.
Adoxa moschatellina	1003	*Filipendula ulmaria*	1105
Ajuga reptans	1008	*Galium palustre*	1110
Alnus glutinosa	3004	*Lysimachia nummularia*	1152
Caltha palustris	1032	*Mentha aquatica*	1156
Cardamine amara	1035	*Mercurialis perennis*	1157
Carex acutiformis	1039	*Prunella vulgaris*	1193
Chrysosplenium oppositifolium	1063	*Ranunculus ficaria*	1198
Circaea lutetiana	1064	*Ribes rubrum*	1204
Cirsium palustre	1066	*Urtica dioica*	1244
Corylus avellana	2005	*Valeriana dioica*	1245
Crataegus monogyna	2007	*Veronica beccabunga*	1247
Dryopteris filix-mas	1085		
TOTAL species	**23**		

Table A4.16 Species recorded at Liphook

Species	Ref.	Species	Ref.
Adoxa moschatellina	1003	*Geranium robertianum*	1114
Aegopodium podagraria	1004	*Geum urbanum*	1116
Allium vineale	1011	*Glechoma hederacea*	1117
Alnus glutinosa	3004	*Hedera helix*	1120
Anthriscus sylvestris	1017	*Ilex aquifolium*	2010
Carex pendula	1051	*Impatiens glandulifera*	1133
Chrysosplenium oppositifolium	1063	*Lonicera periclymenum*	2012
Corylus avellana	2005	*Oenanthe crocata*	1165
Crataegus monogyna	2007	*Ranunculus ficaria*	1198
Dryopteris filix-mas	1085	*Ranunculus repens*	1201
Festuca arundinacea	1102	*Rubus fruticosus* agg.	2024
Filipendula ulmaria	1105	*Silene dioica*	1222
Galium aparine	1108	*Urtica dioica*	1244
TOTAL species	**26**		

Table A4.17 Species recorded at Longmoor

Species	Ref.	Species	Ref.
Alliaria petiolata	1009	*Holcus lanatus*	1123
Alnus glutinosa	3004	*Hyacinthoides non-scripta*	1127
Arum maculatum	1022	*Ilex aquifolium*	2010
Betula pendula	3006	*Iris pseudacorus*	1134
Corylus avellana	2005	*Lonicera periclymenum*	2012
Crataegus monogyna	2007	*Mercurialis perennis*	1157
Digitalis purpurea	1079	*Pteridium aquilinum*	1194
Dryopteris dilatata	1084	*Ranunculus ficaria*	1198
Dryopteris filix-mas	1085	*Rubus fruticosus* agg.	2024
Fraxinus excelsior	3010	*Salix cinerea*	3026
Geranium robertianum	1114	*Sambucus nigra*	2025
Geum urbanum	1116	*Silene dioica*	1222
Glechoma hederacea	1117	*Taxus baccata*	3033
Hedera helix	1120	*Urtica dioica*	1244
Heracleum sphondylium	1122		
TOTAL species	**29**		

Table A4.18 Species recorded at Shobden

Species	Ref.	Species	Ref.
Acer campestre	2001	*Malus sylvestris sens.lat.*	2014
Acer pseudoplatanus	3002	*Poa trivialis*	1183
Alnus glutinosa	3004	*Prunus spinosa*	2020
Betula pendula	3006	*Quercus robur*	3021
Crataegus monogyna	2007	*Rosa canina*	2023
Filipendula ulmaria	1105	*Rubus fruticosus* agg.	2024
Fraxinus excelsior	3010	*Sambucus nigra*	2025
Galium aparine	1108	*Urtica dioica*	1244
Ilex aquifolium	2010	*Viburnum opulus*	2030
TOTAL species	**18**		

Table A4.19 Species recorded at Narborough Bog

Species	Ref.	Species	Ref.
Alnus glutinosa	3004	*Lonicera periclymenum*	2012
Anthriscus sylvestris	1017	*Mercurialis perennis*	1157
Circaea lutetiana	1064	*Rubus fruticosus* agg.	2024
Crataegus monogyna	2007	*Salix cinerea*	3026
Dryopteris dilatata	1084	*Sambucus nigra*	2025
Galium aparine	1108	*Scrophularia nodosa*	1217
Geum urbanum	1116	*Silene dioica*	1222
Glechoma hederacea	1117	*Urtica dioica*	1244
Hyacinthoides non-scripta	1127		
TOTAL species	**17**		

Table A4.20 Species recorded at Meriden Park

Species	Ref.	Species	Ref.
Aegopodium podagraria	1004	*Rubus idaeus*	1207
Caltha palustris	1032	*Rumex obtusifolius*	1211
Carex acutiformis	1039	*Scrophularia nodosa*	1217
Chamerion angustifolium	1060	*Scutellaria galericulata*	1218
Circaea lutetiana	1064	*Silene dioica*	1222
Dactylis glomerata	1075	*Solanum dulcamara*	1223
Deschampsia cespitosa cespitosa	1077	*Urtica dioica*	1244
Dryopteris dilatata	1084	*Corylus avellana*	2005
Dryopteris filix-mas	1085	*Crataegus monogyna*	2007
Epilobium hirsutum	1086	*Ilex aquifolium*	2010
Equisetum fluviatile	1095	*Prunus spinosa*	2020
Filipendula ulmaria	1105	*Rubus fruticosus* agg.	2024
Galium aparine	1108	*Sambucus nigra*	2025
Geranium robertianum	1114	*Viburnum opulus*	2030
Geum urbanum	1116	*Acer pseudoplatanus*	3002
Glyceria maxima	1119	*Aesculus hippocastanum*	3003
Hedera helix	1120	*Alnus glutinosa*	3004
Hyacinthoides non-scripta	1127	*Alnus incana*	3005
Iris pseudacorus	1134	*Fraxinus excelsior*	3010
Mentha aquatica	1156	*Quercus robur*	3021
Phalaris arundinacea	1175	*Salix caprea*	3025
Plantago major	1180	*Salix cinerea*	3026
Ranunculus bulbosus	1197	*Sorbus aucuparia*	3035
Ribes nigrum	1203		
TOTAL species	**47**		

Table A4.21 Species recorded at Olton Wet

Species	Ref.	Rotherlands E	Rotherlands pond
Alnus glutinosa	3004	✓	✓
Carex pendula	1051	✓	
Carex remota	1053	✓	✓
Chrysosplenium oppositifolium	1063	✓	
Cirsium palustre	1066	✓	✓
Dryopteris dilatata	1084	✓	✓
Dryopteris filix-mas	1085	✓	✓
Filipendula ulmaria	1105	✓	
Geranium robertianum	1114		✓
Geum urbanum	1116	✓	
Glechoma hederacea	1117	✓	✓
Ilex aquifolium	2010	✓	
Impatiens glandulifera	1133	✓	✓
Juncus effusus	1138	✓	✓
Oenanthe crocata	1165	✓	✓
Prunus laurocerasus	2017	✓	
Ranunculus repens	1201	✓	✓
Rubus fruticosus agg.	2024	✓	✓
Rumex sanguineus	1212	✓	✓
Salix cinerea	3026		✓
Sambucus nigra	2025	✓	
Silene dioica	1222	✓	✓
Solanum dulcamara	1223	✓	✓
Urtica dioica	1244	✓	✓
Veronica beccabunga	1247	✓	
TOTAL species		**23**	**17**

Table A4.22 Species recorded at Rotherlands

Species	Ref.	Potteric Carr W1/2	Potteric Carr W6e
Acer campestre	2001		✓
Acer pseudoplatanus	3002	✓	✓
Alnus glutinosa	3004	✓	✓
Arrhenatherum elatius	1021		✓
Betula pendula	3006	✓	✓
Calamagrostis canescens	1029	✓	
Carex sylvatica	1056		✓
Chamerion angustifolium	1060	✓	✓
Circaea lutetiana	1064	✓	✓
Crataegus monogyna	2007	✓	✓
Dactylis glomerata	1075		✓
Deschampsia cespitosa cespitosa	1077		✓
Dryopteris dilatata	1084	✓	✓
Dryopteris filix-mas	1085	✓	✓
Fagus sylvatica	3009		✓
Filipendula ulmaria	1105	✓	
Fragaria vesca	1106	✓	✓
Fraxinus excelsior	3010	✓	✓
Galium aparine	1108	✓	✓
Galium palustre	1110	✓	
Geranium robertianum	1114		✓
Glechoma hederacea	1117	✓	✓
Holcus lanatus	1123		✓
Iris pseudacorus	1134	✓	
Juncus effusus	1138	✓	
Lapsana communis	1143		✓
Lysimachia vulgaris	1153	✓	
Melica uniflora	1155	✓	
Mercurialis perennis	1157	✓	✓
Phalaris arundinacea	1175	✓	
Phragmites australis	1177	✓	
Pteridium aquilinum	1194		✓
Rubus fruticosus agg.	2024	✓	✓
Rubus idaeus	1207	✓	✓
Salix caprea	3025	✓	✓
Salix cinerea	3026	✓	✓
Salix viminalis	3031	✓	✓
Sambucus nigra	2025	✓	✓
Scutellaria galericulata	1218	✓	
Senecio vulgaris	1221		✓
Solanum dulcamara	1223	✓	
Sorbus aucuparia	3035		✓
Stellaria media	1232	✓	✓
Urtica dioica	1244	✓	✓
Viburnum opulus	2030		✓
TOTAL species		**32**	**34**

Table A4.23 Species recorded at Potteric Carr

Species	Ref.	Rother A	Rother B	Rother C	Rother D
Acer pseudoplatanus	3002	✓	✓	✓	✓
Adoxa moschatellina	1003			✓	
Aegopodium podagraria	1004	✓			
Aesculus hippocastanum	3003	✓			✓
Ajuga reptans	1008	✓		✓	✓
Alliaria petiolata	1009	✓	✓		
Allium ursinum	1010	✓	✓		✓
Alnus glutinosa	3004	✓	✓	✓	✓
Anemone nemorosa	1013	✓	✓		
Angelica sylvestris	1014		✓		
Anthriscus sylvestris	1017	✓	✓		
Apium nodiflorum	1018	✓			
Arrhenatherum elatius	1021	✓	✓		
Arum maculatum	1022	✓	✓	✓	✓
Athyrium filix-femina	1023	✓	✓	✓	✓
Betula pendula	3006	✓	✓	✓	✓
Caltha palustris	1032			✓	✓
Cardamine flexuosa	1036		✓		
Cardamine pratensis	1038	✓	✓		
Carex pendula	1051	✓	✓		
Carex remota	1053	✓	✓		✓
Carex riparia	1054	✓	✓		✓
Chrysosplenium oppositifolium	1063	✓	✓		
Circaea lutetiana	1064	✓	✓	✓	✓
Conium maculatum	1069	✓			
Corylus avellana	2005	✓	✓	✓	✓
Crataegus monogyna	2007	✓	✓	✓	✓
Dryopteris dilatata	1084	✓	✓		✓
Dryopteris filix-mas	1085	✓	✓	✓	✓
Fagus sylvatica	3009			✓	
Filipendula ulmaria	1105	✓	✓		✓
Frangula alnus	2009				✓
Fraxinus excelsior	3010	✓	✓	✓	✓
Galium aparine	1108	✓	✓	✓	✓
Geranium robertianum	1114	✓			
Geum urbanum	1116	✓	✓	✓	
Glechoma hederacea	1117	✓	✓	✓	✓
Hedera helix	1120	✓	✓	✓	✓
Heracleum sphondylium	1122	✓	✓		
Holcus mollis	1124		✓		
Hyacinthoides hispanica	1126	✓	✓		✓
Hyacinthoides non-scripta	1127	✓			
Ilex aquifolium	2010	✓	✓	✓	
Impatiens glandulifera	1133	✓	✓		
Juncus effusus	1138				✓
Lamium album	1142	✓	✓		
Lapsana communis	1143	✓	✓	✓	
Lathraea clandestina	1144	✓			
Ligustrum vulgare	2011	✓			
Lonicera periclymenum	2012			✓	
Luzula sylvatica	1148				✓
Mahonia aquifolium	2013			✓	
Malus sylvestris sens.lat.	2014			✓	
Mercurialis perennis	1157	✓	✓	✓	✓
Myosotis arvensis	1160	✓	✓		
Myosotis scorpioides	1162		✓		✓
Phyllitis scolopendrium	1178	✓			
Plantago media	1181	✓			
Poa trivialis	1183	✓	✓		
Prunus cerasifera	2016				✓
Prunus laurocerasus	2017	✓			
Prunus lusitanica	2018	✓			
Pteridium aquilinum	1194	✓			

Table A4.24 Species recorded at Rother (Table continues)

Species	Ref.	Rother A	Rother B	Rother C	Rother D
Quercus robur	3021	✓	✓	✓	✓
Ranunculus ficaria	1198	✓	✓		✓
Ranunculus repens	1201	✓	✓		✓
Ribes nigrum	1203	✓	✓		✓
Ribes rubrum	1204	✓		✓	✓
Ribes uva-crispa	1205				✓
Rosa canina	2023	✓	✓		
Rubus fruticosus agg.	2024	✓	✓	✓	✓
Rubus idaeus	1207	✓	✓		
Rumex obtusifolius	1211	✓	✓		✓
Rumex sanguineus	1212	✓	✓	✓	
Salix cinerea	3026	✓	✓	✓	✓
Salix fragilis	3027	✓	✓		
Salix viminalis	3031	✓	✓		
Sambucus nigra	2025	✓	✓	✓	✓
Sanicula europaea	1213		✓	✓	
Scrophularia nodosa	1217				✓
Silene dioica	1222	✓	✓	✓	✓
Sorbus aucuparia	3035			✓	
Stachys sylvatica	1230	✓			
Stellaria holostea	1231		✓		
Stellaria media	1232			✓	
Symphoricarpos albus	2026	✓	✓		
Symphoricarpos orbiculatus	2027	✓			
Symphytum officinale	1235	✓			
Taraxacum officinale	1237	✓	✓		
Urtica dioica	1244	✓	✓	✓	✓
Veronica beccabunga	1247				✓
Veronica hederifolia	1249	✓	✓	✓	
Veronica montana	1250	✓	✓		
Viburnum opulus	2030			✓	
TOTAL species		**72**	**60**	**37**	**42**

Table A4.24 cont. Species recorded at Rother

Species	Ref.	Upper Welson 5	Upper Welson 6	UpperWelson 7/8
Alnus glutinosa	3004	✓	✓	✓
Anemone nemorosa	1013		✓	✓
Caltha palustris	1032		✓	
Carex sylvatica	1056			✓
Chrysosplenium oppositifolium	1063	✓	✓	✓
Corylus avellana	2005	✓	✓	
Deschampsia cespitosa cespitosa	1077	✓		✓
Dryopteris dilatata	1084	✓		✓
Dryopteris filix-mas	1085			✓
Fraxinus excelsior	3010	✓	✓	✓
Geranium robertianum	1114	✓		✓
Geum urbanum	1116	✓		
Hedera helix	1120	✓	✓	✓
Hyacinthoides non-scripta	1127			✓
Ilex aquifolium	2010		✓	✓
Lonicera periclymenum	2012			✓
Mercurialis perennis	1157	✓	✓	✓
Quercus petraea	3020		✓	
Ranunculus ficaria	1198	✓	✓	✓
Rubus fruticosus agg.	2024	✓	✓	✓
Teucrium scorodonia	1238			✓
Urtica dioica	1244	✓		
TOTAL species		**13**	**12**	**17**

Table A4.25 Species recorded at Upper Welson Marsh

Species	Ref.	Species	Ref.
Alnus glutinosa	3004	*Heracleum sphondylium*	1122
Angelica sylvestris	1014	*Hyacinthoides non-scripta*	1127
Anthriscus sylvestris	1017	*Ilex aquifolium*	2010
Betula pendula	3006	*Juncus effusus*	1138
Caltha palustris	1032	*Lonicera periclymenum*	2012
Cirsium palustre	1066	*Mentha aquatica*	1156
Corylus avellana	2005	*Quercus robur*	3021
Crataegus monogyna	2007	*Ranunculus ficaria*	1198
Deschampsia cespitosa cespitosa	1077	*Ranunculus repens*	1201
Digitalis purpurea	1079	*Rubus fruticosus* agg.	2024
Dryopteris dilatata	1084	*Rumex sanguineus*	1212
Dryopteris filix-mas	1085	*Sambucus nigra*	2025
Epilobium montanum	1087	*Silene dioica*	1222
Filipendula ulmaria	1105	*Solanum dulcamara*	1223
Fraxinus excelsior	3010	*Sorbus aucuparia*	3035
Galeopsis tetrahit	1107	*Stellaria media*	1232
Galium aparine	1108	*Urtica dioica*	1244
Geranium robertianum	1114	*Veronica scutellata*	1251
Hedera helix	1120		
TOTAL species	**37**		

Table A4.26 Species recorded at Shadowbrook

Species	Ref.	Titley Pool 2	Titley Pool 6	Titley Pool 9
Alnus glutinosa	3004	✓	✓	✓
Betula pendula	3006			✓
Caltha palustris	1032	✓		
Chrysosplenium oppositifolium	1063	✓	✓	✓
Cornus sanguinea	2004	✓		
Deschampsia cespitosa cespitosa	1077	✓		
Dryopteris dilatata	1084	✓	✓	
Fraxinus excelsior	3010	✓	✓	✓
Juncus effusus	1138	✓		
Mentha aquatica	1156	✓		
Oenanthe crocata	1165			✓
Ranunculus ficaria	1198	✓	✓	✓
Rubus fruticosus agg.	2024	✓		
Salix caprea	3025	✓		
Urtica dioica	1244	✓	✓	
Veronica beccabunga	1247	✓		
TOTAL species		**14**	**10**	**6**

Table A4.27 Species recorded at Titley Pool

Species	Ref.	Species	Ref.
Alnus glutinosa	3004	*Dryopteris dilatata*	1084
Arum maculatum	1022	*Iris pseudacorus*	1134
Caltha palustris	1032	*Juncus effusus*	1138
Carex remota	1053	*Ranunculus ficaria*	1198
Chrysosplenium oppositifolium	1063	*Urtica dioica*	1244
Crataegus monogyna	2007		
TOTAL species	**11**		

Table A4.28 Species recorded at Stockton

Species	Ref.	Species	Ref.
Alnus glutinosa	3004	*Glechoma hederacea*	1117
Angelica sylvestris	1014	*Hypericum tetrapterum*	1131
Arum maculatum	1022	*Juncus effusus*	1138
Athyrium filix-femina	1023	*Lamiastrum galeobdolon*	1141
Brachypodium sylvaticum	1027	*Lysimachia nemorum*	1151
Caltha palustris	1032	*Mercurialis perennis*	1157
Cardamine flexuosa	1036	*Oxalis acetosella*	1168
Carex remota	1053	*Primula vulgaris*	1192
Chrysosplenium oppositifolium	1063	*Pteridium aquilinum*	1194
Circaea lutetiana	1064	*Quercus robur*	3021
Deschampsia cespitosa cespitosa	1077	*Ranunculus repens*	1201
Dryopteris dilatata	1084	*Rubus fruticosus* agg.	2024
Dryopteris filix-mas	1085	*Rumex sanguineus*	1212
Epilobium hirsutum	1086	*Sambucus nigra*	2025
Epilobium parviflorum	1090	*Scrophularia nodosa*	1217
Epilobium roseum	1091	*Solanum dulcamara*	1223
Festuca gigantea	1103	*Teucrium scorodonia*	1238
Fraxinus excelsior	3010	*Urtica dioica*	1244
Galeopsis tetrahit	1107	*Valeriana officinalis*	1246
Galium palustre	1110	*Veronica beccabunga*	1247
Geum urbanum	1116		
TOTAL species	**41**		

Table A4.29 Species recorded at Spring Wood

Species	Ref.	Species	Ref.
Acer pseudoplatanus	3002	*Fraxinus excelsior*	3010
Adoxa moschatellina	1003	*Galium aparine*	1108
Alliaria petiolata	1009	*Geranium robertianum*	1114
Allium ursinum	1010	*Geum urbanum*	1116
Alnus glutinosa	3004	*Glechoma hederacea*	1117
Angelica sylvestris	1014	*Impatiens glandulifera*	1133
Arum maculatum	1022	*Juncus effusus*	1138
Cardamine pratensis	1038	*Lysimachia nemorum*	1151
Carex pendula	1051	*Mercurialis perennis*	1157
Carex remota	1053	*Prunus spinosa*	2020
Chrysosplenium oppositifolium	1063	*Ranunculus ficaria*	1198
Circaea lutetiana	1064	*Ranunculus repens*	1201
Corylus avellana	2005	*Rubus fruticosus* agg.	2024
Dryopteris dilatata	1084	*Rumex sanguineus*	1212
Dryopteris filix-mas	1085	*Silene dioica*	1222
Festuca arundinacea	1102	*Urtica dioica*	1244
Filipendula ulmaria	1105		
TOTAL species	**33**		

Table A4.30 Species recorded at Tankerdale

Species	Ref.	Species	Ref.
Acer pseudoplatanus	3002	*Filipendula ulmaria*	1105
Alnus glutinosa	3004	*Galium aparine*	1108
Angelica sylvestris	1014	*Geranium robertianum*	1114
Betula pendula	3006	*Ranunculus ficaria*	1198
Crataegus monogyna	2007	*Salix fragilis*	3027
Deschampsia cespitosa cespitosa	1077	*Sambucus nigra*	2025
Dryopteris dilatata	1084	*Silene dioica*	1222
Dryopteris filix-mas	1085	*Urtica dioica*	1244
TOTAL species	**16**		

Table A4.31 Species recorded at Whitacre

Species	Ref.	Flits 1	Flits 7	Flits 8	Flits 9
Alnus glutinosa	3004	✓	✓	✓	✓
Arum maculatum	1022			✓	✓
Carex acutiformis	1039			✓	
Carex hirta	1045	✓			
Corylus avellana	2005	✓	✓	✓	✓
Crataegus monogyna	2007	✓			
Deschampsia cespitosa cespitosa	1077		✓		
Dryopteris dilatata	1084			✓	
Dryopteris filix-mas	1085			✓	
Filipendula ulmaria	1105	✓	✓		
Fraxinus excelsior	3010	✓	✓	✓	✓
Geranium robertianum	1114	✓	✓	✓	
Geum urbanum	1116	✓	✓		✓
Glechoma hederacea	1117	✓		✓	
Hedera helix	1120	✓	✓	✓	
Ilex aquifolium	2010			✓	
Iris pseudacorus	1134	✓			
Mentha aquatica	1156	✓			
Mercurialis perennis	1157	✓	✓	✓	✓
Phalaris arundinacea	1175	✓			
Primula vulgaris	1192	✓			
Ranunculus ficaria	1198	✓	✓		✓
Rubus fruticosus agg.	2024	✓		✓	✓
Salix caprea	3025		✓		
Salix cinerea	3026		✓		
Sambucus nigra	2025	✓	✓		✓
Silene dioica	1222	✓			
Stachys officinalis	1229	✓			
Teucrium scorodonia	1238			✓	
Urtica dioica	1244	✓	✓	✓	
TOTAL species		**21**	**14**	**15**	**9**

Table A4.32 Species recorded at The Flits

Species	Ref.	Uxbridge 1	Uxbridge 2	Uxbridge 3
Acer platanoides	3001	✓		
Acer pseudoplatanus	3002	✓	✓	✓
Agrostis stolonifera	1007	✓	✓	
Alnus glutinosa	3004	✓	✓	✓
Arrhenatherum elatius	1021	✓		
Arum maculatum	1022	✓		
Calystegia sepium	1033			✓
Circaea lutetiana	1064	✓		
Clematis vitalba	2003			✓
Corylus avellana	2005		✓	
Crataegus monogyna	2007	✓	✓	✓
Dactylis glomerata	1075	✓		
Epilobium hirsutum	1086	✓		
Epilobium montanum	1087	✓		
Fragaria vesca	1106	✓		
Fraxinus excelsior	3010	✓		✓
Galium aparine	1108	✓		
Geum urbanum	1116	✓		✓
Glechoma hederacea	1117		✓	
Hedera helix	1120	✓	✓	✓
Holcus lanatus	1123	✓		
Humulus lupulus	1125	✓	✓	✓
Ilex aquifolium	2010	✓		
Petasites hybridus	1173		✓	
Phleum pratense	1176	✓		
Plantago lanceolata	1179	✓		✓
Populus alba	3014	✓		
Prunus spinosa	2020		✓	✓
Quercus robur	3021	✓		
Ranunculus repens	1201	✓	✓	
Rhamnus cathartica	2021	✓		
Rosa canina	2023	✓	✓	
Rubus fruticosus agg.	2024	✓	✓	✓
Rumex obtusifolius	1211	✓	✓	✓
Salix caprea	3025	✓		
Sambucus nigra	2025	✓	✓	✓
Scrophularia nodosa	1217	✓		
Solanum dulcamara	1223	✓		
Ulmus procera	2029	✓		✓
Urtica dioica	1244	✓	✓	✓
TOTAL species		**34**	**16**	**16**

Table A4.33 Species recorded at Uxbridge

Species	Ref.	Species	Ref.
Ajuga reptans	1008	*Lysimachia nemorum*	1151
Alnus glutinosa	3004	*Lysimachia nummularia*	1152
Betula pendula	3006	*Lythrum salicaria*	1154
Brachypodium sylvaticum	1027	*Mentha aquatica*	1156
Calamagrostis canescens	1029	*Myosotis laxa caespitosa*	1161
Callitriche stagnalis	1031	*Myosotis scorpioides*	1162
Cardamine flexuosa	1036	*Persicaria hydropiper*	1171
Cardamine pratensis	1038	*Phalaris arundinacea*	1175
Carex acutiformis	1039	*Poa trivialis*	1183
Carex remota	1053	*Quercus robur*	3021
Castanea sativa	3008	*Ranunculus flammula*	1199
Cirsium palustre	1066	*Ranunculus repens*	1201
Crataegus monogyna	2007	*Ranunculus sceleratus*	1202
Dactylis glomerata	1075	*Ribes rubrum*	1204
Deschampsia cespitosa cespitosa	1077	*Rosa canina*	2023
Dryopteris dilatata	1084	*Rubus fruticosus* agg.	2024
Dryopteris filix-mas	1085	*Rumex sanguineus*	1212
Epilobium hirsutum	1086	*Salix cinerea*	3026
Epilobium montanum	1087	*Salix fragilis*	3027
Festuca gigantea	1103	*Sambucus nigra*	2025
Filipendula ulmaria	1105	*Scirpus sylvaticus*	1215
Galeopsis tetrahit	1107	*Scutellaria galericulata*	1218
Galium aparine	1108	*Senecio aquaticus*	1219
Galium palustre	1110	*Silene dioica*	1222
Geranium robertianum	1114	*Solanum dulcamara*	1223
Glechoma hederacea	1117	*Stellaria media*	1232
Glyceria fluitans	1118	*Stellaria uliginosa*	1233
Holcus mollis	1124	*Symphytum officinale*	1235
Impatiens capensis	1132	*Taraxacum officinale*	1237
Impatiens glandulifera	1133	*Urtica dioica*	1244
Iris pseudacorus	1134	*Valeriana officinalis*	1246
Juncus effusus	1138	*Veronica beccabunga*	1247
Lapsana communis	1143	*Viburnum opulus*	2030
Lycopus europaeus	1150	*Viola riviniana*	1529
TOTAL species	**68**		

Table A4.34 Species recorded at Wilden Marsh

Species	Ref.	Species	Ref.
Acer campestre	2001	*Holcus lanatus*	1123
Acer pseudoplatanus	3002	*Hyacinthoides non-scripta*	1127
Alliaria petiolata	1009	*Ilex aquifolium*	2010
Allium ursinum	1010	*Lapsana communis*	1143
Alnus glutinosa	3004	*Mercurialis perennis*	1157
Anemone nemorosa	1013	*Phalaris arundinacea*	1175
Anthriscus sylvestris	1017	*Prunus laurocerasus*	2017
Aquilegia vulgaris	1019	*Prunus spinosa*	2020
Arrhenatherum elatius	1021	*Quercus robur*	3021
Calystegia sepium	1033	*Ranunculus repens*	1201
Carex pendula	1051	*Ribes rubrum*	1204
Chamerion angustifolium	1060	*Rubus fruticosus* agg.	2024
Crataegus monogyna	2007	*Rumex sanguineus*	1212
Dryopteris filix-mas	1085	*Salix fragilis*	3027
Epilobium hirsutum	1086	*Sambucus nigra*	2025
Filipendula ulmaria	1105	*Scrophularia nodosa*	1217
Fraxinus excelsior	3010	*Silene dioica*	1222
Galium aparine	1108	*Urtica dioica*	1244
Geranium endressii	1113	*Veronica chamaedrys*	1248
Geranium robertianum	1114	*Viburnum opulus*	2030
Geum urbanum	1116	*Vicia sativa*	1253
Hedera helix	1120	*Vinca major*	1256
Heracleum sphondylium	1122		
TOTAL species	**45**		

Table A4.35 Species recorded at Wychwood

Species	Ref.	Species	Ref.
Agrostis stolonifera	1007	*Iris pseudacorus*	1134
Ajuga reptans	1008	*Juncus effusus*	1138
Alliaria petiolata	1009	*Lychnis flos-cuculi*	1149
Alnus glutinosa	3004	*Mentha aquatica*	1156
Alnus incana	3005	*Mercurialis perennis*	1157
Angelica sylvestris	1014	*Myosotis arvensis*	1160
Anisantha sterilis	1015	*Myosotis scorpioides*	1162
Anthriscus sylvestris	1017	*Petasites hybridus*	1173
Apium nodiflorum	1018	*Phalaris arundinacea*	1175
Arum maculatum	1022	*Phragmites australis*	1177
Callitriche obtusangula	1030	*Poa trivialis*	1183
Caltha palustris	1032	*Populus alba*	3014
Calystegia sepium	1033	*Populus tremula*	3018
Cardamine flexuosa	1036	*Prunus spinosa*	2020
Cardamine hirsuta	1037	*Pulmonaria longifolia*	1195
Cardamine pratensis	1038	*Ranunculus ficaria*	1198
Carex acutiformis	1039	*Ranunculus repens*	1201
Carex paniculata	1050	*Ranunculus sceleratus*	1202
Carex pendula	1051	*Ribes nigrum*	1203
Carex riparia	1054	*Ribes rubrum*	1204
Crataegus monogyna	2007	*Rosa canina*	2023
Deschampsia cespitosa cespitosa	1077	*Rubus fruticosus* agg.	2024
Dryopteris dilatata	1084	*Rubus idaeus*	1207
Dryopteris filix-mas	1085	*Rumex hydrolapathum*	1210
Epilobium montanum	1087	*Rumex obtusifolius*	1211
Equisetum fluviatile	1095	*Salix alba*	3023
Equisetum palustre	1097	*Salix caprea*	3025
Equisetum sylvaticum	1098	*Salix cinerea*	3026
Euonymus europaeus	2008	*Salix fragilis*	3027
Eupatorium cannabinum	1101	*Salix purpurea*	3029
Fagus sylvatica	3009	*Salix triandra*	3030
Filipendula ulmaria	1105	*Salix viminalis*	3031
Fraxinus excelsior	3010	*Sambucus nigra*	2025
Galeopsis tetrahit	1107	*Scrophularia nodosa*	1217
Galium aparine	1108	*Scutellaria galericulata*	1218
Geranium robertianum	1114	*Solanum dulcamara*	1223
Geum urbanum	1116	*Symphytum officinale*	1235
Glechoma hederacea	1117	*Taraxacum officinale*	1237
Glyceria maxima	1119	*Urtica dioica*	1244
Hedera helix	1120	*Veronica beccabunga*	1247
Impatiens glandulifera	1133	*Viburnum opulus*	2030
TOTAL species	**82**		

Table A4.36 Species recorded at Willowmead

APPENDIX 5: VALIDATING THE APPROACH DEVELOPED TO DETERMINE POTENTIAL ENDEMIC SPECIES OF A HABITAT AND THE UBIQUITY OF SPECIES (SECTION 3.2)

As the approaches described in Section 3.2.1 to assess potentially endemic species of lowland *Alnus glutinosa* woodlands were developed for the current research, this Appendix details the results of the same approach on different habitat types. The purpose of this was to validate the techniques and confirm that the results described and discussed in Sections 4.4 and 4.6.2, were not unique to lowland *Alnus glutinosa* woodlands.

A similar analysis to that undertaken for *Alnus glutinosa* woodland to determine species potentially endemic to a habitat (Section 3.2.1) was completed on a typical mesotrophic woodland (NVC W10) and a contrasting habitat, calcareous grassland (NVC CG3) to validate the approach. The results of this analysis, referred to in Section 3.2.2, are provided in Sections A5.1 and A5.2.

A5.1 W10 WOODLAND

Following the removal (from the list of species included in the NVC W10 floristic table) of all species that occur in any NVC habitat other than W10, 16 species (15%) remained. These species, which could be considered as endemic to W10, are listed in Table A5.1 and considered in relation their specific ecological requirements, geographical distribution and association with ancient woodland.

To illustrate the range of habitats in which species found in W10 woodlands also occur, the species were considered in relation to their association with the main NVC habitats. Figure A5.1 shows the proportions of species associated with a typical mesotrophic UK woodland (W10; Rodwell, 1991) that occur (at any frequency as defined by Rodwell, 1991 *et seq*) in other habitat types described in the NVC.

The majority of species listed in the W10 floristic table, as expected, are associated with woodland habitats. There is also a fairly high proportion of species associated with open habitats and grassland, reflective of glades and woodland edges (Figure A5.1). There are no species which occur in aquatic habitats; this is not unexpected as mesic woodlands are typically dry with few areas of standing water. Any significant areas of standing water are likely to be classified separately in the NVC.

Nearly two thirds of the endemic species (Table A5.1) have at least a mild association with ancient woodland (e.g. provisional Ancient Woodland Inventories, NCC *c.* 1980; Peterken, 1993) and have optimal growing conditions (as determined by the Ellenberg indicator values as calibrated by Hill *et al.*, 2004) typical of mesotrophic woodland habitats:

- light: 4-5 (81% of species), i.e. shade to semi-shade plants;
- moisture: 5 (88%), i.e. moist soils;
- acidity: 5-6 (75%), i.e. moderately acidic to weakly basic soils;
- fertility: 5-6 (88%), i.e. intermediate to richly fertile soils.

The remaining species are native and/or have strong associations with woodland habitats (Stace, 2001) or, as is the case with *Rhododendron ponticum*, commonly planted in woodlands.

Scientific name	Notes on native status and distribution (from Stace, 2001, unless otherwise stated)	Other habitats in which the species occurs (from Stace, 2001)	Association with Ancient woodland
Carex sylvatica	Native. Frequent throughout most of Britain, common in the south, rare in north Scotland	Heavy soils in woods & damp copses, hedgerows, scrub	Mild affinity (Peterken, 1993)
Carpinus betulus	Native. Southeast England extending to Monmouthshire and Cambridgeshire but much planted on roads and as hedging across Britain	Woods and copses on clay soil	Ancient woodland indicator (NCC, *c.* 1980)
Castanea sativa	Introduced. Planted across much of Britain, notable as coppice in the southeast. Naturalised in southeast England	Woodland	Historic coppice species
Euphorbia amygdaloides[1]	Native. South Britain, north to Flintshire and east to Norfolk; rare alien further north	Woods and shady hedgerows	Ancient woodland indicator (NCC, *c.* 1980)
Galium odoratum	Native. Frequent throughout most of Britain	Damp, base-rich woods and hedgerows	Ancient woodland indicator (NCC, *c.* 1980)
Lysimachia nummularia	Native. Throughout most of Britain north to central Scotland Naturalised garden escape in many localities, especially in the north	Damp places, often shaded; garden escape	-
Melica uniflora	Native. Locally common throughout Britain except north Scotland	Woods and shady hedgebanks	Ancient woodland indicator (NCC, *c.* 1980)
Milium effusum	Native. Locally frequent throughout England, scattered in Wales and lowland Scotland	Moist, shady woods on humus-rich soils	Ancient woodland indicator (NCC, *c.* 1980)
Narcissus pseudonarcissus	Native/introduced depending on cultivar – numerous cultivars across Britain	Woods and grasslands. Garden escapes.	-
Pinus nigra	Introduced	Shelter belts, ornamental, forests	-
Poa nemoralis	Native. Frequent – common across most of Britain	Woods. Hedgebanks, walls and shady places	Ancient woodland indicator (NCC, *c.* 1980)
Prunus avium	Native. Throughout Britain	Hedgerows, wood-borders and copses	-
Rhododendron ponticum	Introduced but extensively naturalised throughout Britain. Frequently used as game cover[2]	Woods and in the open on any suitable substrate	-
Sanicula europaea	Native. Locally common throughout Britain	Deciduous woods on leaf mould	Ancient woodland indicator (NCC, *c.* 1980)
Tilia cordata	Native. Mostly central England and Wales. Also planted and more or less naturalised more widely.	Woods on rich soils	Ancient woodland indicator (NCC, *c.* 1980)
Tilia x *europaea*	Native. Rare in few woods where both parents occur from Herefordshire to northeast Yorkshire. Widely planted	Woods; one of Britain's commonest planted trees	Hybrid of two Ancient woodland indicator species (NCC, *c.* 1980)
Notes 1. Assumes sub-species *amygdaloides* **2.** General notes			

Table A5.1 W10 woodland species that are not recorded at any frequency in any other NVC habitat type in relation to their native status in the UK, other habitats in which they occur and association with ancient woodland

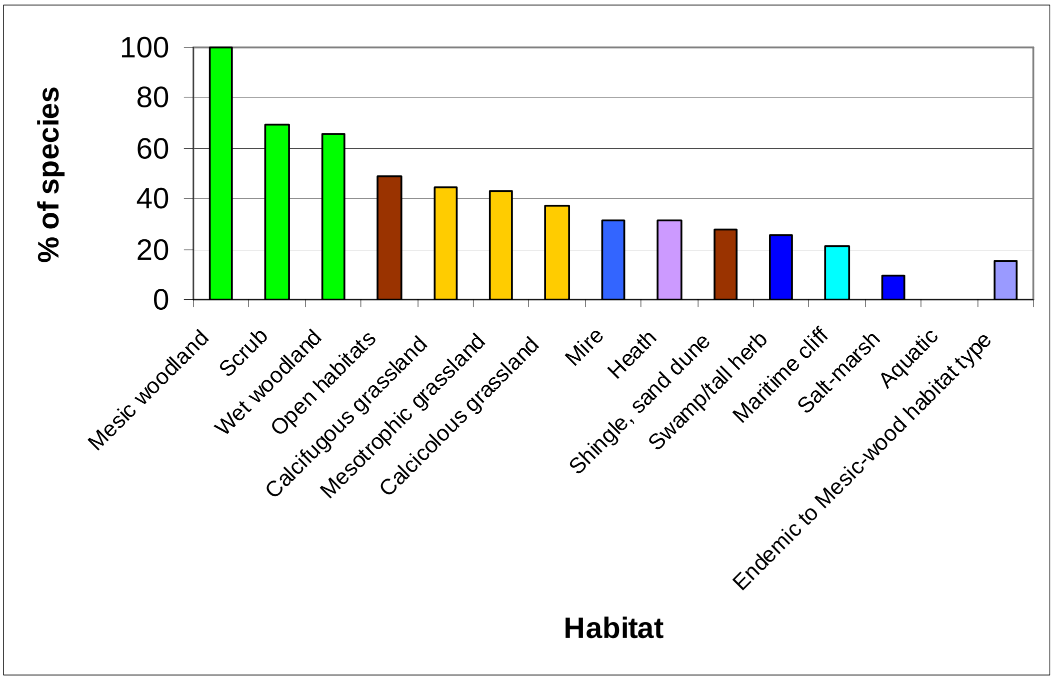

Fig. A5.1 Percentage of species occurring in a typical mesotrophic UK woodland (W10) that occur in other habitat types

In conclusion, the results of the analysis described in Section 3.2.1 and shown here in Table A5.1 and Figure A5.1 indicate that some species (i.e. those listed in Table A5.1) could be considered as endemic to mesic woodland, i.e. they do not occur in other habitat types and have a strong association with woodland but are not restricted to W10 communities.

A5.2 CG3 Grassland

Sixteen species (14%) (Table A5.2) remain, following the removal (from the list of species included in the NVC CG3 floristic table) of all species that occur in any NVC habitat other than CG3; these species, could be considered as endemic to CG3 grassland. Table A5.2 shows that these potentially endemic species, although not necessarily restricted to CG3 communities, have a strong association with calcareous grassland.

Figure A5.2 shows the proportions of species associated with a typical calcareous grassland (CG3, Rodwell, 1998) that occur (at any frequency as defined by Rodwell, 1991 *et seq.*) in other habitat types described in the NVC. This Figure illustrates the range of habitats in which species found in CG3 grassland also occur. Similar to the W10 species (Figure A5.1), none of the species found in CG3 grassland are also associated with aquatic habitats (Figure A5.2). Again, this is not unexpected as any significant wet areas within the CG3 grassland (which are typically dry) are likely to be classified separately in the NVC.

As expected, there are few species listed in the CG3 floristic table that are associated with woodland/scrub habitats (Figure A5.2). The endemic species (14%) have a strong association with calcareous grassland (Table A5.2) and optimal growing conditions (as determined by the Ellenberg indicator values as calibrated by Hill *et al.*, 2004) typical of this habitat (2 species did not have data):

- light: 7-8 (81% of species), i.e. well lit situations/light loving plants;
- moisture: 3-4 (81%), i.e. dry, rarely moist soils;
- acidity: 8 (81%), i.e. calcareous soils;
- fertility: 2-3 (75%), i.e. infertile soils.

Scientific name	Notes on native status and distribution (from Stace, 2001, unless otherwise stated)	Other habitats in which the species occurs (from Stace, 2001)
Asperula cynanchica	Native. Locally common in south Britain and scattered north to Westmorland and southeast Yorkshire	Limestone and chalk grasslands and calcareous dunes
Carex humilis	Native. Very locally common in southeast England from Dorset to Hertfordshire	Short limestone grassland.
Cirsium eriophorum	Native. Locally frequent north to County Durham	Dry grassland, scrub and banks on calcareous soils
Hypochaeris maculata	Native. Very local in Britain north to Westmorland	Grass/open ground mostly on calcareous or sandy soils and maritime cliffs
Linum peremne anglicum	Native. Very local in mainly eastern England from north Essex to Durham and Kirkcudbrightshire	Calcareous grassland
Onobrychis viciifolia	Possibly native. Locally frequent in Britain north to Yorkshire; scattered casual/naturalised alien elsewhere	Grassland and bare patches mostly on chalk or limestone
Ononis spinosa	Native. Locally frequent in Britain north to south Scotland, mostly south and central England	Grassy places and rough ground mostly on well-drained soils
Ophrys apifera	Native. Locally frequent in Britain north to Cumberland and Durham.	Grassland, scrub, spoil heaps and sand dunes on calcareous/base-rich soils
Orobanche elatior	Native. South and eastern England north to northeast Yorkshire and Glamorgan	Host plant *Centaurea scabiosa* – chalk and limestone
Phyteuma orbiculare	Native. Local in south England from north Wiltshire to East Sussex	Open chalk grassland
Polygala calcarea	Native. Local in south England north to south Lincolnshire	Chalk and limestone grassland
Pulsatilla vulgaris	Native. Very local in central and eastern England from west Gloucestershire and south Wiltshire to Cambridgeshire and north Lincolnshire	Dry, calcareous grassland
Tephroseris integrifolia ssp. *integrifolius*	Native. Local in south England north to Cambridgeshire and east Gloucestershire	Chalk and limestone
Thesium humifusum	Native. Very local in England north to south Lincolnshire and east Gloucestershire	Chalk and limestone grassland
Thymus pulegioides	Native. Locally frequent in south and central England, scattered north to southeast Yorkshire. Very rare and scattered in Scotland.	Short, fine turf/barish places in coarse turf on well-drained chalky/sandy soils
Viola hirta	Native. Suitable places in Britain north to central Scotland	Calcareous pasture and open scrub

Table A5.2 CG3 grassland species that are not recorded at any frequency in any other NVC habitat type in relation to their native status and distribution in the UK and other habitats in which they occur

In conclusion, the results of the analysis described in Section 3.2.1 and shown here in Table A5.2 and Figure A5.2 indicate that some species (i.e. those listed in Table A5.2) could be considered as endemic to calcareous grassland, i.e. they do not occur in other habitat types and have a strong association with non-acidic soils but are not restricted to CG3 communities.

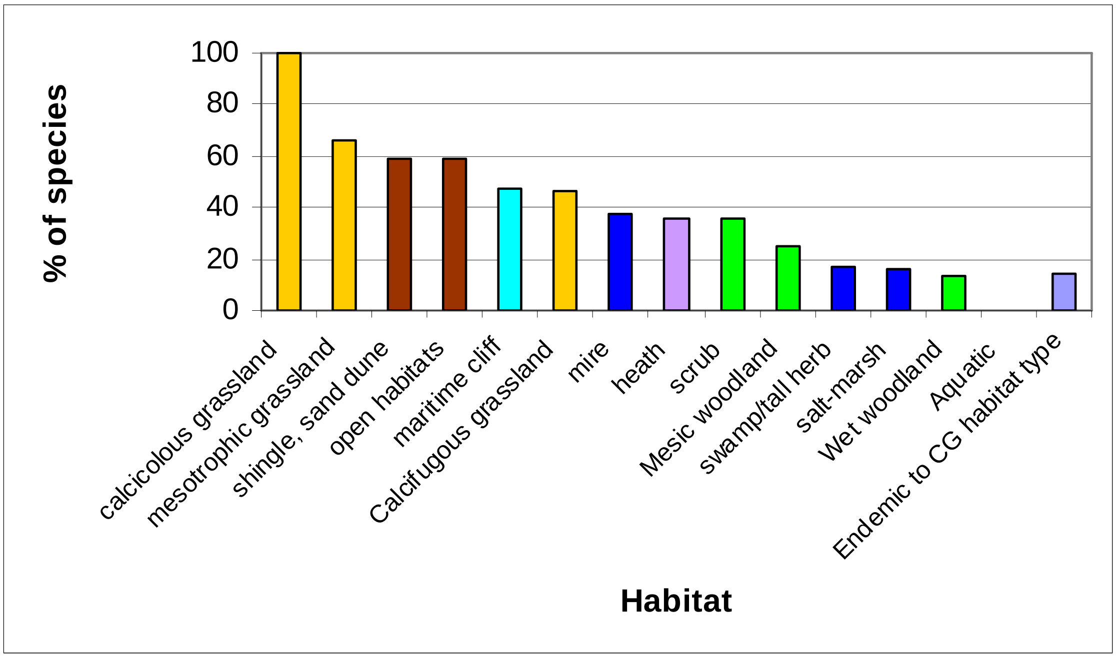

Fig. A5.2 Percentage of species occurring in calcareous grassland (CG3) that occur in other habitat types

APPENDIX 6: BINARY SIGNATURES USED IN TWINSPAN AND DCA ORDINATION ANALYSIS

Table A6.1 details the binary code for each groundflora species used in the TWINSPAN and DCA ordination analysis. For clarity the '0' have been left blank. Species reference refers to the unique reference numbers used during this research; see Appendix 7 for corresponding species.

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1001					1					1								1					1								1	1					
1002			1							1										1						1				1		1					
1003		1						1											1						1							1				1	
1004				1				1											1								1				1	1					
1005					1					1						1							1									1					
1006				1				1									1							1								1					
1007					1				1											1						1					1						
1008			1							1								1							1							1					
1009			1						1											1								1			1						
1010		1							1											1							1					1				1	
1011					1			1													1					1						1		1			
1012					1			1											1								1			1		1					
1013			1						1									1						1								1				1	
1014					1						1								1						1					1	1						
1015			1							1											1						1				1		1				
1016					1				1								1						1									1				1	
1017				1				1												1							1				1						
1018					1								1							1							1				1						
1019				1			1												1						1							1		1			
1020				1			1													1					1						1						
1021					1			1												1							1			1		1					
1022		1						1												1							1					1				1	
1023			1							1								1								1				1					1		
1024						1		1											1					1								1	1				
1025					1								1							1							1				1						
1026			1						1							1							1											1			

Table A6.1 Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1027				1				1											1						1									1	1		
1028		1							1											1							1					1					
1029					1							1								1					1					1					1		
1030					1									1						1						1					1		1				
1031					1								1						1							1					1		1				
1032					1							1							1					1								1		1			
1033					1						1									1							1			1	1						
1034		1						1												1						1						1					
1035				1								1								1						1					1						
1036			1							1									1							1							1			1	
1037						1		1											1							1										1	
1038					1						1							1						1								1	1				
1039					1							1								1						1				1					1		
1040					1							1									1			1													1
1041						1			1											1					1							1		1			
1042						1					1					1						1												1			
1043					1								1							1					1										1		
1044			1								1								1							1											1
1045					1					1										1						1				1		1					
1046			1								1							1						1								1		1			
1047					1						1						1					1												1	1		
1048				1					1									1						1										1			
1049						1					1						1					1												1			
1050				1								1							1							1				1					1		
1051			1								1									1						1								1	1		

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1052					1							1							1							1				1		1					
1053		1									1								1							1						1					
1054					1							1								1							1			1					1		
1055						1							1				1					1													1		
1056		1						1											1						1									1			
1057						1		1											1				1													1	
1058					1			1										1						1								1	1				
1059			1					1									1								1											1	
1060				1				1											1						1					1							
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1062			1								1								1							1						1					
1063			1									1						1							1							1					
1064		1							1											1						1					1						
1065						1			1											1						1				1							
1066					1						1							1						1							1						
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1069						1		1												1								1			1						
1070				1				1										1							1											1	
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1072				1						1									1					1								1					
1073					1			1											1					1								1					
1074				1						1											1			1								1		1			
1075					1			1												1						1				1		1					
1076		1						1												1					1										1		

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1077				1					1									1						1								1			1		
1078				1				1							1								1											1	1		
1079				1					1								1								1						1	1					
1080			1						1									1							1							1			1		
1081																																1			1		
1082				1							1							1						1								1			1		
1083				1								1					1							1													1
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1085			1						1									1							1							1			1		
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1091				1							1									1							1					1					
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1096			1							1										1						1											1
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1099				1							1									1						1				1		1					
1100	1							1												1						1										1	
1101					1						1								1								1			1		1					

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	**4**	**5**	**6**	**7**	**8**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**C**	**CR**	**CSR**	**R**	**S**	**SC**	**SR**	
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1103			1						1											1							1					1					
1104					1			1									1					1												1			
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1111				1					1							1							1											1			
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1114			1						1										1							1						1	1				
1115				1						1									1					1								1		1			
1116		1							1											1							1					1		1			
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1119					1								1							1								1		1							
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1121	1							1													1					1						1			1		
1122					1			1												1							1				1						
1123					1				1										1						1							1					
1124				1					1							1							1							1		1					
1125				1						1										1								1		1							
1126			1				1												1							1										1	

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	**4**	**5**	**6**	**7**	**8**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**C**	**CR**	**CSR**	**R**	**S**	**SC**	**SR**	
1127			1					1										1								1										1	
1128						1					1								1				1									1					
1129			1						1										1						1							1		1			
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1141		1						1												1						1								1	1		
1142					1			1												1								1			1						
1143				1			1													1							1				1		1				
1144																																					1
1145					1									1						1						1					1						
1146					1						1								1					1						1		1					
1147					1				1							1							1											1			
1148			1					1									1							1											1		
1149					1							1							1					1								1					
1150					1						1									1						1					1						
1151			1							1							1								1							1					

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1152			1							1								1							1							1					
1153					1							1								1					1					1					1		
1154					1							1								1					1					1		1					
1155		1						1												1					1									1	1		
1156					1						1									1					1					1	1						
1157	1								1											1							1								1		
1158					1						1					1						1													1		
1159		1						1												1					1							1					
1160					1			1											1							1							1			1	
1161					1							1							1						1						1		1				
1162					1							1							1							1					1						
1163				1								1						1						1							1						
1164						1						1				1						1															1
1165					1							1							1								1				1	1					
1166				1				1												1				1										1		1	
1167				1					1								1						1									1			1		
1168		1							1								1							1								1		1			
1169	1								1											1						1									1		
1170				1						1									1							1				1		1					
1171					1					1									1							1							1				
1172					1				1										1								1						1				
1173				1						1										1							1			1							
1174					1							1								1					1												1
1175					1							1								1							1			1							
1176						1		1												1						1						1					

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1177					1								1							1						1				1							
1178		1						1												1					1									1			
1179					1			1											1					1								1					
1180					1			1											1								1					1	1				
1181						1	1													1			1									1		1			
1182					1			1											1						1							1					
1183					1				1										1							1					1	1					
1184			1					1										1					1											1			
1185			1					1												1					1							1			1		
1186		1						1										1								1						1			1		
1187					1									1							1				1						1						
1188						1				1										1						1					1	1					
1189					1					1						1						1										1		1			
1190					1			1												1					1						1	1					
1191			1					1										1							1									1			
1192			1					1											1					1								1		1			
1193					1			1											1					1								1					
1194				1				1								1							1							1							
1195				1			1												1						1												1
1196					1				1										1					1								1					
1197					1		1													1				1												1	
1198				1					1										1							1							1			1	
1199					1							1						1					1								1	1					
1200					1								1						1								1			1		1					
1201				1						1									1								1				1						

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1202						1					1										1							1					1				
1203			1									1							1							1									1		
1204			1							1										1						1									1		
1205			1					1												1						1									1		
1206					1								1							1							1				1						
1207				1				1										1							1										1		
1208					1			1										1						1								1					
1209						1			1											1						1					1		1				
1210					1								1							1						1				1	1						
1211					1			1												1									1		1						
1212			1							1										1							1					1					
1213		1						1												1					1									1			
1214						1					1									1		1													1		
1215				1							1								1							1				1					1		
1216					1						1									1							1				1						
1217			1						1											1						1					1						
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1219					1						1								1						1						1		1				
1220					1		1												1					1							1		1				
1221					1			1												1							1						1				
1222			1						1										1								1					1					
1223					1						1									1							1			1		1					
1224			1					1									1						1									1		1			
1225					1			1												1						1					1		1				
1227					1								1							1							1					1		1			

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1229					1			1										1					1											1			
1230				1					1											1								1		1	1						
1231			1					1											1							1						1					
1232					1			1											1								1						1				
1233					1						1							1							1						1	1					
1234					1					1								1				1												1			
1235					1					1										1								1		1	1						
1236				1				1												1						1				1	1						
1237					1			1												1						1						1	1				
1238				1			1										1						1									1		1			
1239					1						1									1					1					1		1					
1240				1							1									1					1												1
1241					1			1											1							1					1	1					
1242					1				1										1							1					1						
1243						1							1							1							1			1							
1244				1					1											1								1		1							
1245						1					1								1				1									1		1			
1246				1							1								1						1							1					
1247					1								1						1							1					1						
1248				1				1											1						1							1					
1249				1				1												1						1							1			1	
1250		1							1										1							1						1		1			
1251						1						1						1					1								1	1					
1252					1			1											1						1							1	1				
1253					1		1													1				1								1	1				

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis (Table continues)

Spp. Ref.	Light (L)						Moisture (F)								Acidity (R)							Fertility (N)								CSR-strategy							no value
	3	4	5	6	7	8	4	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8	9	C	CR	CSR	R	S	SC	SR	
1254				1				1											1							1				1		1					
1255					1			1												1					1					1		1					
1256			1						1											1						1				1					1		
1257			1					1												1							1					1					
1258					1							1				1						1										1		1			
1259				1				1										1						1										1			
1260				1							1					1							1									1				1	
1261			1					1										1					1											1			
1262					1					1										1						1									1		
1263					1						1								1					1						1		1					
1264					1				1											1			1											1		1	
1265				1				1												1					1							1		1			
1266						1							1				1						1											1	1		
1267						1						1						1					1											1	1		
1268						1					1									1							1				1						
1269					1						1									1							1				1						
1270					1								1							1							1					1	1				
1271					1				1											1					1					1		1					

Table A6.1 cont. Binary codes for each groundflora species used in DCA ordination analysis

APPENDIX 7: THE SPECIES IDENTIFIED AS BEING ASSOCIATED WITH LOWLAND *ALNUS GLUTINOSA* WOODLAND

A7.1 LOWLAND *ALNUS GLUTINOSA* SPECIES

The following, lists the species associated with lowland *Alnus glutinosa* woodlands (using the methodology described and discussed in Section 3.2.); nomenclature follows Stace (2000). The reference number (and those in all Appendices) is a unique reference number used in the current research. Numbers starting at:

- 1 are groundflora species;
- 2 are shrub layers species;
- 3 are canopy layer species.

Ref.	Species	Vernacular name	Family
2001	*Acer campestre* L.	Field maple	Aceraceae
3001	*Acer platanoides* L.	Norway maple	Aceraceae
3002	*Acer pseudoplatanus* L.	Sycamore	Aceraceae
1001	*Achillea ptarmica* L.	Sneezewort	Asteraceae
1002	*Aconitum napellus* L.	Monk's hood	Ranunculaceae
1003	*Adoxa moschatellina* L.	Moschatel	Adoxaceae
1004	*Aegopodium podagraria* L.	Ground elder	Apiaceae
3003	*Aesculus hippocastanum* L.	Horse-chestnut	Hippocastanaceae
1005	*Agrostis canina* L.	Velvet bent	Poaceae
1006	*Agrostis capillaris* L.	Common bent	Poaceae
1007	*Agrostis stolonifera* L.	Creeping bent	Poaceae
1008	*Ajuga reptans* L.	Bugle	Lamiaceae
1009	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	Garlic mustard	Brassicaceae
1010	*Allium ursinum* L.	Ramsons	Liliaceae
1011	*Allium vineale* L.	Wild onion	Liliaceae
3004	*Alnus glutinosa* (L.) Gaertn.	Alder	Betulaceae
3005	*Alnus incana* (L.) Moench	Grey alder	Betulaceae
1012	*Alopecurus pratensis* L.	Meadow foxtail	Poaceae
1013	*Anemone nemorosa* L.	Wood anemone	Ranunculaceae
1014	*Angelica sylvestris* L.	Wild angelica	Apiaceae
1015	*Anisantha sterilis* (L.) Nevski	Barren brome	Poaceae
1016	*Anthoxanthum odoratum* L.	Sweet vernal grass	Poaceae
1017	*Anthriscus sylvestris* (L.) Hoffm.	Cow parsley	Apiaceae
1018	*Apium nodiflorum* (L.) Lag.	Fool's water parsley	Apiaceae
1019	*Aquilegia vulgaris* L.	Columbine	Ranunculaceae
1020	*Arctium minus* (Hill) Bernh.	Lesser burdock	Asteraceae
1021	*Arrhenatherum elatius* (L.) Beauv. ex J. & C. Presl.	False oat grass	Poaceae
1022	*Arum maculatum* L.	Lords and ladies	Araceae
1023	*Athyrium filix-femina* (L.) Roth	Lady fern	Woodsiaceae
1024	*Bellis perennis* L.	Daisy	Asteraceae
1025	*Berula erecta* (Huds.) Coville	Lesser water parsnip	Apiaceae
3006	*Betula pendula* Roth	Silver birch	Betulaceae
3007	*Betula pubescens* Ehrh.	Downy birch	Betulaceae
1026	*Blechnum spicant* (L.) Roth	Hard fern	Blechnaceae
1027	*Brachypodium sylvaticum* (Huds.) Beauv.	False brome	Poaceae
1028	*Bromopsis ramosa* (Huds.) Holub	Hairy brome	Poaceae
2002	*Buddleja davidii* Franch.	Butterfly bush	Buddlejaceae
1029	*Calamagrostis canescens* (F. H. Wigg.) Roth.	Purple small reed	Poaceae
1030	*Callitriche obtusangula* Le Gall	Blunt-fruited water starwort	Callitrichaceae
1031	*Callitriche stagnalis* Scop.	Common water starwort	Callitrichaceae
1032	*Caltha palustris* L.	Marsh marigold	Ranunculaceae
1033	*Calystegia sepium* (L.) R. Br.	Hedge bindweed	Convolvulaceae
1034	*Campanula trachelium* L.	Nettle-leaved bellflower	Campanulaceae
1035	*Cardamine amara* L.	Large bittercress	Brassicaceae
1036	*Cardamine flexuosa* With.	Wavy bittercress	Brassicaceae
1037	*Cardamine hirsuta* L.	Hairy bittercress	Brassicaceae
1038	*Cardamine pratensis* L.	Cuckooflower	Brassicaceae
1039	*Carex acutiformis* Ehrh.	Lesser pond sedge	Cyperaceae
1040	*Carex appropinquata* Schumach.	Fibrous tussock sedge	Cyperaceae

Ref.	Species	Vernacular name	Family
1041	*Carex distans* L.	Distant sedge	Cyperaceae
1263	*Carex disticha* Huds.	Brown sedge	Cyperaceae
1042	*Carex echinata* Murray	Star sedge	Cyperaceae
1043	*Carex elata* All.	Tufted sedge	Cyperaceae
1044	*Carex elongata* L.	Elongated sedge	Cyperaceae
1045	*Carex hirta* L.	Hairy sedge	Cyperaceae
1046	*Carex laevigata* Sm.	Small-stalked sedge	Cyperaceae
1047	*Carex nigra* (L.) Reichard.	Common sedge	Cyperaceae
1048	*Carex pallescens* L.	Pale sedge	Cyperaceae
1049	*Carex panicea* L.	Carnation sedge	Cyperaceae
1050	*Carex paniculata* L.	Great tussock sedge	Cyperaceae
1051	*Carex pendula* Huds.	Pendulous sedge	Cyperaceae
1052	*Carex pseudocyperus* L.	Cyperus sedge	Cyperaceae
1053	*Carex remota* L.	Remote sedge	Cyperaceae
1054	*Carex riparia* Curtis.	Greater pond sedge	Cyperaceae
1055	*Carex rostrata* Stokes	Bottle sedge	Cyperaceae
1056	*Carex sylvatica* Huds.	Wood sedge	Cyperaceae
3008	*Castanea sativa* Mill.	Sweet chestnut	Fagaceae
1057	*Centaurium erythraea* Rafn	Common centaury	Gentianaceae
1058	*Cerastium fontanum* Baumg.	Common mouse-ear	Caryophyllaceae
1059	*Ceratocapnos claviculata* (L.) Lidén	Climbing corydalis	Papaveraceae
1060	*Chamerion angustifolium* (L.) Holub.	Rosebay willowherb	Onagraceae
1061	*Chenopodium album* L.	Fat hen	Chenopodiaceae
1062	*Chrysosplenium alternifolium* L.	Alternate-leaved golden saxifrage	Saxifragaceae
1063	*Chrysosplenium oppositifolium* L.	Opposite-leaved golden saxifrage	Saxifragaceae
1064	*Circaea lutetiana* L.	Enchanter's nightshade	Onagraceae
1065	*Cirsium arvense* (L.) Scop.	Creeping thistle	Asteraceae
1066	*Cirsium palustre* (L.) Scop.	Marsh thistle	Asteraceae
1067	*Cirsium vulgare* (Sabi) Ten.	Spear thistle	Asteraceae
2003	*Clematis vitalba* L.	Traveller's joy	Ranunculaceae
1068	*Colchium autumnale* L.	Meadow saffron	Liliaceae
1069	*Conium maculatum* L.	Hemlock	Apiaceae
1070	*Conopodium majus* (Gouan) Loret	Pignut	Apiaceae
1071	*Convallaria majalis* L.	Lily of the valley	Liliaceae
2004	*Cornus sanguinea* L.	Dogwood	Cornaceae
2005	*Corylus avellana* L.	Hazel	Betulaceae
2006	*Crataegus laevigata* (Poir.) DC.	Midland hawthorn	Rosaceae
2007	*Crataegus monogyna* Jacq.	Hawthorn	Rosaceae
1072	*Crepis paludosa* (L.) Moench	Marsh hawksbeard	Asteraceae
1073	*Cynosurus cristatus* L.	Crested dog's tail	Poaceae
1074	*Cystopteris fragilis* (L.) Bernh.	Bladder fern	Woodsiaceae
1075	*Dactylis glomerata* L.	Cock's foot	Poaceae
1076	*Daphne laureola* L.	Spurge laurel	Thymelaeaceae
1077	*Deschampsia cespitosa* (L.) P. Beauv. c*espitosa* (L.) P. Beauv.	Tufted hair grass	Poaceae
1078	*Deschampsia flexuosa* (L.) Trin.	Wavy hair grass	Poaceae
1079	*Digitalis purpurea* L.	Foxglove	Scrophulariaceae
1080	*Dryopteris affinis* (Lowe) Fraser-Jenk.	Scaley male fren	Dryopteridaceae
1081	*Dryopteris affinis* (Lowe) Fraser-Jenk. *borreri* (Newman) Fraser-Jenk.		Dryopteridaceae
1082	*Dryopteris carthusiana* (Vill.) H. P. Fuchs	Narrow buckler fern	Dryopteridaceae
1083	*Dryopteris cristata* (L.) A. Gray	Crested buckler fern	Dryopteridaceae
1084	*Dryopteris dilatata* (Hoffm.) A. Gray	Broad buckler fern	Dryopteridaceae
1085	*Dryopteris filix-mas* (L.) Schott	Male fern	Dryopteridaceae
1086	*Epilobium hirsutum* L.	Great willowherb	Onagraceae
1087	*Epilobium montanum* L.	Broad-leaved willowherb	Onagraceae
1088	*Epilobium obscurum* Schreb.	Short-fruited willowherb	Onagraceae
1089	*Epilobium palustre* L.	Marsh willowherb	Onagraceae
1090	*Epilobium parviflorum* Schreb.	Hoary willowherb	Onagraceae
1091	*Epilobium roseum* Schreb.	Pale willowherb	Onagraceae
1092	*Epilobium tetragonum* L.	Sqaure-stalked willowherb	Onagraceae
1093	*Epipactis helleborine* (L.) Crantz.	Broad-leaved helleborine	Orchidaceae
1094	*Equisetum arvense* L.	Field horsetail	Equisetaceae
1095	*Equisetum fluviatile* L.	Water horsetail	Equisetaceae
1096	*Equisetum hyemale* L.	Rough horsetail	Equisetaceae

Ref.	Species	Vernacular name	Family
1097	*Equisetum palustre* L.	Marsh horsetail	Equisetaceae
1098	*Equisetum sylvaticum* L.	Wood horsetail	Equisetaceae
1099	*Equisetum telmateia* Ehrh.	Great horsetail	Equisetaceae
1100	*Eranthis hyemalis* (L.) Salisb.	Winter aconite	Ranunculaceae
2008	*Euonymus europaeus* L.	Spindle	Celastraceae
1101	*Eupatorium cannabinum* L.	Hemp agrimony	Asteraceae
3009	*Fagus sylvatica* L.	Beech	Fagaceae
1102	*Festuca arundinacea* Schreb.	Tall fescue	Poaceae
1103	*Festuca gigantea* (L.) Vill.	Giant fescue	Poaceae
1104	*Festuca ovina* L.	Sheep's fescue	Poaceae
1105	*Filipendula ulmaria* (L.) Maxim.	Meadowsweet	Rosaceae
1106	*Fragaria vesca* L.	Wild strawberry	Rosaceae
2009	*Frangula alnus* Mill.	Alder buckthorn	Rhamnaceae
3010	*Fraxinus excelsior* L.	Ash.	Oleaceae
1107	*Galeopsis tetrahit* L.	Common hemp nettle	Lamiaceae
1108	*Galium aparine* L.	Cleavers	Rubiaceae
1109	*Galium odoratum* (L.) Scrop.	Woodruff	Rubiaceae
1110	*Galium palustre* L.	Common marsh bedstraw	Rubiaceae
1111	*Galium saxatile* L.	Heath bedstraw	Rubiaceae
1112	*Galium uliginosum* L.	Fen bedstraw	Rubiaceae
1113	*Geranium endressii* J. Gay	French cranesbill	Geraniaceae
1114	*Geranium robertianum* L.	Herb Robert	Geraniaceae
1115	*Geum rivale* L.	Water avens	Rosaceae
1116	*Geum urbanum* L.	Wood avens	Rosaceae
1117	*Glechoma hederacea* L.	Ground ivy	Lamiaceae
1118	*Glyceria fluitans* (L.) R. Br.	Floating sweet grass	Poaceae
1119	*Glyceria maxima* (Hartm.) Holmb.	Reed sweet grass	Poaceae
1264	*Gymnadenia conopsea* (L.) R. Br.	Fragrant orchid	Orchidaceae
1120	*Hedera helix* L.	Ivy..	Araliaceae
1121	*Helleborus viridis* L.	Green hellebore	Ranunculaceae
1122	*Heracleum sphondylium* L.	Hogweed	Apiaceae
1123	*Holcus lanatus* L.	Yorkshire fog	Poaceae
1124	*Holcus mollis* L.	Creeping soft grass	Poaceae
1125	*Humulus lupulus* L.	Hop	Cannabaceae
1126	*Hyacinthoides hispanica* (Mill.) Rothm.	Spanish bluebell	Liliaceae
1127	*Hyacinthoides non-scripta* (L.) Chouard ex Rothm..	Bluebell	Liliaceae
1128	*Hydrocotyle vulgaris* L.	Marsh pennywort	Apiaceae
1129	*Hypericum androsaemum* L.	Tutsan	Clusiaceae
1130	*Hypericum hirsutum* L.	Hairy St John's wort	Clusiaceae
1131	*Hypericum tetrapterum* Fr.	Square-stalked St John's wort	Clusiaceae
2010	*Ilex aquifolium* L.	Holly	Aquifoliaceae
1132	*Impatiens capensis* Meerb.	Orange balsam	Balsaminaceae
1133	*Impatiens glandulifera* Royle.	Indian balsam	Balsaminaceae
1134	*Iris pseudacorus* L.	Yellow iris	Iridaceae
1135	*Juncus acutiflorus* Ehrh. ex Hoffm.	Sharp-flowered rush	Juncaceae
1136	*Juncus articulatus* L.	Jointed rush	Juncaceae
1137	*Juncus bufonius* L.	Toad rush	Juncaceae
1138	*Juncus effusus* L.	Soft rush	Juncaceae
1139	*Juncus inflexus* L.	Hard rush	Juncaceae
1140	*Juncus subnodulosus* Schrank.	Blunt-flowered rush	Juncaceae
1141	*Lamiastrum galeobdolon* (L.) Ehrend. & Polatschek	Yellow archangel	Lamiaceae
1142	*Lamium album* L.	White dead nettle	Lamiaceae
1143	*Lapsana communis* L.	Nipplewort	Asteraceae
1144	*Lathraea clandestina* L.	Purple toothwort	Orobanchaceae
1145	*Lemna minor* L.	Common duckweed	Lemnaceae
2011	*Ligustrum vulgare* L.	Wild privet	Oleaceae
1265	*Listera ovata* (L.) R. Br.	Common twayblade	Orchidaceae
2012	*Lonicera periclymenum* L.	Honeysuckle	Caprifoliaceae
1146	*Lotus pedunculatus* Cav.	Greater bird's foot trefoil	Fabaceae
1147	*Luzula multiflora* (Ehrh.) Lej.	Heath wood rush	Juncaceae
1261	*Luzula pilosa* (L.) Willd.	Hairy wood rush	Juncaceae
1148	*Luzula sylvatica* (Huds.) Gaudin	Great wood rush	Juncaceae
1149	*Lychnis flos-cuculi* L.	Ragged robin	Caryophyllaceae

Ref.	Species	Vernacular name	Family
1150	*Lycopus europaeus* L.	Gypsywort	Lamiaceae
1151	*Lysimachia nemorum* L.	Yellow pimpernel	Primulaceae
1152	*Lysimachia nummularia* L.	Creeping Jenny	Primulaceae
1153	*Lysimachia vulgaris* L.	Yellow loosestrife	Primulaceae
1154	*Lythrum salicaria* L.	Purple loosestrife	Lythraceae
2013	*Mahonia aquifolium* (Pursh) Nutt.	Oregon grape	Berberidaceae
2014	*Malus sylvestris sens.lat.* (L.) Mill.	Crab apple	Rosaceae
1155	*Melica uniflora* Retz.	Wood Medick	Poaceae
1156	*Mentha aquatica* L.	Water mint	Lamiaceae
1266	*Menyanthes trifoliata* L.	Bogbean	Menyanthaceae
1157	*Mercurialis perennis* L.	Dog's mercury	Euphorbiaceae
1158	*Molinia caerulea* (L.) Moench	Purple moor grass	Poaceae
1159	*Mycelis muralis* (L.) Dumort.	Wall lettuce	Asteraceae
1160	*Myosotis arvensis* (L.) Hill	Field forget-me-not	Boraginaceae
1161	*Myosotis laxa* Lehm. c*aespitosa* (Schultz) Hyl. ex Nordh	Tufted forget-me-not	Boraginaceae
1162	*Myosotis scorpioides* L.	Water forget-me-not	Boraginaceae
1163	*Myosotis secunda* Al. Murray	Creeping forget-me-not	Boraginaceae
1164	*Myrica gale* L.	Bog myrtle	Myricaceae
1165	*Oenanthe crocata* L.	Hemlock water dropwort	Apiaceae
1166	*Orchis mascula* (L.) L.	Early purple orchid	Orchidaceae
1167	*Oreopteris limbosperma* (Bellardi ex All.) Holub	Lemon-scented fern	Thelypteridaceae
1168	*Oxalis acetosella* L.	Wood sorrel	Oxalidaceae
1169	*Paris quadrifolia* L.	Herb Paris	Liliaceae
1170	*Persicaria bistorta* (L.) Samp.	Common bistort	Polygonaceae
1171	*Persicaria hydropiper* (L.) Spach	Water pepper	Polygonaceae
1172	*Persicaria maculosa* Gray	Redshank	Polygonaceae
1173	*Petasites hybridus* (L.) P. Gaertn., B. Mey. & Scherb.	Butterbur	Asteraceae
1174	*Peucedanum palustre* (L.) Moench	Milk parsley	Apiaceae
1175	*Phalaris arundinacea* L.	Reed canary grass	Poaceae
1176	*Phleum pratense* L.	Timothy	Poaceae
1177	*Phragmites australis* (Cav.) Trin. ex Steud.	Common reed	Poaceae
1178	*Phyllitis scolopendrium* (L.) Newman	Hart's tongue	Aspleniaceae
3011	*Picea abies* (L.) H. Karst.	Norway spruce	Pinaceae
3012	*Pinus nigra* agg. J. F. Arnold	Corsican pine	Pinaceae
3013	*Pinus sylvestris* L.	Scot's pine	Pinaceae
1179	*Plantago lanceolata* L.	Ribwort plantain	Plantaginaceae
1180	*Plantago major* L.	Greater plantain	Plantaginaceae
1181	*Plantago media* L.	Hoary plantain	Plantaginaceae
1182	*Poa pratensis* L.	Smooth meadow grass	Poaceae
1183	*Poa trivialis* L.	Rough meadow grass	Poaceae
1184	*Polypodium vulgare* L.	Polypody	Polypodiaceae
1185	*Polystichum aculeatum* (L.) Roth	Hard shield fern	Dryopteridaceae
1186	*Polystichum setiferum* (Forssk.) T. Moore ex Wyon.	Soft shield fern	Dryopteridaceae
3015	*Populus × canescens* (Aiton) Sm.	Grey poplar	Salicaceae
3014	*Populus alba* L.	White poplar	Salicaceae
3016	*Populus nigra* L.	Black poplar	Salicaceae
3017	*Populus nigra* 'Italica' L.	Lombardy poplar	Salicaceae
3018	*Populus tremula* L.	Aspen	Salicaceae
1187	*Potamogeton coloratus* Hornem.	Marsh pondweed	Potamogetonaceae
1188	*Potentilla anserina* L.	Silverweed	Rosaceae
1189	*Potentilla erecta* (L.) Raeusch.	Tomentil	Rosaceae
1267	*Potentilla palustris* (L.) Scop.	Marsh cinquefoil	Rosaceae
1190	*Potentilla reptans* L.	Creeping cinquefoil	Rosaceae
1191	*Potentilla sterilis* (L.) Garcke	Barren strawberry	Rosaceae
1192	*Primula vulgaris* Huds.	Primrose	Primulaceae
1193	*Prunella vulgaris* L.	Self heal	Lamiaceae
2015	*Prunus avium* (L.) L	Wild cherry	Rosaceae
2016	*Prunus cerasifera* Ehrh.	Cherry plum	Rosaceae
2017	*Prunus laurocerasus* L.	Cherry laurel	Rosaceae
2018	*Prunus lusitanica* L.	Portugal laurel	Rosaceae
2019	*Prunus padus* L.	Bird cherry	Rosaceae
2020	*Prunus spinosa* L.	Blackthorn	Rosaceae
1194	*Pteridium aquilinum* (L.) Kuhn	Bracken	Dennstaedtiaceae

Ref.	Species	Vernacular name	Family
1195	*Pulmonaria longifolia* (Bastard) Boreau	Narrow-leaved lungwort	Boranginaceae
3020	*Quercus petraea* (Matt.) Liebl.	Sessile oak	Fagaceae
3021	*Quercus robur* L.	Pedunculate oak	Fagaceae
1196	*Ranunculus acris* L.	Meadow buttercup	Ranunculaceae
1197	*Ranunculus bulbosus* L.	Bulbous buttercup	Ranunculaceae
1198	*Ranunculus ficaria* L.	Lesser celandine	Ranunculaceae
1199	*Ranunculus flammula* L.	Lesser spearwort	Ranunculaceae
1200	*Ranunculus lingua* L.	Greater spearwort	Ranunculaceae
1201	*Ranunculus repens* L.	Creeping buttercup	Ranunculaceae
1202	*Ranunculus sceleratus* L.	Celery-leaved buttercup	Ranunculaceae
2021	*Rhamnus cathartica* L.	Buckthorn	Rhamnaceae
2022	*Rhododendron ponticum* L.	Rhododendron	Ericaceae
1203	*Ribes nigrum* L.	Black currant	Grossulariaceae
1204	*Ribes rubrum* L.	Red currant	Grossulariaceae
1205	*Ribes uva-crispa* L.	Gooseberry	Grossulariaceae
1206	*Rorippa nasturtium-aquaticum* (L.) Hayek	Watercress	Brassicaceae
2023	*Rosa canina* L.	Dog rose	Rosaceae
1262	*Rubus caesius* L.	Dewberry	Rosaceae
2024	*Rubus fruticosus agg.* L.	Bramble	Rosaceae
1207	*Rubus idaeus* L.	Raspberry	Rosaceae
1208	*Rumex acetosa* L.	Common sorrel	Polygonaceae
1268	*Rumex conglomeratus* Murray	Clustered dock	Polygonaceae
1209	*Rumex crispus* L.	Curled dock	Polygonaceae
1210	*Rumex hydrolapathum* Huds.	Water dock	Polygonaceae
1211	*Rumex obtusifolius* L.	Broad-leaved dock	Polygonaceae
1212	*Rumex sanguineus* L.	Wood dock	Polygonaceae
3023	*Salix alba* L.	White willow	Salicaceae
3024	*Salix aurita* L.	Eared willow	Salicaceae
3025	*Salix caprea* L.	Goat willow	Salicaceae
3026	*Salix cinerea* L.	Grey willow	Salicaceae
3027	*Salix fragilis* L.	Crack willow	Salicaceae
3028	*Salix pentandra* L.	Bay willow	Salicaceae
3029	*Salix purpurea* L.	Purple willow	Salicaceae
3030	*Salix triandra* L.	Almond willow	Salicaceae
3031	*Salix viminalis* L.	Osier	Salicaceae
2025	*Sambucus nigra* L.	Elder	Caprifoliaceae
1213	*Sanicula europaea* L.	Sanicle	Apiaceae
1214	*Schoenus nigricans* L.	Black bog rush	Cyperaceae
1215	*Scirpus sylvaticus* L.	Wood club-rush	Cyperaceae
1216	*Scrophularia auriculata* L.	Water figwort	Scrophulariaceae
1217	*Scrophularia nodosa* L.	Common figwort	Scrophulariaceae
1218	*Scutellaria galericulata* L.	Skullcap	Lamiaceae
1219	*Senecio aquaticus* Hill	Marsh ragwort	Asteraceae
1220	*Senecio jacobaea* L.	Common ragwort	Asteraceae
1221	*Senecio vulgaris* L.	Groundsel	Asteraceae
1222	*Silene dioica* (L.) Clairv.	Red campion	Caryophyllaceae
1223	*Solanum dulcamara* L.	Bittersweet	Solanaceae
1224	*Solidago virgaurea* L.	Goldenrod	Asteraceae
1225	*Sonchus asper* (L.) Hill	Prickly sow-thistle	Asteraceae
3035	*Sorbus aucuparia* L.	Rowan	Rosaceae
3032	*Sorbus torminalis* (L.) Crantz	Wild service tree	Rosaceae
1227	*Sparganium erectum* L.	Branched bur reed	Sparganiaceae
1229	*Stachys officinalis* (L.) Trevis.	Betony	Lamiaceae
1269	*Stachys palustris* L.	Marsh woundwort	Lamiaceae
1230	*Stachys sylvatica* L.	Hedge woundwort	Lamiaceae
1231	*Stellaria holostea* L.	Greater stitchwort	Caryophyllaceae
1232	*Stellaria media* (L.) Vill.	Common chickweed	Caryophyllaceae
1233	*Stellaria uliginosa* Murray	Bog stitchwort	Caryophyllaceae
1234	*Succisa pratensis* Moench.	Devil's bit scabious	Dipsacaceae
2026	*Symphoricarpos albus* (L.) S. F. Blake	Snowberry	Caprifoliaceae
2027	*Symphoricarpos orbiculatus* Moench	Coralberry	Caprifoliaceae
1235	*Symphytum officinale* L.	Common comfrey	Boraginaceae
1236	*Tamus communis* L.	Black bryony	Dioscoreaceae

Ref.	Species	Vernacular name	Family
1237	*Taraxacum officinale* agg. F. H. Wigg.	Dandelion	Asteraceae
3033	*Taxus baccata* L.	Yew	Taxaceae
1238	*Teucrium scorodonia* L.	Wood sage	Lamiaceae
1239	*Thalictrum flavum* L.	Common meadow rue	Ranunculaceae
1240	*Thelypteris palustris* Schott	Marsh fern	Thelypteridaceae
3034	*Tilia cordata* Mill.	Small-leaved lime	Tiliaceae
1241	*Trifolium repens* L.	White clover	Fabaceae
1242	*Tussilago farfara* L.	Coltsfoot	Asteraceae
1243	*Typha latifolia* L.	Bulrush	Typhaceae
2028	*Ulmus glabra* Huds.	Wych elm	Ulmaceae
2029	*Ulmus procera* Salisb.	English elm	Ulmaceae
1244	*Urtica dioica* L.	Common nettle	Urticaceae
1245	*Valeriana dioica* L.	Marsh valerian	Valerianaceae
1246	*Valeriana officinalis* L.	Common valerian	Valerianaceae
1270	*Veronica anagallis-aquatica* L.	Blue water speedwell	Scrophulariaceae
1247	*Veronica beccabunga* L.	Brooklime	Scrophulariaceae
1248	*Veronica chamaedrys* L.	Germander speedwell	Scrophulariaceae
1249	*Veronica hederifolia* L.	Ivy-leaved speedwell	Scrophulariaceae
1250	*Veronica montana* L.	Wood speedwell	Scrophulariaceae
1251	*Veronica scutellata* L.	Marsh speedwell	Scrophulariaceae
1252	*Veronica serpyllifolia* L.	Thyme-leaved speedwell	Scrophulariaceae
2030	*Viburnum opulus* L.	Guelder rose	Caprifoliaceae
1271	*Vicia cracca* L.	Tufted vetch	Fabaceae
1253	*Vicia sativa* L.	Common vetch	Fabaceae
1254	*Vicia sepium* L.	Bush vetch	Fabaceae
1255	*Vicia sylvatica* L.	Wood vetch	Fabaceae
1256	*Vinca major* L.	Greater periwinkle	Apocynaceae
1257	*Viola odorata* L.	Sweet violet	Violaceae
1258	*Viola palustris* L.	Marsh violet	Violaceae
1259	*Viola riviniana* Rchb.	Common dog violet	Violaceae
1260	*Wahlenbergia hederacea* (L.) Rchb.	Ivy-leaved bellflower	Campanulaceae

A7.2 CSR-Strategies and Ellenberg Indicator Values for Lowland *Alnus glutinosa* Woodland Species

Tables A7.1 and A7.2 detail the CSR-strategies and Ellenberg indicator values for each species listed above.

Ref.	Species	CSR	L	F	R	N
1001	*Achillea ptarmica*	CR/CSR	7	7	5	3
1002	*Aconitum napellus*	C/CSR	5	7	7	6
1003	*Adoxa moschatellina*	SR/CSR	4	5	6	5
1004	*Aegopodium podagraria*	CR/CSR	6	5	6	7
1005	*Agrostis canina*	CSR	7	7	3	3
1006	*Agrostis capillaris*	CSR	6	5	4	4
1007	*Agrostis stolonifera*	CR	7	6	7	6
1008	*Ajuga reptans*	CSR	5	7	5	5
1009	*Alliaria petiolata*	CR	5	6	7	8
1010	*Allium ursinum*	SR/CSR	4	6	7	7
1011	*Allium vineale*	S/CSR	7	5	8	6
1012	*Alopecurus pratensis*	C/CSR	7	5	6	7
1013	*Anemone nemorosa*	SR/CSR	5	6	5	4
1014	*Angelica sylvestris*	C/CR	7	8	6	5
1015	*Anisantha sterilis*	R/CR	5	7	8	7
1016	*Anthoxanthum odoratum*	SR/CSR	7	6	4	3
1017	*Anthriscus sylvestris*	CR	6	5	7	7
1018	*Apium nodiflorum*	CR	7	10	7	7
1019	*Aquilegia vulgaris*	S/CSR	6	4	6	5
1020	*Arctium minus*	CR	6	4	7	5
1021	*Arrhenatherum elatius*	C/CSR	7	5	7	7
1022	*Arum maculatum*	SR/CSR	4	5	7	7

Table A7.1 CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: groundflora (Table continues)

Ref.	Species	CSR	L	F	R	N
1023	*Athyrium filix-femina*	C/SC	5	7	5	6
1024	*Bellis perennis*	R/CSR	8	5	6	4
1025	*Berula erecta*	CR	7	10	7	7
1026	*Blechnum spicant*	S	5	6	3	3
1027	*Brachypodium sylvaticum*	S/SC	6	5	6	5
1028	*Bromopsis ramosa*	CSR	4	6	7	7
1029	*Calamagrostis canescens*	C/SC	7	9	7	5
1030	*Callitriche obtusangula*	R/CR	7	11	7	6
1031	*Callitriche stagnalis*	R/CR	7	10	6	6
1032	*Caltha palustris*	S/CSR	7	9	6	4
1033	*Calystegia sepium*	C/CR	7	8	7	7
1034	*Campanula trachelium*	CSR	4	5	7	6
1035	*Cardamine amara*	CR	6	9	7	6
1036	*Cardamine flexuosa*	R/SR	5	7	6	6
1037	*Cardamine hirsuta*	SR	8	5	6	6
1038	*Cardamine pratensis*	R/CSR	7	8	5	4
1039	*Carex acutiformis*	C/SC	7	9	7	6
1040	*Carex appropinquata*	-	7	9	8	4
1041	*Carex distans*	S/CSR	8	6	7	5
1263	*Carex disticha*	C/CSR	7	8	6	4
1042	*Carex echinata*	S	8	8	3	2
1043	*Carex elata*	SC	7	10	7	5
1044	*Carex elongata*	-	5	8	6	6
1045	*Carex hirta*	C/CSR	7	7	7	6
1046	*Carex laevigata*	S/CSR	5	8	5	4
1047	*Carex nigra*	S/SC	7	8	4	2
1048	*Carex pallescens*	S	6	6	5	4
1049	*Carex panicea*	S	8	8	4	2
1050	*Carex paniculata*	C/SC	6	9	6	6
1051	*Carex pendula*	S/SC	5	8	7	6
1052	*Carex pseudocyperus*	C/CSR	7	9	6	6
1053	*Carex remota*	CSR	4	8	6	6
1054	*Carex riparia*	C/SC	7	9	7	7
1055	*Carex rostrata*	SC	8	10	4	2
1056	*Carex sylvatica*	S	4	5	6	5
1057	*Centaurium erythraea*	SR	8	5	6	3
1058	*Cerastium fontanum*	R/CSR	7	5	5	4
1059	*Ceratocapnos claviculata*	SR	5	5	4	5
1060	*Chamerion angustifolium*	C	6	5	6	5
1061	*Chenopodium album*	R/CR	7	5	7	7
1062	*Chrysosplenium alternifolium*	CSR	5	8	6	6
1063	*Chrysosplenium oppositifolium*	CSR	5	9	5	5
1064	*Circaea lutetiana*	CR	4	6	7	6
1065	*Cirsium arvense*	C	8	6	7	6
1066	*Cirsium palustre*	CR	7	8	5	4
1067	*Cirsium vulgare*	CR	7	5	6	6
1068	*Colchium autumnale*	-	6	6	6	4
1069	*Conium maculatum*	CR	8	5	7	8
1070	*Conopodium majus*	SR	6	5	5	5
1071	*Convallaria majalis*	S/SC	5	5	6	5
1072	*Crepis paludosa*	CSR	6	7	6	4
1073	*Cynosurus cristatus*	CSR	7	5	6	4
1074	*Cystopteris fragilis*	S/CSR	6	7	8	4
1075	*Dactylis glomerata*	C/CSR	7	5	7	6
1076	*Daphne laureola*	SC	4	5	7	5
1077	*Deschampsia cespitosa cespitosa*	SC/CSR	6	6	5	4
1078	*Deschampsia flexuosa*	S/SC	6	5	2	3
1079	*Digitalis purpurea*	CR/CSR	6	6	4	5
1080	*Dryopteris affinis*	SC/CSR	5	6	5	5
1081	*Dryopteris affinis* ssp *borreri*	SC/CSR	-	-	-	-
1082	*Dryopteris carthusiana*	SC/CSR	6	8	5	4

Table A7.1 cont. CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: groundflora (Table continues)

Ref.	Species	CSR	L	F	R	N
1083	*Dryopteris cristata*	-	6	9	4	4
1084	*Dryopteris dilatata*	SC/CSR	5	6	4	5
1085	*Dryopteris filix-mas*	SC/CSR	5	6	5	5
1086	*Epilobium hirsutum*	C	7	8	7	7
1087	*Epilobium montanum*	CSR	6	6	6	6
1088	*Epilobium obscurum*	CSR	6	8	5	5
1089	*Epilobium palustre*	S/CSR	7	8	5	3
1090	*Epilobium parviflorum*	CSR	7	9	7	5
1091	*Epilobium roseum*	CSR	6	8	7	7
1092	*Epilobium tetragonum*	CSR	6	7	5	5
1093	*Epipactis helleborine*	S	4	5	7	4
1094	*Equisetum arvense*	CR	7	6	6	6
1095	*Equisetum fluviatile*	SC	8	10	6	4
1096	*Equisetum hyemale*	-	5	7	7	6
1097	*Equisetum palustre*	CR/CSR	7	8	6	3
1098	*Equisetum sylvaticum*	CSR	5	8	5	5
1099	*Equisetum telmateia*	C/CSR	6	8	7	6
1100	*Eranthis hyemalis*	SR	3	5	7	6
1101	*Eupatorium cannabinum*	C/CSR	7	8	6	7
1102	*Festuca arundinacea*	CSR	8	6	7	6
1103	*Festuca gigantea*	CSR	5	6	7	7
1104	*Festuca ovina*	S	7	5	4	2
1105	*Filipendula ulmaria*	C/SC	7	8	6	5
1106	*Fragaria vesca*	CSR	6	5	6	4
1107	*Galeopsis tetrahit*	R/CR	7	5	6	6
1108	*Galium aparine*	CR	6	6	7	8
1109	*Galium odoratum*	SC/CSR	3	5	7	6
1110	*Galium palustre*	CR/CSR	7	9	5	4
1111	*Galium saxatile*	S	6	6	3	3
1112	*Galium uliginosum*	S/CSR	7	9	6	4
1113	*Geranium endressii*	C/CSR	6	5	7	6
1114	*Geranium robertianum*	R/CSR	5	6	6	6
1115	*Geum rivale*	S/CSR	6	7	6	4
1116	*Geum urbanum*	S/CSR	4	6	7	7
1117	*Glechoma hederacea*	CSR	6	6	7	7
1118	*Glyceria fluitans*	CR	7	10	6	6
1119	*Glyceria maxima*	C	7	10	7	8
1264	*Gymnadenia conopsea*	S/SR	7	6	7	3
1120	*Hedera helix*	SC	4	5	7	6
1121	*Helleborus viridis*	SC/CSR	3	5	8	6
1122	*Heracleum sphondylium*	CR	7	5	7	7
1123	*Holcus lanatus*	CSR	7	6	6	5
1124	*Holcus mollis*	C/CSR	6	6	3	3
1125	*Humulus lupulus*	C	6	7	7	8
1126	*Hyacinthoides hispanica*	SR	5	4	6	6
1127	*Hyacinthoides non-scripta*	SR	5	5	5	6
1128	*Hydrocotyle vulgaris*	CSR	8	8	6	3
1129	*Hypericum androsaemum*	S/CSR	5	6	6	5
1130	*Hypericum hirsutum*	S/CSR	6	5	7	5
1131	*Hypericum tetrapterum*	CSR	7	8	6	4
1132	*Impatiens capensis*	-	7	9	7	6
1133	*Impatiens glandulifera*	CR	6	8	7	7
1134	*Iris pseudacorus*	C/SC	7	9	6	6
1135	*Juncus acutiflorus*	SC	8	8	4	2
1136	*Juncus articulatus*	CSR	8	9	6	3
1137	*Juncus bufonius*	R/SR	7	7	6	5
1138	*Juncus effusus*	C/SC	7	7	4	4
1139	*Juncus inflexus*	SC	7	7	7	5
1140	*Juncus subnodulosus*	SC	8	9	8	4
1141	*Lamiastrum galeobdolon*	S/SC	4	5	7	6
1142	*Lamium album*	CR	7	5	7	8
1143	*Lapsana communis*	R/CR	6	4	7	7

Table A7.1 cont. CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: groundflora (Table continues)

Ref.	Species	CSR	L	F	R	N
1144	*Lathraea clandestina*	-	-	-	-	-
1145	*Lemna minor*	CR	7	11	7	6
1265	*Listera ovata*	S/CSR	6	5	7	5
1146	*Lotus pedunculatus*	C/CSR	7	8	6	4
1147	*Luzula multiflora*	S	7	6	3	3
1261	*Luzula pilosa*	S	5	5	5	3
1148	*Luzula sylvatica*	SC	5	5	4	4
1149	*Lychnis flos-cuculi*	CSR	7	9	6	4
1150	*Lycopus europaeus*	CR	7	8	7	6
1151	*Lysimachia nemorum*	CSR	5	7	4	5
1152	*Lysimachia nummularia*	CSR	5	7	5	5
1153	*Lysimachia vulgaris*	C/SC	7	9	7	5
1154	*Lythrum salicaria*	C/CSR	7	9	7	5
1155	*Melica uniflora*	S/SC	4	5	7	5
1156	*Mentha aquatica*	C/CR	7	8	7	5
1266	*Menyanthes trifoliata*	S/SC	8	10	4	3
1157	*Mercurialis perennis*	SC	3	6	7	7
1158	*Molinia caerulea*	SC	7	8	3	2
1159	*Mycelis muralis*	CSR	4	5	7	5
1160	*Myosotis arvensis*	R/SR	7	5	6	6
1161	*Myosotis laxa caespitosa*	R/CR	7	9	6	5
1162	*Myosotis scorpioides*	CR	7	9	6	6
1163	*Myosotis secunda*	CR	6	9	5	4
1164	*Myrica gale*	-	8	9	3	2
1165	*Oenanthe crocata*	CR/CSR	7	9	6	7
1166	*Orchis mascula*	S/SR	6	5	7	4
1167	*Oreopteris limbosperma*	SC/CSR	6	6	4	3
1168	*Oxalis acetosella*	S/CSR	4	6	4	4
1169	*Paris quadrifolia*	SC	3	6	7	6
1170	*Persicaria bistorta*	C/CSR	6	7	6	6
1171	*Persicaria hydropiper*	R	7	7	6	6
1172	*Persicaria maculosa*	R	7	6	6	7
1173	*Petasites hybridus*	C	6	7	7	7
1174	*Peucedanum palustre*	-	7	9	7	5
1175	*Phalaris arundinacea*	C	7	9	7	7
1176	*Phleum pratense*	CSR	8	5	7	6
1177	*Phragmites australis*	C	7	10	7	6
1178	*Phyllitis scolopendrium*	S	4	5	7	5
1179	*Plantago lanceolata*	CSR	7	5	6	4
1180	*Plantago major*	R/CSR	7	5	6	7
1181	*Plantago media*	S/CSR	8	4	7	3
1182	*Poa pratensis*	CSR	7	5	6	5
1183	*Poa trivialis*	CR/CSR	7	6	6	6
1184	*Polypodium vulgare*	S	5	5	5	3
1185	*Polystichum aculeatum*	SC/CSR	5	5	7	5
1186	*Polystichum setiferum*	SC/CSR	4	5	5	6
1187	*Potamogeton coloratus*	CR	7	11	8	5
1188	*Potentilla anserina*	CR/CSR	8	7	7	6
1189	*Potentilla erecta*	S/CSR	7	7	3	2
1267	*Potentilla palustris*	S/SC	8	9	5	3
1190	*Potentilla reptans*	CR/CSR	7	5	7	5
1191	*Potentilla sterilis*	S	5	5	5	5
1192	*Primula vulgaris*	S/CSR	5	5	6	4
1193	*Prunella vulgaris*	CSR	7	5	6	4
1194	*Pteridium aquilinum*	C	6	5	3	3
1195	*Pulmonaria longifolia*	-	6	4	6	5
1196	*Ranunculus acris*	CSR	7	6	6	4
1197	*Ranunculus bulbosus*	SR	7	4	7	4
1198	*Ranunculus ficaria*	R/SR	6	6	6	6
1199	*Ranunculus flammula*	CR/CSR	7	9	5	3
1200	*Ranunculus lingua*	C/CSR	7	10	6	7
1201	*Ranunculus repens*	CR	6	7	6	7

Table A7.1 cont. CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: groundflora (Table continues)

Ref.	Species	CSR	L	F	R	N
1202	*Ranunculus sceleratus*	R	8	8	8	8
1203	*Ribes nigrum*	SC	5	9	6	6
1204	*Ribes rubrum*	SC	5	7	7	6
1205	*Ribes uva-crispa*	SC	5	5	7	6
1206	*Rorippa nasturtium-aquaticum*	CR	7	10	7	7
1262	*Rubus caesius*	SC	7	7	7	6
1207	*Rubus idaeus*	SC	6	5	5	5
1208	*Rumex acetosa*	CSR	7	5	5	4
1268	*Rumex conglomeratus*	CR	8	8	7	7
1209	*Rumex crispus*	R/CR	8	6	7	6
1210	*Rumex hydrolapathum*	C/CR	7	10	7	6
1211	*Rumex obtusifolius*	CR	7	5	7	9
1212	*Rumex sanguineus*	CSR	5	7	7	7
1213	*Sanicula europaea*	S	4	5	7	5
1214	*Schoenus nigricans*	SC	8	8	7	2
1215	*Scirpus sylvaticus*	C/SC	6	8	6	6
1216	*Scrophularia auriculata*	CR	7	8	7	7
1217	*Scrophularia nodosa*	CR	5	6	7	6
1218	*Scutellaria galericulata*	CR/CSR	7	8	6	5
1219	*Senecio aquaticus*	R/CR	7	8	6	5
1220	*Senecio jacobaea*	R/CR	7	4	6	4
1221	*Senecio vulgaris*	R	7	5	7	7
1222	*Silene dioica*	CSR	5	6	6	7
1223	*Solanum dulcamara*	C/CSR	7	8	7	7
1224	*Solidago virgaurea*	S/CSR	5	5	4	3
1225	*Sonchus asper*	R/CR	7	5	7	6
1227	*Sparganium erectum*	S/CSR	7	10	7	7
1229	*Stachys officinalis*	S	7	5	5	3
1269	*Stachys palustris*	CR	7	8	7	7
1230	*Stachys sylvatica*	C/CR	6	6	7	8
1231	*Stellaria holostea*	CSR	5	5	6	6
1232	*Stellaria media*	R	7	5	6	7
1233	*Stellaria uliginosa*	CR/CSR	7	8	5	5
1234	*Succisa pratensis*	S	7	7	5	2
1235	*Symphytum officinale*	C/CR	7	7	7	8
1236	*Tamus communis*	C/CR	6	5	7	6
1237	*Taraxacum officinale*	R/CSR	7	5	7	6
1238	*Teucrium scorodonia*	S/CSR	6	4	4	3
1239	*Thalictrum flavum*	C/CSR	7	8	7	5
1240	*Thelypteris palustris*	-	6	8	7	5
1241	*Trifolium repens*	CR/CSR	7	5	6	6
1242	*Tussilago farfara*	CR	7	6	6	6
1243	*Typha latifolia*	C	8	10	7	7
1244	*Urtica dioica*	C	6	6	7	8
1245	*Valeriana dioica*	S/CSR	8	8	6	3
1246	*Valeriana officinalis*	CSR	6	8	6	5
1270	*Veronica anagallis-aquatica*	R/CSR	7	10	7	7
1247	*Veronica beccabunga*	CR	7	10	6	6
1248	*Veronica chamaedrys*	CSR	6	5	6	5
1249	*Veronica hederifolia*	R/SR	6	5	7	6
1250	*Veronica montana*	S/CSR	4	6	6	6
1251	*Veronica scutellata*	CR/CSR	8	9	5	3
1252	*Veronica serpyllifolia*	R/CSR	7	5	6	5
1271	*Vicia cracca*	C/CSR	7	6	7	5
1253	*Vicia sativa*	R/CSR	7	4	7	4
1254	*Vicia sepium*	C/CSR	6	5	6	6
1255	*Vicia sylvatica*	C/CSR	7	5	7	5
1256	*Vinca major*	C/SC	5	6	7	6
1257	*Viola odorata*	CSR	5	5	7	7
1258	*Viola palustris*	S/CSR	7	9	3	2
1259	*Viola riviniana*	S	6	5	5	4
1260	*Wahlenbergia hederacea*	SR/CSR	6	8	3	3

Table A7.1 cont. CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: groundflora

Ref.	Species	CSR	L	F	R	N
2001	*Acer campestre*	SC	5	5	7	6
2002	*Buddleja davidii*	-	7	5	7	5
2003	*Clematis vitalba*	SC	6	4	8	5
2004	*Cornus sanguinea*	SC	7	5	7	6
2005	*Corylus avellana*	SC	4	5	6	6
2006	*Crataegus laevigata*	-	5	5	7	5
2007	*Crataegus monogyna*	SC	6	5	7	6
2008	*Euonymus europaeus*	SC	5	5	8	5
2009	*Frangula alnus*	-	6	8	5	5
2010	*Ilex aquifolium*	SC	5	5	5	5
2011	*Ligustrum vulgare*	SC	6	5	7	5
2012	*Lonicera periclymenum*	SC	5	6	5	5
2013	*Mahonia aquifolium*	SC	5	4	6	5
2014	*Malus sylvestris sens.lat.*	SC	7	5	6	6
2015	*Prunus avium*	SC	4	5	6	6
2016	*Prunus cerasifera*	-	6	5	7	6
2017	*Prunus laurocerasus*	-	4	6	5	6
2018	*Prunus lusitanica*	-	6	5	7	6
2019	*Prunus padus*	SC	5	6	6	7
2020	*Prunus spinosa*	SC	6	5	7	6
2021	*Rhamnus cathartica*	SC	7	5	7	6
2022	*Rhododendron ponticum*	SC	5	5	3	3
2023	*Rosa canina*	SC	6	5	7	6
2024	*Rubus fruticosus* agg.	SC	6	6	6	6
2025	*Sambucus nigra*	C	6	5	7	7
2026	*Symphoricarpos albus*	C/SC	5	5	6	7
2027	*Symphoricarpos orbiculatus*	-	-	-	-	-
2028	*Ulmus glabra*	C	4	5	7	6
2029	*Ulmus procera*	C	5	5	8	6
2030	*Viburnum opulus*	SC	6	7	6	6
3001	*Acer platanoides*	SC	4	5	7	7
3002	*Acer pseudoplatanus*	C/SC	4	5	6	6
3003	*Aesculus hippocastanum*	-	5	5	7	7
3004	*Alnus glutinosa*	SC	5	8	6	6
3005	*Alnus incana*	-	6	7	6	4
3006	*Betula pendula*	C/SC	7	5	4	4
3007	*Betula pubescens*	C/SC	7	7	4	4
3008	*Castanea sativa*	SC	5	5	5	5
3009	*Fagus sylvatica*	SC	3	5	5	5
3010	*Fraxinus excelsior*	C	5	6	7	6
3011	*Picea abies*	-	7	6	3	4
3012	*Pinus nigra*	-	7	3	5	2
3013	*Pinus sylvestris*	-	7	6	2	2
3014	*Populus alba*	-	6	6	7	6
3015	*Populus canescens*	SC	6	6	6	5
3016	*Populus nigra*	-	6	8	7	7
3017	*Populus nigra* 'Italica'	-	6	8	7	7
3018	*Populus tremula*	SC	6	5	5	6
3020	*Quercus petraea*	SC	6	6	3	4
3021	*Quercus robur*	SC	7	5	5	4
3023	*Salix alba*	-	6	7	8	8
3024	*Salix aurita*	-	7	8	4	3
3025	*Salix caprea*	-	7	7	7	7
3026	*Salix cinerea*	-	7	8	6	5
3027	*Salix fragilis*	C	6	8	7	7
3028	*Salix pentandra*	-	7	8	6	4
3029	*Salix purpurea*	C/SC	8	9	7	5
3030	*Salix triandra*	-	7	8	7	5
3031	*Salix viminalis*	C/SC	7	8	6	6
3035	*Sorbus aucuparia*	SC	6	6	3	4
3032	*Sorbus torminalis*	-	4	5	6	5
3033	*Taxus baccata*	SC	4	4	7	5
3034	*Tilia cordata*	-	5	5	6	5

Table A7.2 CSR-strategies and Ellenberg indicator values for species associated with lowland *Alnus glutinosa* woodlands: shrub and canopy layers

APPENDIX 8: INFLUENCE OF ADJACENT HABITATS AND UBIQUITY OF SPECIES IN LOWLAND *ALNUS GLUTINOSA* WOODLANDS

This Appendix details the results of an initial assessment to review the influence adjacent habitats have on the species composition of lowland *Alnus glutinosa* woodland. The Tables in Sections A8.1 to A8.3 list the species found at 2 m, 12 m and 24 m across the lowland *Alnus glutinosa* woodland boundaries at Stonebridge, see Figure A8.1. Species in quadrats located at these intervals on each side of the woodland, except where the woodland edge was the River Sowe (northern boundaries Sites B and C), were recorded. Each quadrat was the length of the woodland and 2 m wide.

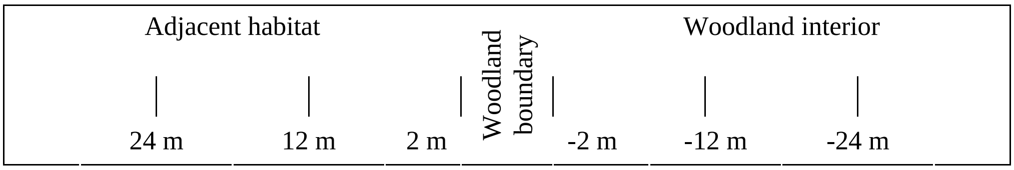

Fig. A8.1 Quadrat locations, in relation to woodland boundary, used to review the effects of the adjacent habitats on species composition within the woodland

A8.1 Site A Stonebridge

Species	**-12 m**	**-2 m**	**2 m**	**12 m**	**24 m**
Aegopodium podagraria		✓			
Agrostis capillaris	✓	✓	✓	✓	✓
Agrostis stolonifera	✓	✓	✓	✓	✓
Alopecurus pratensis		✓	✓	✓	✓
Angelica sylvestris		✓			
Anthoxanthum odoratum		✓	✓	✓	✓
Brachypodium sylvaticum		✓		✓	
Callitriche stagnalis		✓			
Cardamine amara		✓			
Cardamine flexuosa		✓			
Cardamine pratense					✓
Carex hirta				✓	✓
Carex panicea				✓	✓
Carex remota	✓	✓			
Cerastium fontanum		✓	✓	✓	✓
Chenopodium album			✓		
Circaea lutetiana	✓				✓
Cirsium arvense				✓	✓
Cirsium palustre		✓	✓	✓	✓
Conopodium majus			✓	✓	✓
Dactylis glomerata		✓	✓	✓	✓
Deschampsia cespitosa cespitosa		✓	✓	✓	✓
Digitalis purpurea			✓	✓	✓
Dryopteris dilatata		✓		✓	✓
Dryopteris filix-mas					✓

Table A8.1 Site A: Species recorded at 12 m and 2 m inside the woodland boundary (woodland was not large enough to enable quadrats at 24 m to be placed) and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland. Species recorded in quadrats along each edge are combined (Table continues)

Species	-12 m	-2 m	2 m	12 m	24 m
Epilobium montanum	✓	✓			✓
Epilobium tetragonum			✓		
Equisetum arvense		✓	✓		
Filipendula ulmaria		✓	✓	✓	✓
Galium aparine				✓	✓
Galium palustre		✓			✓
Geum urbanum	✓	✓	✓	✓	
Glyceria fluitans		✓	✓	✓	✓
Holcus lanatus	✓	✓	✓	✓	✓
Holcus mollis		✓			
Hyacinthoides non-scripta		✓	✓	✓	✓
Juncus articulatus				✓	✓
Juncus bufonius		✓			
Juncus effusus		✓	✓	✓	✓
Lapsana communis		✓			
Persicaria hydropiper		✓	✓		
Plantago lanceolata			✓	✓	✓
Poa trivialis	✓	✓	✓	✓	✓
Potentilla anserina					✓
Potentilla erecta		✓		✓	✓
Ranunculus acris		✓	✓	✓	✓
Ranunculus flammula		✓		✓	✓
Ranunculus repens	✓	✓	✓	✓	✓
Rumex acetosa		✓	✓	✓	✓
Rumex obtusifolius		✓	✓		✓
Rumex sanguineus	✓	✓	✓	✓	✓
Senecio jacobaea		✓	✓	✓	✓
Silene dioica		✓	✓		
Stellaria holostea					✓
Stellaria media			✓	✓	
Taraxacum officinale					✓
Trifolium repens				✓	✓
Urtica dioica	✓		✓	✓	✓
Veronica chamaedrys	✓	✓	✓	✓	✓
Veronica hederifolia				✓	✓
Crataegus monogyna		✓	✓	✓	✓
Prunus spinosa		✓	✓		
Rosa canina	✓	✓			
Rubus fruticosus	✓	✓	✓	✓	✓
Sambucus nigra	✓	✓	✓	✓	✓
Alnus glutinosa		✓			
Stellaria graminea		✓	✓	✓	✓
Viola arvense		✓			
Carex viridula					✓
Centaurea nigra				✓	

Table A8.1 Site A: Species recorded at 12 m and 2 m inside the woodland boundary (woodland was not large enough to enable quadrats at 24 m to be placed) and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland. Species recorded in quadrats along each edge are combined. (Table continues)

Species	-12 m	-2 m	2 m	12 m	24 m
Fescue rubra				✓	
Galium verum				✓	
Lathyrus pratensis					✓
Lotus coniculatus				✓	✓
Luzula campestris				✓	✓
Myosotis caespitoasa			✓	✓	
Poa annua			✓	✓	✓
Sanguisorba officinale				✓	✓
Stellaria palustre				✓	✓
Trifolium pratense					✓
no. spp. only in woodland	**2**	**12**	**NA**	**NA**	**NA**
no. spp. only in adjacent	**NA**	**NA**	**8**	**20**	**24**
no. spp. also in woodland	**NA**	**NA**	**31**	**30**	**31**
no. spp. also in adjacent	**13**	**36**	**NA**	**NA**	**NA**

Table A8.1 cont. Site A: Species recorded at 12 m and 2 m inside the woodland boundary (woodland was not large enough to enable quadrats at 24 m to be placed) and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland. Species recorded in quadrats along each edge are combined.

A8.2 Site B Stonebridge

Species	-24 m	-12 m	-2 m	2 m	12 m	24 m
Adoxa moschatellina		✓	✓			
Agrostis capillaris			✓			
Agrostis stolonifera				✓	✓	✓
Alliaria petiolata		✓	✓	✓		
Alopecurus pratensis					✓	
Angelica sylvestris			✓		✓	✓
Anthoxanthum odoratum				✓	✓	✓
Anthriscus sylvestris		✓	✓			
Bellis perennis				✓		
Caltha palustris		✓				
Calystegia sepium			✓			
Cardamine flexuosa		✓			✓	
Cardamine pratense						✓
Carex acutiformis		✓			✓	
Carex hirta					✓	✓
Carex panicea						✓
Carex remota		✓				
Cerastium fontanum					✓	✓
Chamerion angustifolium					✓	✓
Circaea lutetiana		✓				
Cirsium arvense				✓		✓
Cirsium palustre			✓	✓	✓	✓
Conopodium majus				✓		✓

Table A8.2 Site B: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry and wet grassland and scrub. Species recorded in quadrats along each edge are combined (Table continues)

Species	**-24 m**	**-12 m**	**-2 m**	**2 m**	**12 m**	**24 m**
Dactylis glomerata					✓	
Deschampsia cespitosa cespitosa				✓	✓	✓
Digitalis purpurea			✓	✓		
Dryopteris dilatata		✓	✓	✓	✓	
Dryopteris filix-mas		✓				✓
Epilobium hirsutum						✓
Epilobium montanum		✓		✓	✓	✓
Equisetum arvense					✓	✓
Festuca gigantea			✓			
Filipendula ulmaria		✓	✓	✓	✓	✓
Galeopsis tetrahit			✓			
Galium aparine		✓	✓	✓	✓	✓
Galium palustre		✓				
Geum urbanum		✓	✓	✓	✓	✓
Glechoma hederacea			✓			
Glyceria fluitans					✓	
Glyceria maxima		✓				
Heracleum sphondylium		✓	✓		✓	
Holcus lanatus			✓	✓	✓	✓
Hyacinthoides non-scripta			✓	✓	✓	✓
Impatiens capensis			✓			
Impatiens glandulifera			✓	✓		
Iris pseudacorus					✓	
Juncus effusus			✓		✓	✓
Lapsana communis			✓			
Lycnis flos-cuculi						✓
Phalaris arundinacea		✓				
Plantago lanceolata					✓	✓
Poa trivialis	✓	✓	✓	✓	✓	✓
Potentilla erecta				✓	✓	✓
Ranunculus acris					✓	
Ranunculus ficaria						✓
Ranunculus repens	✓	✓	✓	✓	✓	✓
Rorippa nasturtium-aquaticum		✓				
Rumex acetosa				✓	✓	✓
Rumex obtusifolius				✓	✓	✓
Rumex sanguineus	✓	✓	✓	✓	✓	✓
Scutellaria galericulata		✓		✓	✓	✓
Senecio jacobaea				✓	✓	✓
Silene dioica	✓	✓	✓	✓		
Stellaria media		✓		✓		
Trifolium repens					✓	✓
Urtica dioica	✓	✓	✓	✓		✓
Valeriana officinalis		✓	✓			
Veronica chamaedrys			✓	✓	✓	
Crataegus monogyna		✓	✓	✓	✓	✓

Table A8.2 cont. Site B: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry and wet grassland and scrub. Species recorded in quadrats along each edge are combined (Table continues)

Species	-24 m	-12 m	-2 m	2 m	12 m	24 m
Lonicera periclymenum			✓			
Rosa canina			✓			
Rubus fruticosus		✓	✓	✓	✓	✓
Sambucus nigra		✓	✓			
Alnus glutinosa		✓	✓		✓	
Betula pendula			✓			
Quercus robur			✓	✓	✓	✓
Stellaria graminea				✓		✓
Bryonia dioica						✓
Carex viridula					✓	
Dipsacus fullonum						✓
Fescue rubra					✓	✓
Hieracium sp.					✓	✓
Lathyrus pratensis						✓
Poa annua					✓	✓
Sanguisorba officinale					✓	✓
Stellaria palustre				✓	✓	✓
Ulex europeaus					✓	✓
no. spp. only in woodland	**0**	**11**	**14**	**NA**	**NA**	**NA**
no. spp. only in adjacent	**NA**	**NA**	**NA**	**12**	**29**	**31**
no. spp. also in woodland	**NA**	**NA**	**NA**	**22**	**18**	**17**
no. spp. also in adjacent	**5**	**20**	**23**	**NA**	**NA**	**NA**

Table A8.2 cont. Site B: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry and wet grassland and scrub. Species recorded in quadrats along each edge are combined.

A8.3 SITE C STONEBRIDGE

Species	-24 m	-12 m	-2 m	2 m	12 m	24 m
Aegopodium podagraria			✓			
Agrostis capillaris						✓
Agrostis stolonifera				✓	✓	✓
Alliaria petiolata	✓	✓	✓	✓	✓	✓
Alopecurus pratensis				✓	✓	✓
Angelica sylvestris	✓	✓				
Anthoxanthum odoratum				✓	✓	✓
Anthriscus sylvestris		✓			✓	✓
Arrhenatherum elatius			✓			
Arum maculatum						✓
Brachypodium sylvaticum			✓			
Callitriche stagnalis		✓		✓		
Caltha palustris		✓				
Cardamine flexuosa				✓	✓	✓
Carex hirta				✓	✓	✓
Carex remota	✓	✓		✓	✓	✓

Table A8.3. Site C: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland, scrub and tall ruderal vegetation. Species recorded in quadrats along each edge are combined (Table continues)

Species	**-24 m**	**-12 m**	**-2 m**	**2 m**	**12 m**	**24 m**
Cerastium fontanum				✓	✓	✓
Circaea lutetiana	✓	✓				
Cirsium arvense				✓	✓	✓
Cirsium palustre				✓	✓	
Cirsium vulgare				✓		
Conopodium majus			✓	✓	✓	✓
Dactylis glomerata				✓	✓	✓
Deschampsia cespitosa cespitosa					✓	✓
Dryopteris filix-mas			✓			
Epilobium montanum				✓		
Equisetum arvense					✓	✓
Festuca gigantea			✓			
Filipendula ulmaria	✓	✓		✓	✓	✓
Galium aparine	✓	✓	✓	✓	✓	✓
Galium palustre					✓	
Geum urbanum	✓	✓	✓	✓	✓	✓
Glechoma hederacea			✓	✓		✓
Heracleum sphondylium			✓		✓	✓
Holcus lanatus			✓	✓	✓	✓
Hyacinthoides non-scripta			✓	✓	✓	✓
Impatiens capensis		✓		✓	✓	✓
Impatiens glandulifera				✓	✓	✓
Juncus effusus				✓	✓	✓
Myosotis scorpioides				✓		✓
Persicaria hydropiper		✓		✓		✓
Plantago lanceolata				✓	✓	✓
Plantago majus						✓
Poa trivialis	✓	✓	✓	✓	✓	✓
Potentilla erecta					✓	✓
Ranunculus acris					✓	✓
Ranunculus ficaria		✓				
Ranunculus repens		✓		✓	✓	✓
Ranunculus sceleratus		✓				
Rumex acetosa				✓	✓	✓
Rumex obtusifolius		✓		✓	✓	✓
Rumex sanguineus		✓	✓	✓	✓	✓
Senecio jacobaea				✓	✓	
Silene dioica		✓	✓	✓		✓
Stachys officinalis					✓	
Stellaria media		✓	✓	✓	✓	✓
Taraxacum officinale				✓	✓	
Trifolium repens				✓	✓	✓
Urtica dioica	✓	✓	✓	✓	✓	✓
Veronica beccabunga				✓	✓	✓
Veronica chamaedrys			✓	✓	✓	✓
Veronica hederifolia						✓

Table A8.3 cont. Site C: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland, scrub and tall ruderal vegetation. Species recorded in quadrats along each edge are combined (Table continues)

Species	-24 m	-12 m	-2 m	2 m	12 m	24 m
Crataegus monogyna		✓		✓	✓	✓
Prunus spinosa			✓	✓	✓	✓
Rosa canina						✓
Rubus fruticosus			✓	✓	✓	✓
Sambucus nigra			✓			
Alnus glutinosa		✓			✓	✓
Fraxinus excelsior		✓	✓		✓	✓
Quercus robur				✓	✓	
Salix caprea						✓
Salix fragilis						✓
Salix vimilius					✓	
Stellaria graminea				✓	✓	✓
Bryonia dioica					✓	
Carex viridula				✓		
Galium verum					✓	
Hieracium sp.				✓		
Lotus coniculatus					✓	
Luzula campestris				✓	✓	✓
Myosotis caespitosa						✓
Poa annua				✓	✓	✓
Sanguisorba officinale					✓	
Stellaria palustre				✓	✓	✓
no. spp. only in woodland	**2**	**5**	**6**	**NA**	**NA**	**NA**
no. spp. only in adjacent	**NA**	**NA**	**NA**	**27**	**33**	**31**
no. spp. also in woodland	**NA**	**NA**	**NA**	**23**	**23**	**26**
no. spp. also in adjacent	**7**	**19**	**17**	**NA**	**NA**	**NA**

Table A8.3 cont. Site C: Species recorded at 24 m, 12 m and 2 m inside the woodland boundary and 24 m, 12 m and 2 m outside the woodland boundary in dry grassland, scrub and tall ruderal vegetation. Species recorded in quadrats along each edge are combined

APPENDIX 9: LIGHT CONDITIONS OF CONTRASTING NVC COMMUNITIES

The results of the analysis to determine the theoretical light conditions of lowland *Alnus glutinosa* woodlands (see Section 3.3.2) produced unexpected results (Section 4.6.3) suggesting that the component species had preferences for well-lit conditions. Therefore the same analysis was undertaken on a number of contrasting communities described by the NVC to review this unexpected result. Table A9.1 summarises the communities that were assessed.

NVC community	Community light characteristics and notes
W5 *Alnus glutinosa-Carex paniculata*	Included for comparison to lowland *Alnus glutinosa* woodland
W6 *Alnus glutinosa-Urtica dioica*	
W7 *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum*	
W10 *Quercus robur-Pteridium aquilinum-Rubus fruticosus*	The 'typical' British woodland type. Average light levels
W14 *Fagus sylvatica-Rubus fruticosus*	Darker light levels resulting from denser canopy
W13 *Taxus baccata*	Continuous, evergreen canopy cover throughout the year, generally dense and dark
W18 *Pinus sylvestris-Hylocomium splendens* woodland	Continuous, evergreen canopy cover throughout the year, although fairly light
A11 *Potamogetum pectinatus-Myriophyllum spicatum*	A community of *"clear, standing to moderately fast-moving waters, which are generally mesotrophic to eutrophic and base-rich."* (Rodwell, 2000. p.60). Degree of shading likely to be dependant on adjacent habitats
S26 *Phragmites australis-Urtica dioica fen*	Swamp community, occurring on water and mire margins, so is likely to be open and unshaded, although some shading may occur where adjacent to trees
SD2 *Honkenya peploides-Cakile maritim*e strandline community	"*characteristic pioneer vegetation of sand and fine shingle strandlines…Periodic additions of organic detritus along the tidal limit encourages the development of the vegetation, particularly the more nitrophilous ephemerals…*" (Rodwell, 2001. p.137). Likely to be open and unshaded
CG3 *Bromus erectus* calcareous grassland	Grasslands are typically open and unshaded. CG3 is south-eastern grazed or ungrazed grassland

Table A9.1 NVC communities used to review the validity of results of determining the theoretical light conditions of lowland *Alnus glutinosa* woodland

The results of the analysis are provided in Sections A9.1 and A9.2.

A9.1 THEORETICAL LIGHT CONDITIONS OF WOODLAND COMMUNITIES

The light conditions indicated by the Ellenberg values are reflective of the conditions of the different woodland types as noted by observation. Figure A9.1 demonstrates the light preferences of plants and shows that plants in:

- *Alnus glutinosa*-based woodlands (W5-7) have higher light preferences: semi-shade to well lit conditions (Ellenberg values 6 and 7, 81-93% of species). It is noted that these figures are consistent with *Alnus glutinosa* woodland in the Baltic Region (Prieditis, 1997);
- *Taxus baccata* (W13) and *Fagus sylvatica* (W14) woodlands have preferences for lighter conditions than would be expected: semi-shade and shade to well lit (Ellenberg values 5 and 6, 45-63% of species). Light preferences in *Fagus sylvatica* woodlands may reflect a high proportion of vernals which flower before

the dense shade is created once the *Fagus sylvatica* comes into leaf; *c*. 17% of the groundflora species could be considered vernals;

- *Pinus sylvestris* (W18) also appears lighter than would initially be expected: semi-shade to well lit (Ellenberg values 6 and 7, 63% of species). However these woodlands are dominated by *Pinus sylvestris* which has a fairly light canopy.

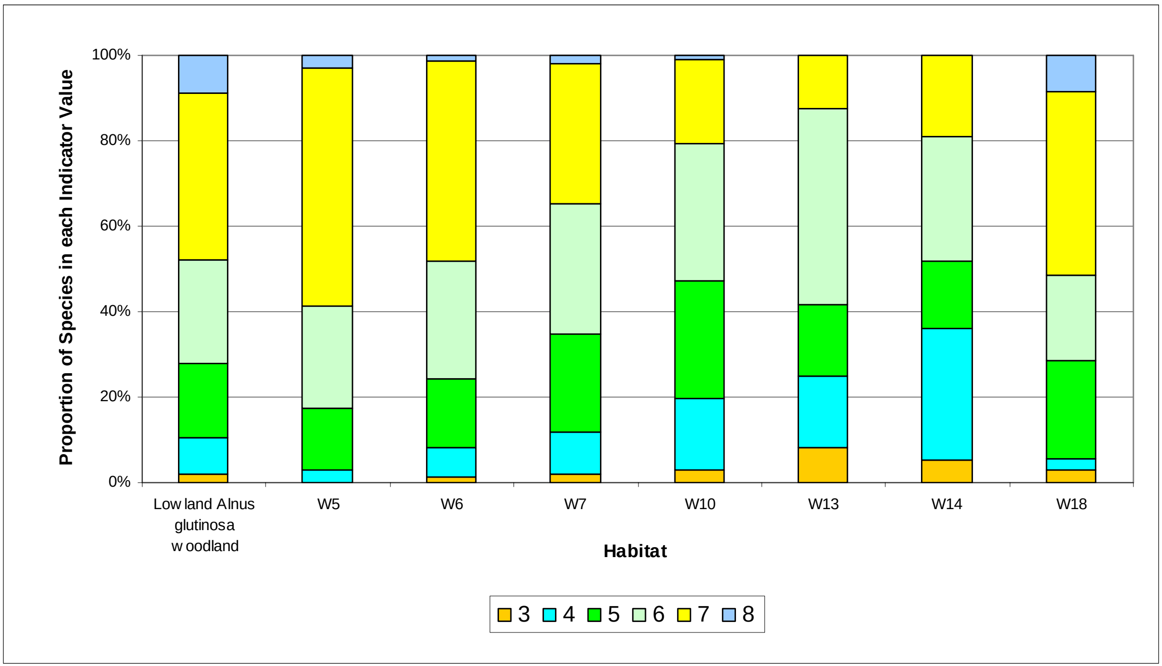

Fig. A9.1 Ellenberg light indicator value distribution across a variety of woodland types (utilising NVC data) (Ellenberg values: 3, shaded – 8, lighter) W5-7 *Alnus glutinosa* woodlands; W10 *Quercus* spp. woodland, W13 *Taxus baccata* woodland, W14 *Fagus sylvatica* woodland, W18 *Pinus sylvestris* woodland

A9.2 Theoretical Light Conditions of Non-Woodland Communities

Figure A9.2 shows that habitats typically associated with open conditions (shingle-SD2; grasslands-CG3; open water-A11 and swamp-S26) are dominated by species with preferences for well lit (Ellenberg light value 7) to full lit (Ellenberg light value 9) conditions. In contrast, the woodland habitat (W10), however, has a greater proportion of species associated with shaded to semi-shaded conditions (Ellenberg light values 3 to 6).

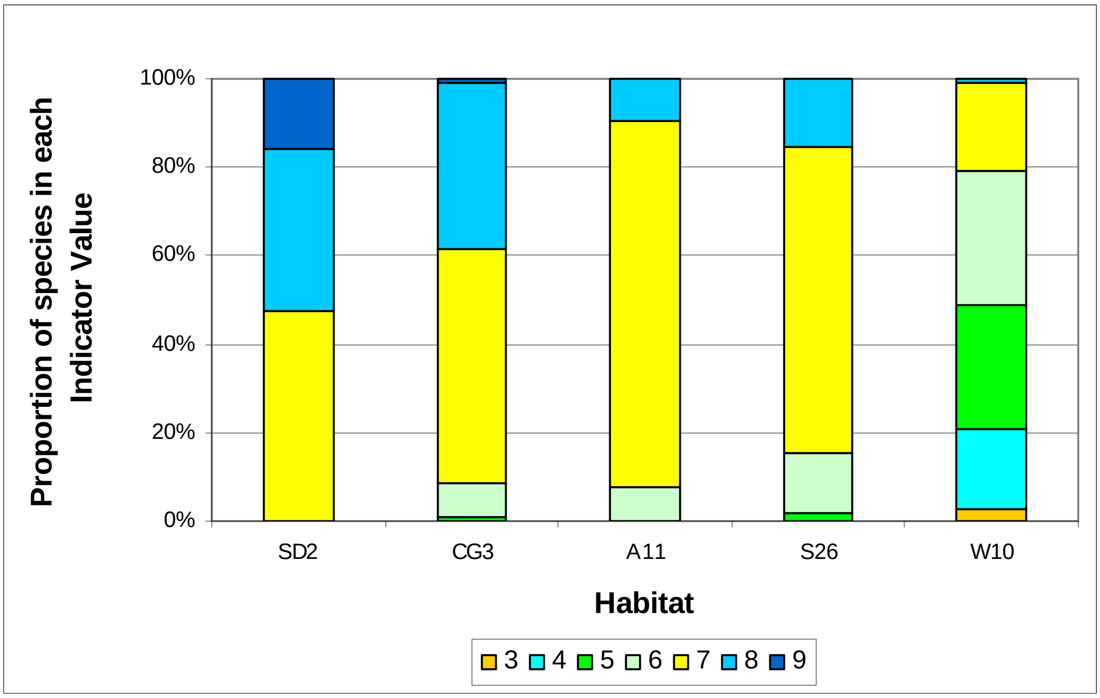

Fig. A9.2 Ellenberg light indicator value distribution across a variety of habitats (utilising NVC data) (Ellenberg values: 3, low - 9, high) SD2 Shingle; CG3 Calcareous grassland; A11 Aquatic; S26 Swamp; W10 mesic woodland

APPENDIX 10: LOWLAND *ALNUS GLUTINOSA* WOODLAND GROUNDFLORA SPECIES THAT DEFINE THE CHARACTERISTICS OF THE HABITAT

The following species do not have Ellenberg Indicator value data (Sections A10.2-A10.5):

- 1081 *Dryopteris affinis* ssp. *borreri*
- 1144 *Lathraea clandestina*

In all Tables in this Appendix, species high-lighted in bold text have the potential to form (in some situations) extensive, near monoculture stands with only a few other species associated within them.

A10.1 CSR-STRATEGY GROUPS – CSR-COAH

CoaH-A. Competitors		
Ref.	**Species**	**Strategy**
1060	*Chamerion angustifolium*	C
1065	*Cirsium arvense*	C
1086	*Epilobium hirsutum*	C
1119	***Glyceria maxima***	**C**
1125	*Humulus lupulus*	C
1173	***Petasites hybridus***	**C**
1175	***Phalaris arundinacea***	**C**
1194	*Pteridium aquilinum*	C
1243	***Typha latifolia***	**C**
1244	***Urtica dioica***	**C**
1014	*Angelica sylvestris*	C/CR
1033	*Calystegia sepium*	C/CR
1156	*Mentha aquatica*	C/CR
1210	*Rumex hydrolapathum*	C/CR
1230	*Stachys sylvatica*	C/CR
1235	***Symphytum officinale***	**C/CR**
1236	*Tamus communis*	C/CR
1002	*Aconitum napellus*	C/CSR
1012	*Alopecurus pratensis*	C/CSR
1021	*Arrhenatherum elatius*	C/CSR
1263	*Carex disticha*	C/CSR
1045	*Carex hirta*	C/CSR
1052	*Carex pseudocyperus*	C/CSR
1075	*Dactylis glomerata*	C/CSR
1099	*Equisetum telmateia*	C/CSR
1101	*Eupatorium cannabinum*	C/CSR
1113	*Geranium endressii*	C/CSR
1124	*Holcus mollis*	C/CSR
1146	*Lotus pedunculatus*	C/CSR
1154	*Lythrum salicaria*	C/CSR
1170	*Persicaria bistorta*	C/CSR
1200	*Ranunculus lingua*	C/CSR
1223	*Solanum dulcamara*	C/CSR
1239	*Thalictrum flavum*	C/CSR
1271	*Vicia cracca*	C/CSR
1254	*Vicia sepium*	C/CSR
1255	*Vicia sylvatica*	C/CSR
1023	*Athyrium filix-femina*	C/SC
1029	*Calamagrostis canescens*	C/SC
1039	***Carex acutiformis***	**C/SC**
1050	***Carex paniculata***	**C/SC**
1054	***Carex riparia***	**C/SC**
1105	*Filipendula ulmaria*	C/SC
1134	***Iris pseudacorus***	**C/SC**
1138	*Juncus effusus*	C/SC
1153	*Lysimachia vulgaris*	C/SC
1215	*Scirpus sylvaticus*	C/SC
1256	*Vinca major*	C/SC

CoaH-B. Stress-tolerators		
Ref.	**Species**	**Strategy**
1026	*Blechnum spicant*	S
1042	*Carex echinata*	S
1048	*Carex pallescens*	S
1049	*Carex panicea*	S
1056	*Carex sylvatica*	S
1093	*Epipactis helleborine*	S
1104	*Festuca ovina*	S
1111	*Galium saxatile*	S
1147	*Luzula multiflora*	S
1261	*Luzula pilosa*	S
1178	*Phyllitis scolopendrium*	S
1184	*Polypodium vulgare*	S
1191	*Potentilla sterilis*	S
1213	*Sanicula europaea*	S
1229	*Stachys officinalis*	S
1234	*Succisa pratensis*	S
1259	*Viola riviniana*	S
1011	*Allium vineale*	S/CSR
1019	*Aquilegia vulgaris*	S/CSR
1032	***Caltha palustris***	**S/CSR**
1041	*Carex distans*	S/CSR
1046	*Carex laevigata*	S/CSR
1074	*Cystopteris fragilis*	S/CSR
1089	*Epilobium palustre*	S/CSR
1112	*Galium uliginosum*	S/CSR
1115	*Geum rivale*	S/CSR
1116	*Geum urbanum*	S/CSR
1129	*Hypericum androsaemum*	S/CSR
1130	*Hypericum hirsutum*	S/CSR
1265	*Listera ovata*	S/CSR
1168	*Oxalis acetosella*	S/CSR
1181	*Plantago media*	S/CSR
1189	*Potentilla erecta*	S/CSR
1192	*Primula vulgaris*	S/CSR
1224	*Solidago virgaurea*	S/CSR
1227	***Sparganium erectum***	**S/CSR**
1238	*Teucrium scorodonia*	S/CSR
1245	*Valeriana dioica*	S/CSR
1250	*Veronica montana*	S/CSR
1258	*Viola palustris*	S/CSR
1027	*Brachypodium sylvaticum*	S/SC
1047	*Carex nigra*	S/SC
1051	*Carex pendula*	S/SC
1071	*Convallaria majalis*	S/SC
1078	*Deschampsia flexuosa*	S/SC
1141	***Lamiastrum galeobdolon***	**S/SC**
1155	*Melica uniflora*	S/SC
1266	*Menyanthes trifoliata*	S/SC
1267	*Potentilla pulsutris*	S/SC
1264	*Gymnadenia conopsea*	S/SR
1166	*Orchis mascula*	S/SR

Table A10.1 Species in each main CSR -strategy group (Table continues)

CoaH-C. Ruderals		
Ref.	**Species**	**Strategy**
1171	*Persicaria hydropiper*	R
1172	*Persicaria maculosa*	R
1202	*Ranunculus sceleratus*	R
1221	*Senecio vulgaris*	R
1232	*Stellaria media*	R
1015	*Anisantha sterilis*	R/CR
1030	*Callitriche obtusangula*	R/CR
1031	*Callitriche stagnalis*	R/CR
1061	*Chenopodium album*	R/CR
1107	*Galeopsis tetrahit*	R/CR
1143	*Lapsana communis*	R/CR
1161	*Myosotis laxa caespitosa*	R/CR
1209	*Rumex crispus*	R/CR
1219	*Senecio aquaticus*	R/CR
1220	*Senecio jacobaea*	R/CR
1225	*Sonchus asper*	R/CR
1024	*Bellis perennis*	R/CSR
1038	*Cardamine pratensis*	R/CSR
1058	*Cerastium fontanum*	R/CSR
1114	*Geranium robertianum*	R/CSR
1180	*Plantago major*	R/CSR
1237	*Taraxacum officinale*	R/CSR
1270	*Veronica anagallis-aquatica*	R/CSR
1252	*Veronica serpyllifolia*	R/CSR
1253	*Vicia sativa*	R/CSR
1036	*Cardamine flexuosa*	R/SR
1137	*Juncus bufonius*	R/SR
1160	*Myosotis arvensis*	R/SR
1198	*Ranunculus ficaria*	R/SR
1249	*Veronica hederifolia*	R/SR

CoaH D. Stress tolerant-competitors		
Ref.	**Species**	**Strategy**
1043	*Carex elata*	SC
1055	*Carex rostrata*	SC
1076	*Daphne laureola*	SC
1095	*Equisetum fluviatile*	SC
1120	***Hedera helix***	SC
1135	*Juncus acutiflorus*	SC
1139	*Juncus inflexus*	SC
1140	*Juncus subnodulosus*	SC
1148	*Luzula sylvatica*	SC
1157	***Mercurialis perennis***	**SC**
1158	***Molinia caerulea***	**SC**
1169	*Paris quadrifolia*	SC
1203	*Ribes nigrum*	SC
1204	*Ribes rubrum*	SC
1205	*Ribes uva-crispa*	SC
1262	*Rubus caesius*	SC
1207	*Rubus idaeus*	SC
1214	*Schoenus nigricans*	SC
1077	*Deschampsia cespitosa cespitosa*	SC/CSR
1080	*Dryopteris affinis*	SC/CSR
1081	*Dryopteris affinis ssp. borreri*	SC/CSR
1082	*Dryopteris carthusiana*	SC/CSR
1084	*Dryopteris dilatata*	SC/CSR
1085	*Dryopteris filix-mas*	SC/CSR
1109	*Galium odoratum*	SC/CSR
1121	*Helleborus viridis*	SC/CSR
1167	*Oreopteris limbosperma*	SC/CSR
1185	*Polystichum aculeatum*	SC/CSR
1186	*Polystichum setiferum*	SC/CSR

CoaH-E. Competitive ruderals		
Ref.	**Species**	**Strategy**
1007	*Agrostis stolonifera*	CR
1009	*Alliaria petiolata*	CR
1017	*Anthriscus sylvestris*	CR
1018	*Apium nodiflorum*	CR
1020	*Arctium minus*	CR
1025	*Berula erecta*	CR
1035	*Cardamine amara*	CR
1064	*Circaea lutetiana*	CR
1066	*Cirsium palustre*	CR
1067	*Cirsium vulgare*	CR
1069	*Conium maculatum*	CR
1094	*Equisetum arvense*	CR
1108	*Galium aparine*	CR
1118	*Glyceria fluitans*	CR
1122	*Heracleum sphondylium*	CR
1133	***Impatiens glandulifera***	**CR**
1142	*Lamium album*	CR
1145	***Lemna minor***	**CR**
1150	*Lycopus europaeus*	CR
1162	*Myosotis scorpioides*	CR
1163	*Myosotis secunda*	CR
1187	*Potamogetum coloratus*	CR
1201	*Ranunculus repens*	CR
1206	***Rorippa nasturtium-aquaticum***	**CR**
1268	*Rumex conglomeratus*	CR
1211	*Rumex obtusifolius*	CR
1216	*Scrophularia auriculata*	CR
1217	*Scrophularia nodosa*	CR
1269	*Stachys palustris*	CR
1242	***Tussilago farfara***	**CR**
1247	*Veronica beccabunga*	CR
1001	*Achillea ptarmica*	CR/CSR
1004	***Aegopodium podagraria***	**CR/CSR**
1079	*Digitalis purpurea*	CR/CSR
1097	*Equisetum palustre*	CR/CSR
1110	*Galium palustre*	CR/CSR
1165	***Oenanthe crocata***	**CR/CSR**
1183	*Poa trivialis*	CR/CSR
1188	*Potentilla anserina*	CR/CSR
1190	*Potentilla reptans*	CR/CSR
1199	*Ranunculus flammula*	CR/CSR
1218	*Scutellaria galericulata*	CR/CSR
1233	*Stellaria uliginosa*	CR/CSR
1241	*Trifolium repens*	CR/CSR
1251	*Veronica scutellata*	CR/CSR

CoaH-F. Stress tolerant ruderals		
Ref.	**Species**	**Strategy**
1037	*Cardamine hirsuta*	SR
1057	*Centaurium erythraea*	SR
1059	*Ceratocapnos claviculata*	SR
1070	*Conopodium majus*	SR
1100	*Eranthis hyemalis*	SR
1126	***Hyacinthoides hispanica***	**SR**
1127	***Hyacinthoides non-scripta***	**SR**
1197	*Ranunculus bulbosus*	SR
1003	*Adoxa moschatellina*	SR/CSR
1010	***Allium ursinum***	**SR/CSR**
1013	*Anemone nemorosa*	SR/CSR
1016	*Anthoxanthum odoratum*	SR/CSR
1022	*Arum maculatum*	SR/CSR
1260	*Wahlenbergia hederacea*	SR/CSR

Table A10.1 cont. Species in each main CSR-strategy group (Table continues)

CoaH-G. Competitive, stress tolerant ruderals		
Ref.	**Species**	**Strategy**
1005	*Agrostis canina*	CSR
1006	*Agrostis capillaris*	CSR
1008	*Ajuga reptans*	CSR
1028	*Bromopsis ramosa*	CSR
1034	*Campanula trachelium*	CSR
1053	*Carex remota*	CSR
1062	*Chrysosplenium alternifolium*	CSR
1063	***Chrysosplenium oppositifolium***	**CSR**
1072	*Crepis paludosa*	CSR
1073	*Cynosaurus cristatus*	CSR
1087	*Epilobium montanum*	CSR
1088	*Epilobium obscurum*	CSR
1090	*Epilobium parviflorum*	CSR
1091	*Epilobium roseum*	CSR
1092	*Epilobium tetragonum*	CSR
1098	*Equisetum sylvaticum*	CSR
1102	*Festuca arundinacea*	CSR
1103	*Festuca gigantea*	CSR
1106	*Fragaria vesca*	CSR
1117	***Glechoma hederacea***	**CSR**
1123	*Holcus lanatus*	CSR
1128	*Hydrocotyle vulgaris*	CSR
1131	*Hypericum tetrapterum*	CSR
1136	*Juncus articulatus*	CSR
1149	*Lychnis flos-cuculi*	CSR
1151	*Lysimachia nemorum*	CSR
1152	***Lysimachia nummularia***	**CSR**
1159	*Mycelis muralis*	CSR
1176	*Phleum pratense*	CSR
1179	*Plantago lanceolata*	CSR
1182	*Poa pratensis*	CSR
1193	*Prunella vulgaris*	CSR
1196	*Ranunculus acris*	CSR
1208	*Rumex acetosa*	CSR
1212	*Rumex sanguineus*	CSR
1222	*Silene dioica*	CSR
1231	*Stellaria holostea*	CSR
1246	*Valeriana officinalis*	CSR
1248	*Veronica chamaedrys*	CSR
1257	*Viola odorata*	CSR

Table A10.1 cont. Species in each main CSR-strategy group

The following have no CSR-Strategy data:
1040 *Carex appropinquata;* 1044 *Carex elongata;* 1068 *Colchium autumnale;* 1083 *Dryopteris cristata;* 1096 *Equisetum hyemale;* 1132 *Impatiens capensis;* 1144 *Lathraea clandestina;* 1164 *Myrica gale;* 1174 *Peucedanum palustre;* **1195 *Pulmonaria longifolia;*** 1240 *Thelypteris palustris;*

A10.2 Ellenberg Light Indicator Groups – Light-CoaH

CoaH-H. Shaded						
Ref.	**Species**	**L**		**Ref.**	**Species**	**L**
1100	*Eranthis hyemalis*	3		1076	*Daphne laureola*	4
1109	*Galium odoratum*	3		1093	*Epipactis helleborine*	4
1121	*Helleborus viridis*	3		1116	*Geum urbanum*	4
1157	***Mercurialis perennis***	**3**		**1120**	***Hedera helix***	**4**
1169	*Paris quadrifolia*	3		1141	***Lamiastrum galeobdolon***	4
1003	*Adoxa moschatellina*	4		1155	*Melica uniflora*	4
1010	***Allium ursinum***	4		1159	*Mycelis muralis*	4
1022	*Arum maculatum*	4		1168	*Oxalis acetosella*	4
1028	*Bromopsis ramosa*	4		1178	*Phyllitis scolopendrium*	4
1034	*Campanula trachelium*	4		1186	*Polystichum setiferum*	4
1053	*Carex remota*	4		1213	*Sanicula europaea*	4
1056	*Carex sylvatica*	4		1250	*Veronica montana*	4
1064	*Circaea lutetiana*	4				

Table A10.2 Lowland *Alnus glutinosa* woodland groundflora species in each distinct light condition derived from the Ellenberg indicator values (Table continues)

CoaH-L. Semi-shade						
Ref.	**Species**	**L**		**Ref.**	**Species**	**L**
1002	*Aconitum napellus*	5		1050	***Carex paniculata***	6
1008	*Ajuga reptans*	5		1060	*Chamerion angustifolium*	6
1009	*Alliaria petiolata*	5		1068	*Colchium autumnale*	6
1013	*Anemone nemorosa*	5		1070	*Conopodium majus*	6
1015	*Anisantha sterilis*	5		1072	*Crepis paludosa*	6
1023	*Athyrium filix-femina*	5		1074	*Cystopteris fragilis*	6
1026	*Blechnum spicant*	5		1077	*Deschampsia cespitosa*	6
1036	*Cardamine flexuosa*	5		1078	*Deschampsia flexuosa*	6
1044	*Carex elongata*	5		1079	*Digitalis purpurea*	6
1046	*Carex laevigata*	5		1082	*Dryopteris carthusiana*	6
1051	*Carex pendula*	5		1083	*Dryopteris cristata*	6
1059	*Ceratocapnos claviculata*	5		1087	*Epilobium montanum*	6
1062	*Chrysosplenium*	5		1088	*Epilobium obscurum*	6
1063	***Chrysosplenium***	5		1091	*Epilobium roseum*	6
1071	*Convallaria majalis*	5		1092	*Epilobium tetragonum*	6
1080	*Dryopteris affinis*	5		1099	*Equisetum telmateia*	6
1084	*Dryopteris dilatata*	5		1106	*Fragaria vesca*	6
1085	*Dryopteris filix-mas*	5		1108	*Galium aparine*	6
1096	*Equisetum hyemale*	5		1111	*Galium saxatile*	6
1098	*Equisetum sylvaticum*	5		1113	*Geranium endressii*	6
1103	*Festuca gigantea*	5		1115	*Geum rivale*	6
1114	*Geranium robertianum*	5		1117	***Glechoma hederacea***	6
1126	***Hyacinthoides hispanica***	5		1124	*Holcus mollis*	6
1127	***Hyacinthoides non-***	5		1125	*Humulus lupulus*	6
1129	*Hypericum androsaemum*	5		1130	*Hypericum hirsutum*	6
1261	*Luzula pilosa*	5		1133	***Impatiens glandulifera***	6
1148	*Luzula sylvatica*	5		1143	*Lapsana communis*	6
1151	*Lysimachia nemorum*	5		1265	*Listera ovata*	6
1152	***Lysimachia nummularia***	5		1163	*Myosotis secunda*	6
1184	*Polypodium vulgare*	5		1166	*Orchis mascula*	6
1185	*Polystichum aculeatum*	5		1167	*Oreopteris limbosperma*	6
1191	*Potentilla sterilis*	5		1170	*Persicaria bistorta*	6
1192	*Primula vulgaris*	5		1173	***Petasites hybridus***	6
1203	*Ribes nigrum*	5		1194	*Pteridium aquilinum*	6
1204	*Ribes rubrum*	5		1195	***Pulmonaria longifolia***	6
1205	*Ribes uva-crispa*	5		1198	*Ranunculus ficaria*	6
1212	*Rumex sanguineus*	5		1201	*Ranunculus repens*	6
1217	*Scrophularia nodosa*	5		1207	*Rubus idaeus*	6
1222	*Silene dioica*	5		1215	*Scirpus sylvaticus*	6
1224	*Solidago virgaurea*	5		1230	*Stachys sylvatica*	6
1231	*Stellaria holostea*	5		1236	*Tamus communis*	6
1256	*Vinca major*	5		1238	*Teucrium scorodonia*	6
1257	*Viola odorata*	5		1240	*Thelypteris palustris*	6
1004	***Aegopodium podagraria***	6		1244	***Urtica dioica***	6
1006	*Agrostis capillaris*	6		1246	*Valeriana officinalis*	6
1017	*Anthriscus sylvestris*	6		1248	*Veronica chamaedrys*	6
1019	*Aquilegia vulgaris*	6		1249	*Veronica hederifolia*	6
1020	*Arctium minus*	6		1254	*Vicia sepium*	6
1027	*Brachypodium sylvaticum*	6		1259	*Viola riviniana*	6
1035	*Cardamine amara*	6		1260	*Wahlenbergia hederacea*	6
1048	*Carex pallescens*	6				

Table A10.2 cont. Lowland *Alnus glutinosa* woodland groundflora species in each distinct light condition derived from the Ellenberg indicator values (Table continues)

CoaH-J. Well lit					
Ref.	Species	L value	Ref.	Species	L value
1001	*Achillea ptarmica*	7	1150	*Lycopus europaeus*	7
1005	*Agrostis canina*	7	1153	*Lysimachia vulgaris*	7
1007	*Agrostis stolonifera*	7	1154	*Lythrum salicaria*	7
1011	*Allium vineale*	7	1156	*Mentha aquatica*	7
1012	*Alopecurus pratensis*	7	1158	***Molinia caerulea***	7
1014	*Angelica sylvestris*	7	1160	*Myosotis arvensis*	7
1016	*Anthoxanthum odoratum*	7	1161	*Myosotis laxa caespitosa*	7
1018	*Apium nodiflorum*	7	1162	*Myosotis scorpioides*	7
1021	*Arrhenatherum elatius*	7	1165	***Oenanthe crocata***	7
1025	*Berula erecta*	7	1171	*Persicaria hydropiper*	7
1029	*Calamagrostis canescens*	7	1172	*Persicaria maculosa*	7
1030	*Callitriche obtusangula*	7	1174	*Peucedanum palustre*	7
1031	*Callitriche stagnalis*	7	1175	***Phalaris arundinacea***	7
1032	***Caltha palustris***	7	1177	*Phragmites australis*	7
1033	*Calystegia sepium*	7	1179	*Plantago lanceolata*	7
1038	*Cardamine pratensis*	7	1180	*Plantago major*	7
1039	***Carex acutiformis***	7	1182	*Poa pratensis*	7
1040	*Carex appropinquata*	7	1183	*Poa trivialis*	7
1263	*Carex disticha*	7	1187	*Potamogetum coloratus*	7
1043	*Carex elata*	7	1189	*Potentilla erecta*	7
1045	*Carex hirta*	7	1190	*Potentilla reptans*	7
1047	*Carex nigra*	7	1193	*Prunella vulgaris*	7
1052	*Carex pseudocyperus*	7	1196	*Ranunculus acris*	7
1054	*Carex riparia*	7	1197	*Ranunculus bulbosus*	7
1058	*Cerastium fontanum*	7	1199	*Ranunculus flammula*	7
1061	*Chenopodium album*	7	1200	*Ranunculus lingua*	7
1066	*Cirsium palustre*	7	1206	***Rorippa nasturtium-aquaticum***	7
1067	*Cirsium vulgare*	7	1262	*Rubus caesius*	7
1073	*Cynosaurus cristatus*	7	1208	*Rumex acetosa*	7
1075	*Dactylis glomerata*	7	1210	*Rumex hydrolapathum*	7
1086	*Epilobium hirsutum*	7	1211	*Rumex obtusifolius*	7
1089	*Epilobium palustre*	7	1216	*Scrophularia auriculata*	7
1090	*Epilobium parviflorum*	7	1218	*Scutellaria galericulata*	7
1094	*Equisetum arvense*	7	1219	*Senecio aquaticus*	7
1097	*Equisetum palustre*	7	1220	*Senecio jacobaea*	7
1101	*Eupatorium cannabinum*	7	1221	*Senecio vulgaris*	7
1104	*Festuca ovina*	7	1223	*Solanum dulcamara*	7
1105	*Filipendula ulmaria*	7	1225	*Sonchus asper*	7
1107	*Galeopsis tetrahit*	7	1227	***Sparganium erectum***	7
1110	*Galium palustre*	7	1229	*Stachys officinalis*	7
1112	*Galium uliginosum*	7	1269	*Stachys palustris*	7
1118	*Glyceria fluitans*	7	1232	*Stellaria media*	7
1119	***Glyceria maxima***	7	1233	*Stellaria uliginosa*	7
1264	*Gymnadenia conopsea*	7	1234	*Succisa pratensis*	7
1122	*Heracleum sphondylium*	7	1235	***Symphytum officinale***	7
1123	*Holcus lanatus*	7	1237	*Taraxacum officinale*	7
1131	*Hypericum tetrapterum*	7	1239	*Thalictrum flavum*	7
1132	*Impatiens capensis*	7	1241	*Trifolium repens*	7
1134	***Iris pseudacorus***	7	1242	***Tussilago farfara***	7
1137	*Juncus bufonius*	7	1270	*Veronica anagallis-aquatica*	7
1138	*Juncus effusus*	7	1247	*Veronica beccabunga*	7
1139	*Juncus inflexus*	7	1252	*Veronica serpyllifolia*	7
1142	*Lamium album*	7	1271	*Vicia cracca*	7
1145	***Lemna minor***	7	1253	*Vicia sativa*	7
1146	*Lotus pedunculatus*	7	1255	*Vicia sylvatica*	7
1147	*Luzula multiflora*	7	1258	*Viola palustris*	7
1149	*Lychnis flos-cuculi*	7			

Table A10.2 cont. Lowland *Alnus glutinosa* woodland groundflora species in each distinct light condition derived from the Ellenberg indicator values (Table continues)

Very well lit		
Ref.	**Species**	**L value**
1024	*Bellis perennis*	8
1037	*Cardamine hirsuta*	8
1041	*Carex distans*	8
1042	*Carex echinata*	8
1049	*Carex panicea*	8
1055	*Carex rostrata*	8
1057	*Centaurium erythraea*	8
1065	*Cirsium arvense*	8
1069	*Conium maculatum*	8
1095	*Equisetum fluviatile*	8
1102	*Festuca arundinacea*	8
1128	*Hydrocotyle vulgaris*	8
1135	*Juncus acutiflorus*	8
1136	*Juncus articulatus*	8
1140	*Juncus subnodulosus*	8
1164	*Myrica gale*	8
1176	*Phleum pratense*	8
1181	*Plantago media*	8
1188	*Potentilla anserina*	8
1202	*Ranunculus sceleratus*	8
1209	*Rumex crispus*	8
1214	*Schoenus nigricans*	8
1243	***Typha latifolia***	8
1245	*Valeriana dioica*	8
1251	*Veronica scutellata*	8
1266	*Menyanthes trifoliata*	8
1267	*Potentilla pulsutris*	8
1268	*Rumex conglomeratus*	8

Table A10.2 cont. Lowland *Alnus glutinosa* woodland groundflora species in each distinct light condition derived from the Ellenberg indicator values

A10.3 Ellenberg Soil Moisture Indicator Groups – Moisture-CoaH

CoaH-L. Drier/moist conditions						
Ref.	**Species**	**F value**		**Ref.**	**Species**	**F value**
1019	*Aquilegia vulgaris*	4		1058	*Cerastium fontanum*	5
1020	*Arctium minus*	4		1059	*Ceratocapnos claviculata*	5
1126	***Hyacinthoides hispanica***	4		1060	*Chamerion angustifolium*	5
1143	*Lapsana communis*	4		1061	*Chenopodium album*	5
1181	*Plantago media*	4		1067	*Cirsium vulgare*	5
1195	***Pulmonaria longifolia***	4		1069	*Conium maculatum*	5
1197	*Ranunculus bulbosus*	4		1070	*Conopodium majus*	5
1220	*Senecio jacobaea*	4		1071	*Convallaria majalis*	5
1238	*Teucrium scorodonia*	4		1073	*Cynosaurus cristatus*	5
1253	*Vicia sativa*	4		1075	*Dactylis glomerata*	5
1003	*Adoxa moschatellina*	5		1076	*Daphne laureola*	5
1004	***Aegopodium podagraria***	5		1078	*Deschampsia flexuosa*	5
1006	*Agrostis capillaris*	5		1093	*Epipactis helleborine*	5
1011	*Allium vineale*	5		1100	*Eranthis hyemalis*	5
1012	*Alopecurus pratensis*	5		1104	*Festuca ovina*	5
1017	*Anthriscus sylvestris*	5		1106	*Fragaria vesca*	5
1021	*Arrhenatherum elatius*	5		1107	*Galeopsis tetrahit*	5
1022	*Arum maculatum*	5		1109	*Galium odoratum*	5
1024	*Bellis perennis*	5		1113	*Geranium endressii*	5
1027	*Brachypodium sylvaticum*	5		1120	***Hedera helix***	5
1034	*Campanula trachelium*	5		1121	*Helleborus viridis*	5
1037	*Cardamine hirsuta*	5		1122	*Heracleum sphondylium*	5
1056	*Carex sylvatica*	5		1127	***Hyacinthoides non-scripta***	5
1057	*Centaurium erythraea*	5		1130	*Hypericum hirsutum*	5

Table A10.3 Lowland *Alnus glutinosa* woodland groundflora species in each distinct soil moisture condition derived from the Ellenberg indicator values (Table continues)

Ref.	Species	F value		Ref.	Species	F value
CoaH-L. Drier/moist conditions						
1141	***Lamiastrum galeobdolon***	5		1205	*Ribes uva-crispa*	5
1142	*Lamium album*	5		1207	*Rubus idaeus*	5
1265	*Listera ovata*	5		1208	*Rumex acetosa*	5
1261	*Luzula pilosa*	5		1211	*Rumex obtusifolius*	5
1148	*Luzula sylvatica*	5		1213	*Sanicula europaea*	5
1155	*Melica uniflora*	5		1221	*Senecio vulgaris*	5
1159	*Mycelis muralis*	5		1224	*Solidago virgaurea*	5
1160	*Myosotis arvensis*	5		1225	*Sonchus asper*	5
1166	*Orchis mascula*	5		1229	*Stachys officinalis*	5
1176	*Phleum pratense*	5		1231	*Stellaria holostea*	5
1178	*Phyllitis scolopendrium*	5		1232	*Stellaria media*	5
1179	*Plantago lanceolata*	5		1236	*Tamus communis*	5
1180	*Plantago major*	5		1237	*Taraxacum officinale*	5
1182	*Poa pratensis*	5		1241	*Trifolium repens*	5
1184	*Polypodium vulgare*	5		1248	*Veronica chamaedrys*	5
1185	*Polystichum aculeatum*	5		1249	*Veronica hederifolia*	5
1186	*Polystichum setiferum*	5		1252	*Veronica serpyllifolia*	5
1190	*Potentilla reptans*	5		1254	*Vicia sepium*	5
1191	*Potentilla sterilis*	5		1255	*Vicia sylvatica*	5
1192	*Primula vulgaris*	5		1257	*Viola odorata*	5
1193	*Prunella vulgaris*	5		1259	*Viola riviniana*	5
1194	*Pteridium aquilinum*	5				
CoaH-M. Constantly moist conditions						
1007	*Agrostis stolonifera*	6		1168	*Oxalis acetosella*	6
1009	*Alliaria petiolata*	6		1169	*Paris quadrifolia*	6
1010	***Allium ursinum***	6		1172	*Persicaria maculosa*	6
1013	*Anemone nemorosa*	6		1183	*Poa trivialis*	6
1016	*Anthoxanthum odoratum*	6		1196	*Ranunculus acris*	6
1026	*Blechnum spicant*	6		1198	*Ranunculus ficaria*	6
1028	*Bromopsis ramosa*	6		1209	*Rumex crispus*	6
1041	*Carex distans*	6		1217	*Scrophularia nodosa*	6
1048	*Carex pallescens*	6		1222	*Silene dioica*	6
1064	*Circaea lutetiana*	6		1230	*Stachys sylvatica*	6
1065	*Cirsium arvense*	6		1242	***Tussilago farfara***	6
1068	*Colchium autumnale*	6		1244	***Urtica dioica***	6
1077	*Deschampsia cespitosa cespitosa*	6		1250	*Veronica montana*	6
1079	*Digitalis purpurea*	6		1271	*Vicia cracca*	6
1080	*Dryopteris affinis*	6		1256	*Vinca major*	6
1084	*Dryopteris dilatata*	6		1001	*Achillea ptarmica*	7
1085	*Dryopteris filix-mas*	6		1002	*Aconitum napellus*	7
1087	*Epilobium montanum*	6		1005	*Agrostis canina*	7
1094	*Equisetum arvense*	6		1008	*Ajuga reptans*	7
1102	*Festuca arundinacea*	6		1015	*Anisantha sterilis*	7
1103	*Festuca gigantea*	6		1023	*Athyrium filix-femina*	7
1108	*Galium aparine*	6		1036	*Cardamine flexuosa*	7
1111	*Galium saxatile*	6		1045	*Carex hirta*	7
1114	*Geranium robertianum*	6		1072	*Crepis paludosa*	7
1116	*Geum urbanum*	6		1074	*Cystopteris fragilis*	7
1117	***Glechoma hederacea***	6		1092	*Epilobium tetragonum*	7
1264	*Gymnadenia conopsea*	6		1096	*Equisetum hyemale*	7
1123	*Holcus lanatus*	6		1115	*Geum rivale*	7
1124	*Holcus mollis*	6		1125	*Humulus lupulus*	7
1129	*Hypericum androsaemum*	6		1137	*Juncus bufonius*	7
1147	*Luzula multiflora*	6		1138	*Juncus effusus*	7
1157	***Mercurialis perennis***	6		1139	*Juncus inflexus*	7
1167	*Oreopteris limbosperma*	6		1151	*Lysimachia nemorum*	7

Table A10.3 cont. Lowland *Alnus glutinosa* woodland groundflora species in each distinct soil moisture condition derived from the Ellenberg indicator values

Ref.	Species	F value		Ref.	Species	F value
CoaH-M. Constantly moist conditions						
1152	***Lysimachia nummularia***	7		1201	*Ranunculus repens*	7
1170	*Persicaria bistorta*	7		1204	*Ribes rubrum*	7
1171	*Persicaria hydropiper*	7		1262	*Rubus caesius*	7
1173	***Petasites hybridus***	7		1212	*Rumex sanguineus*	7
1188	*Potentilla anserina*	7		1234	*Succisa pratensis*	7
1189	*Potentilla erecta*	7		1235	***Symphytum officinale***	7
CoaH-N. Wet conditions e.g. saturated soils						
1014	*Angelica sylvestris*	8		1269	*Stachys palustris*	8
1033	*Calystegia sepium*	8		1233	*Stellaria uliginosa*	8
1038	*Cardamine pratensis*	8		1239	*Thalictrum flavum*	8
1263	*Carex disticha*	8		1240	*Thelypteris palustris*	8
1042	*Carex echinata*	8		1245	*Valeriana dioica*	8
1044	*Carex elongata*	8		1246	*Valeriana officinalis*	8
1046	*Carex laevigata*	8		1260	*Wahlenbergia hederacea*	8
1047	*Carex nigra*	8		1029	*Calamagrostis canescens*	9
1049	*Carex panicea*	8		1032	***Caltha palustris***	9
1051	*Carex pendula*	8		1035	*Cardamine amara*	9
1053	*Carex remota*	8		1039	***Carex acutiformis***	9
1062	*Chrysosplenium alternifolium*	8		1040	*Carex appropinquata*	9
1066	*Cirsium palustre*	8		1050	***Carex paniculata***	9
1082	*Dryopteris carthusiana*	8		1052	*Carex pseudocyperus*	9
1086	*Epilobium hirsutum*	8		1054	*Carex riparia*	9
1088	*Epilobium obscurum*	8		1063	***Chrysosplenium oppositifolium***	9
1089	*Epilobium palustre*	8		1083	*Dryopteris cristata*	9
1091	*Epilobium roseum*	8		1090	*Epilobium parviflorum*	9
1097	*Equisetum palustre*	8		1110	*Galium palustre*	9
1098	*Equisetum sylvaticum*	8		1112	*Galium uliginosum*	9
1099	*Equisetum telmateia*	8		1132	*Impatiens capensis*	9
1101	*Eupatorium cannabinum*	8		1134	***Iris pseudacorus***	9
1105	*Filipendula ulmaria*	8		1136	*Juncus articulatus*	9
1128	*Hydrocotyle vulgaris*	8		1140	*Juncus subnodulosus*	9
1131	*Hypericum tetrapterum*	8		1149	*Lychnis flos-cuculi*	9
1133	***Impatiens glandulifera***	8		1153	*Lysimachia vulgaris*	9
1135	*Juncus acutiflorus*	8		1154	*Lythrum salicaria*	9
1146	*Lotus pedunculatus*	8		1161	*Myosotis laxa caespitosa*	9
1150	*Lycopus europaeus*	8		1162	*Myosotis scorpioides*	9
1156	*Mentha aquatica*	8		1163	*Myosotis secunda*	9
1158	***Molinia caerulea***	8		1164	*Myrica gale*	9
1202	*Ranunculus sceleratus*	8		1165	***Oenanthe crocata***	9
1268	*Rumex conglomeratus*	8		1174	*Peucedanum palustre*	9
1214	*Schoenus nigricans*	8		1175	***Phalaris arundinacea***	9
1215	*Scirpus sylvaticus*	8		1267	*Potentilla palustris*	9
1216	*Scrophularia auriculata*	8		1199	*Ranunculus flammula*	9
1218	*Scutellaria galericulata*	8		1203	*Ribes nigrum*	9
1219	*Senecio aquaticus*	8		1251	*Veronica scutellata*	9
1223	*Solanum dulcamara)*	8		1258	*Viola palustris*	9
CoaH-O. Very wet conditions e.g. open water						
1018	*Apium nodiflorum*	10		1200	*Ranunculus lingua*	10
1025	*Berula erecta*	10		1206	***Rorippa nasturtium-aquaticum***	10
1031	*Callitriche stagnalis*	10		1210	*Rumex hydrolapathum*	10
1043	*Carex elata*	10		1227	***Sparganium erectum***	10
1055	*Carex rostrata*	10		1243	***Typha latifolia***	10
1095	*Equisetum fluviatile*	10		1270	*Veronica anagllis-aquatica*	10
1118	*Glyceria fluitans*	10		1247	*Veronica beccabunga*	10
1119	***Glyceria maxima***	10		1030	*Callitriche obtusangula*	11
1266	*Menyanthes trifoliata*	10		1145	***Lemna minor***	11
1177	***Phragmites australis***	10		1187	*Potamogetum coloratus*	11

Table A10.3 cont. Lowland *Alnus glutinosa* woodland groundflora species in each distinct soil moisture condition derived from the Ellenberg indicator values

A10.4 Ellenberg Soil Acidity Indicator Groups – Acidity-CoaH

CoaH-P. Acidic soil conditions					
Ref.	**Species**	**R value**	**Ref.**	**Species**	**R value**
1078	*Deschampsia flexuosa*	2	1013	*Anemone nemorosa*	5
1005	*Agrostis canina*	3	1023	*Athyrium filix-femina*	5
1026	*Blechnum spicant*	3	1038	*Cardamine pratensis*	5
1042	*Carex echinata*	3	1046	*Carex laevigata*	5
1111	*Galium saxatile*	3	1048	*Carex pallescens*	5
1124	*Holcus mollis*	3	1058	*Cerastium fontanum*	5
1147	*Luzula multiflora*	3	1063	***Chrysosplenium oppositifolium***	5
1158	***Molinia caerulea***	3	1066	*Cirsium palustre*	5
1164	*Myrica gale*	3	1070	*Conopodium majus*	5
1189	*Potentilla erecta*	3	1077	*Deschampsia cespitosa cespitosa*	5
1194	*Pteridium aquilinum*	3	1080	*Dryopteris affinis*	5
1258	*Viola palustris*	3	1082	*Dryopteris carthusiana*	5
1260	*Wahlenbergia hederacea*	3	1085	*Dryopteris filix-mas*	5
1006	*Agrostis capillaris*	4	1088	*Epilobium obscurum*	5
1016	*Anthoxanthum odoratum*	4	1089	*Epilobium palustre*	5
1047	*Carex nigra*	4	1092	*Epilobium tetragonum*	5
1049	*Carex panicea*	4	1098	*Equisetum sylvaticum*	5
1055	*Carex rostrata*	4	1110	*Galium palustre*	5
1059	*Ceratocapnos claviculata*	4	1127	***Hyacinthoides non-scripta***	5
1079	*Digitalis purpurea*	4	1261	*Luzula pilosa*	5
1083	*Dryopteris cristata*	4	1152	***Lysimachia nummularia***	5
1084	*Dryopteris dilatata*	4	1163	*Myosotis secunda*	5
1104	*Festuca ovina*	4	1184	*Polypodium vulgare*	5
1135	*Juncus acutiflorus*	4	1186	*Polystichum setiferum*	5
1138	*Juncus effusus*	4	1267	*Potentilla pulsutris*	5
1148	*Luzula sylvatica*	4	1191	*Potentilla sterilis*	5
1151	*Lysimachia nemorum*	4	1199	*Ranunculus flammula*	5
1266	*Menyanthes trifoliata*	4	1207	*Rubus idaeus*	5
1167	*Oreopteris limbosperma*	4	1208	*Rumex acetosa*	5
1168	*Oxalis acetosella*	4	1229	*Stachys officinalis*	5
1224	*Solidago virgaurea*	4	1233	*Stellaria uliginosa*	5
1238	*Teucrium scorodonia*	4	1234	*Succisa pratensis*	5
1001	*Achillea ptarmica*	5	1251	*Veronica scutellata*	5
1008	*Ajuga reptans*	5	1259	*Viola riviniana*	5
CoaH-Q. More or less neutral					
1003	*Adoxa moschatellina*	6	1062	*Chrysosplenium alternifolium*	6
1004	***Aegopodium podagraria***	6	1067	*Cirsium vulgare*	6
1012	*Alopecurus pratensis*	6	1068	*Colchium autumnale*	6
1014	*Angelica sylvestris*	6	1071	*Convallaria majalis*	6
1019	*Aquilegia vulgaris*	6	1072	*Crepis paludosa*	6
1024	*Bellis perennis*	6	1073	*Cynosaurus cristatus*	6
1027	*Brachypodium sylvaticum*	6	1087	*Epilobium montanum*	6
1031	*Callitriche stagnalis*	6	1094	*Equisetum arvense*	6
1032	***Caltha palustris***	6	1095	*Equisetum fluviatile*	6
1036	*Cardamine flexuosa*	6	1097	*Equisetum palustre*	6
1037	*Cardamine hirsuta*	6	1101	*Eupatorium cannabinum*	6
1263	*Carex disticha*	6	1105	*Filipendula ulmaria*	6
1044	*Carex elongata*	6	1106	*Fragaria vesca*	6
1050	***Carex paniculata***	6	1107	*Galeopsis tetrahit*	6
1052	*Carex pseudocyperus*	6	1112	*Galium uliginosum*	6
1053	*Carex remota*	6	1114	*Geranium robertianum*	6
1056	*Carex sylvatica*	6	1115	*Geum rivale*	6
1057	*Centaurium erythraea*	6	1118	*Glyceria fluitans*	6
1060	*Chamerion angustifolium*	6	1123	*Holcus lanatus*	6

Table A10.4 Lowland *Alnus glutinosa* woodland groundflora species in each soil acidity condition derived from the Ellenberg indicator values (Table continues)

CoaH-Q. More or less neutral					
Ref.	Species	R value	Ref.	Species	R value
1126	***Hyacinthoides hispanica***	6	1030	*Callitriche obtusangula*	7
1128	*Hydrocotyle vulgaris*	6	1033	*Calystegia sepium*	7
1129	*Hypericum androsaemum*	6	1034	*Campanula trachelium*	7
1131	*Hypericum tetrapterum*	6	1035	*Cardamine amara*	7
1134	***Iris pseudacorus***	6	1039	***Carex acutiformis***	7
1136	*Juncus articulatus*	6	1041	*Carex distans*	7
1137	*Juncus bufonius*	6	1043	*Carex elata*	7
1146	*Lotus pedunculatus*	6	1045	*Carex hirta*	7
1149	*Lychnis flos-cuculi*	6	1051	*Carex pendula*	7
1160	*Myosotis arvensis*	6	1054	*Carex riparia*	7
1161	*Myosotis laxa caespitosa*	6	1061	*Chenopodium album*	7
1162	*Myosotis scorpioides*	6	1064	*Circaea lutetiana*	7
1165	***Oenanthe crocata***	6	1065	*Cirsium arvense*	7
1170	*Persicaria bistorta*	6	1069	*Conium maculatum*	7
1171	*Persicaria hydropiper*	6	1075	*Dactylis glomerata*	7
1172	*Persicaria maculosa*	6	1076	*Daphne laureola*	7
1179	*Plantago lanceolata*	6	1086	*Epilobium hirsutum*	7
1180	*Plantago major*	6	1090	*Epilobium parviflorum*	7
1182	*Poa pratensis*	6	1091	*Epilobium roseum*	7
1183	*Poa trivialis*	6	1093	*Epipactis helleborine*	7
1192	*Primula vulgaris*	6	1096	*Equisetum hyemale*	7
1193	*Prunella vulgaris*	6	1099	*Equisetum telmateia*	7
1195	***Pulmonaria longifolia***	6	1100	*Eranthis hyemalis*	7
1196	*Ranunculus acris*	6	1102	*Festuca arundinacea*	7
1198	*Ranunculus ficaria*	6	1103	*Festuca gigantea*	7
1200	*Ranunculus lingua*	6	1108	*Galium aparine*	7
1201	*Ranunculus repens*	6	1109	*Galium odoratum*	7
1203	*Ribes nigrum*	6	1113	*Geranium endressii*	7
1215	*Scirpus sylvaticus*	6	1116	*Geum urbanum*	7
1218	*Scutellaria galericulata*	6	1117	***Glechoma hederacea***	7
1219	*Senecio aquaticus*	6	1119	***Glyceria maxima***	7
1220	*Senecio jacobaea*	6	1264	*Gymnadenia conopsea*	7
1222	*Silene dioica*	6	1120	***Hedera helix***	7
1231	*Stellaria holostea*	6	1122	*Heracleum sphondylium*	7
1232	*Stellaria media*	6	1125	*Humulus lupulus*	7
1241	*Trifolium repens*	6	1130	*Hypericum hirsutum*	7
1242	***Tussilago farfara***	6	1132	*Impatiens capensis*	7
1245	*Valeriana dioica*	6	1133	***Impatiens glandulifera***	7
1246	*Valeriana officinalis*	6	1139	*Juncus inflexus*	7
1247	*Veronica beccabunga*	6	1141	***Lamiastrum galeobdolon***	7
1248	*Veronica chamaedrys*	6	1142	*Lamium album*	7
1250	*Veronica montana*	6	1143	*Lapsana communis*	7
1252	*Veronica serpyllifolia*	6	1145	***Lemna minor***	7
1254	*Vicia sepium*	6	1265	*Listera ovata*	7
1002	*Aconitum napellus*	7	1150	*Lycopus europaeus*	7
1007	*Agrostis stolonifera*	7	1153	*Lysimachia vulgaris*	7
1009	*Alliaria petiolata*	7	1154	*Lythrum salicaria*	7
1010	***Allium ursinum***	7	1155	*Melica uniflora*	7
1017	*Anthriscus sylvestris*	7	1156	*Mentha aquatica*	7
1018	*Apium nodiflorum*	7	1157	***Mercurialis perennis***	7
1020	*Arctium minus*	7	1159	*Mycelis muralis*	7
1021	*Arrhenatherum elatius*	7	1166	*Orchis mascula*	7
1022	*Arum maculatum*	7	1169	*Paris quadrifolia*	7
1025	*Berula erecta*	7	1173	***Petasites hybridus***	7
1028	*Bromopsis ramosa*	7	1174	*Peucedanum palustre*	7
1029	*Calamagrostis canescens*	7	1175	***Phalaris arundinacea***	7

Table A10.4 cont. Lowland *Alnus glutinosa* woodland groundflora species in each soil acidity condition derived from the Ellenberg indicator values (Table continues)

CoaH-Q. More or less neutral						
Ref.	**Species**	**R value**		**Ref.**	**Species**	**R value**
1176	*Phleum pratense*	7		1269	*Stachys palustris*	7
1177	*Phragmites australis*	7		1230	*Stachys sylvatica*	7
1178	*Phyllitis scolopendrium*	7		1235	***Symphytum officinale***	7
1181	*Plantago media*	7		1236	*Tamus communis*	7
1185	*Polystichum aculeatum*	7		1237	*Taraxacum officinale*	7
1188	*Potentilla anserina*	7		1239	*Thalictrum flavum*	7
1190	*Potentilla reptans*	7		1240	*Thelypteris palustris*	7
1197	*Ranunculus bulbosus*	7		1243	***Typha latifolia***	7
1204	*Ribes rubrum*	7		1244	***Urtica dioica***	7
1205	*Ribes uva-crispa*	7		1270	*Veronica anagllis-aquatica*	7
1206	***Rorippa nasturtium-aquaticum***	7		1249	*Veronica hederifolia*	7
1262	*Rubus caesius*	7		1271	*Vicia cracca*	7
1268	*Rumex conglomeratus*	7		1253	*Vicia sativa*	7
1209	*Rumex crispus*	7		1255	*Vicia sylvatica*	7
1210	*Rumex hydrolapathum*	7		1256	*Vinca major*	7
1211	*Rumex obtusifolius*	7		1257	*Viola odorata*	7
1212	*Rumex sanguineus*	7		1011	*Allium vineale*	8
1213	*Sanicula europaea*	7		1015	*Anisantha sterilis*	8
1214	*Schoenus nigricans*	7		1040	*Carex appropinquata*	8
1216	*Scrophularia auriculata*	7		1074	*Cystopteris fragilis*	8
1217	*Scrophularia nodosa*	7		1121	*Helleborus viridis*	8
1221	*Senecio vulgaris*	7		1140	*Juncus subnodulosus*	8
1223	*Solanum dulcamara*	7		1187	*Potamogetum coloratus*	8
1225	*Sonchus asper*	7		1202	*Ranunculus sceleratus*	8
1227	***Sparganium erectum***	7				

Table A10.4 cont. Lowland *Alnus glutinosa* woodland groundflora species in each soil acidity condition derived from the Ellenberg indicator values

A10.5 Ellenberg Soil Fertility Indicator Groups – Fertility-CoaH

CoaH-R. Low fertility conditions						
Ref.	**Species**	**N value**		**Ref.**	**Species**	**N value**
1042	*Carex echinata*	2		1261	*Luzula pilosa*	3
1047	*Carex nigra*	2		1266	*Menyanthes trifoliata*	3
1049	*Carex panicea*	2		1167	*Oreopteris limbosperma*	3
1055	*Carex rostrata*	2		1181	*Plantago media*	3
1104	*Festuca ovina*	2		1184	*Polypodium vulgare*	3
1135	*Juncus acutiflorus*	2		1267	*Potentilla pulsutris*	3
1158	***Molinia caerulea***	2		1194	*Pteridium aquilinum*	3
1164	*Myrica gale*	2		1199	*Ranunculus flammula*	3
1189	*Potentilla erecta*	2		1224	*Solidago virgaurea*	3
1214	*Schoenus nigricans*	2		1229	*Stachys officinalis*	3
1234	*Succisa pratensis*	2		1238	*Teucrium scorodonia*	3
1258	*Viola palustris*	2		1245	*Valeriana dioica*	3
1001	*Achillea ptarmica*	3		1251	*Veronica scutellata*	3
1005	*Agrostis canina*	3		1260	*Wahlenbergia hederacea*	3
1016	*Anthoxanthum odoratum*	3		1006	*Agrostis capillaris*	4
1026	*Blechnum spicant*	3		1013	*Anemone nemorosa*	4
1057	*Centaurium erythraea*	3		1024	*Bellis perennis*	4
1078	*Deschampsia flexuosa*	3		1032	***Caltha palustris***	4
1089	*Epilobium palustre*	3		1038	*Cardamine pratensis*	4
1097	*Equisetum palustre*	3		1040	*Carex appropinquata*	4
1111	*Galium saxatile*	3		1263	*Carex disticha*	4
1264	*Gymnadenia conopsea*	3		1046	*Carex laevigata*	4
1124	*Holcus mollis*	3		1048	*Carex pallescens*	4
1128	*Hydrocotyle vulgaris*	3		1058	*Cerastium fontanum*	4
1136	*Juncus articulatus*	3		1066	*Cirsium palustre*	4
1147	*Luzula multiflora*	3		1068	*Colchium autumnale*	4

Table A10.5 Lowland *Alnus glutinosa* woodland species associated with each soil fertility condition derived from the Ellenberg indicator values (Table continues)

CoaH-R. Low fertility conditions						
Ref.	**Species**	**N value**		**Ref.**	**Species**	**N value**
1072	*Crepis paludosa*	4		1146	*Lotus pedunculatus*	4
1073	*Cynosaurus cristatus*	4		1148	*Luzula sylvatica*	4
1074	*Cystopteris fragilis*	4		1149	*Lychnis flos-cuculi*	4
1077	*Deschampsia cespitosa cespitosa*	4		1163	*Myosotis secunda*	4
1082	*Dryopteris carthusiana*	4		1166	*Orchis mascula*	4
1083	*Dryopteris cristata*	4		1168	*Oxalis acetosella*	4
1093	*Epipactis helleborine*	4		1179	*Plantago lanceolata*	4
1095	*Equisetum fluviatile*	4		1192	*Primula vulgaris*	4
1106	*Fragaria vesca*	4		1193	*Prunella vulgaris*	4
1110	*Galium palustre*	4		1196	*Ranunculus acris*	4
1112	*Galium uliginosum*	4		1197	*Ranunculus bulbosus*	4
1115	*Geum rivale*	4		1208	*Rumex acetosa*	4
1131	*Hypericum tetrapterum*	4		1220	*Senecio jacobaea*	4
1138	*Juncus effusus*	4		1253	*Vicia sativa*	4
1140	*Juncus subnodulosus*	4		1259	*Viola riviniana*	4
CoaH-S. Intermediate fertility						
1003	*Adoxa moschatellina*	5		1233	*Stellaria uliginosa*	5
1008	*Ajuga reptans*	5		1239	*Thalictrum flavum*	5
1014	*Angelica sylvestris*	5		1240	*Thelypteris palustris*	5
1019	*Aquilegia vulgaris*	5		1246	*Valeriana officinalis*	5
1020	*Arctium minus*	5		1248	*Veronica chamaedrys*	5
1027	*Brachypodium sylvaticum*	5		1252	*Veronica serpyllifolia*	5
1029	*Calamagrostis canescens*	5		1271	*Vicia cracca*	5
1041	*Carex distans*	5		1255	*Vicia sylvatica*	5
1043	*Carex elata*	5		1002	*Aconitum napellus*	6
1056	*Carex sylvatica*	5		1007	*Agrostis stolonifera*	6
1059	*Ceratocapnos claviculata*	5		1011	*Allium vineale*	6
1060	*Chamerion angustifolium*	5		1023	*Athyrium filix-femina*	6
1063	***Chrysosplenium oppositifolium***	5		1030	*Callitriche obtusangula*	6
1070	*Conopodium majus*	5		1031	*Callitriche stagnalis*	6
1071	*Convallaria majalis*	5		1034	*Campanula trachelium*	6
1076	*Daphne laureola*	5		1035	*Cardamine amara*	6
1079	*Digitalis purpurea*	5		1036	*Cardamine flexuosa*	6
1080	*Dryopteris affinis*	5		1037	*Cardamine hirsuta*	6
1084	*Dryopteris dilatata*	5		1039	***Carex acutiformis***	6
1085	*Dryopteris filix-mas*	5		1044	*Carex elongata*	6
1088	*Epilobium obscurum*	5		1045	*Carex hirta*	6
1090	*Epilobium parviflorum*	5		1050	***Carex paniculata***	6
1092	*Epilobium tetragonum*	5		1051	*Carex pendula*	6
1098	*Equisetum sylvaticum*	5		1052	*Carex pseudocyperus*	6
1105	*Filipendula ulmaria*	5		1053	*Carex remota*	6
1123	*Holcus lanatus*	5		1062	*Chrysosplenium alternifolium*	6
1129	*Hypericum androsaemum*	5		1064	*Circaea lutetiana*	6
1130	*Hypericum hirsutum*	5		1065	*Cirsium arvense*	6
1137	*Juncus bufonius*	5		1067	*Cirsium vulgare*	6
1139	*Juncus inflexus*	5		1075	*Dactylis glomerata*	6
1265	*Listera ovata*	5		1087	*Epilobium montanum*	6
1151	*Lysimachia nemorum*	5		1094	*Equisetum arvense*	6
1152	***Lysimachia nummularia***	5		1096	*Equisetum hyemale*	6
1153	*Lysimachia vulgaris*	5		1099	*Equisetum telmateia*	6
1154	*Lythrum salicaria*	5		1100	*Eranthis hyemalis*	6
1155	*Melica uniflora*	5		1102	*Festuca arundinacea*	6
1156	*Mentha aquatica*	5		1107	*Galeopsis tetrahit*	6
1159	*Mycelis muralis*	5		1109	*Galium odoratum*	6
1161	*Myosotis laxa caespitosa*	5		1113	*Geranium endressii*	6
1174	*Peucedanum palustre*	5		1114	*Geranium robertianum*	6
1178	*Phyllitis scolopendrium*	5		1118	*Glyceria fluitans*	6
1182	*Poa pratensis*	5		1120	***Hedera helix***	6
1185	*Polystichum aculeatum*	5		1121	*Helleborus viridis*	6
1187	*Potamogetum coloratus*	5		1126	***Hyacinthoides hispanica***	6
1190	*Potentilla reptans*	5		1127	***Hyacinthoides non-scripta***	6
1191	*Potentilla sterilis*	5		1132	*Impatiens capensis*	6
1195	***Pulmonaria longifolia***	5		1134	***Iris pseudacorus***	6
1207	*Rubus idaeus*	5		1141	***Lamiastrum galeobdolon***	6
1213	*Sanicula europaea*	5		1145	***Lemna minor***	6
1218	*Scutellaria galericulata*	5		1150	*Lycopus europaeus*	6
1219	*Senecio aquaticus*	5		1160	*Myosotis arvensis*	6

Table A10.5 cont. Lowland *Alnus glutinosa* woodland species associated with each soil fertility condition derived from the Ellenberg indicator values (Table continues)

CoaH-S. Intermediate fertility conditions					
Ref.	**Species**	**N value**	**Ref.**	**Species**	**N value**
1162	*Myosotis scorpioides*	6	1210	*Rumex hydrolapathum*	6
1169	*Paris quadrifolia*	6	1215	*Scirpus sylvaticus*	6
1170	*Persicaria bistorta*	6	1217	*Scrophularia nodosa*	6
1171	*Persicaria hydropiper*	6	1225	*Sonchus asper*	6
1176	*Phleum pratense*	6	1231	*Stellaria holostea*	6
1177	*Phragmites australis*	6	1236	*Tamus communis*	6
1183	*Poa trivialis*	6	1237	*Taraxacum officinale*	6
1186	*Polystichum setiferum*	6	1241	*Trifolium repens*	6
1188	*Potentilla anserina*	6	1242	***Tussilago farfara***	6
1198	*Ranunculus ficaria*	6	1247	*Veronica beccabunga*	6
1203	*Ribes nigrum*	6	1249	*Veronica hederifolia*	6
1204	*Ribes rubrum*	6	1250	*Veronica montana*	6
1205	*Ribes uva-crispa*	6	1254	*Vicia sepium*	6
1262	*Rubus caesius*	6	1256	*Vinca major*	6
1209	*Rumex crispus*	6			
CoaH-T. High fertility					
1004	***Aegopodium podagraria***	7	1180	*Plantago major*	7
1010	***Allium ursinum***	7	1200	*Ranunculus lingua*	7
1012	*Alopecurus pratensis*	7	1201	*Ranunculus repens*	7
1015	*Anisantha sterilis*	7	1206	***Rorippa nasturtium-aquaticum***	7
1017	*Anthriscus sylvestris*	7	1268	*Rumex conglomeratus*	7
1018	*Apium nodiflorum*	7	1212	*Rumex sanguineus*	7
1021	*Arrhenatherum elatius*	7	1216	*Scrophularia auriculata*	7
1022	*Arum maculatum*	7	1221	*Senecio vulgaris*	7
1025	*Berula erecta*	7	1222	*Silene dioica*	7
1028	*Bromopsis ramosa*	7	1223	*Solanum dulcamara*	7
1033	*Calystegia sepium*	7	1227	***Sparganium erectum***	7
1054	*Carex riparia*	7	1269	*Stachys palustris*	7
1061	*Chenopodium album*	7	1232	*Stellaria media*	7
1086	*Epilobium hirsutum*	7	1243	***Typha latifolia***	7
1091	*Epilobium roseum*	7	1270	*Veronica anagallis-aquatica*	7
1101	*Eupatorium cannabinum*	7	1257	*Viola odorata*	7
1103	*Festuca gigantea*	7	1009	*Alliaria petiolata*	8
1116	*Geum urbanum*	7	1069	*Conium maculatum*	8
1117	***Glechoma hederacea***	7	1108	*Galium aparine*	8
1122	*Heracleum sphondylium*	7	1119	***Glyceria maxima***	8
1133	***Impatiens glandulifera***	7	1125	*Humulus lupulus*	8
1143	*Lapsana communis*	7	1142	*Lamium album*	8
1157	***Mercurialis perennis***	7	1202	*Ranunculus sceleratus*	8
1165	***Oenanthe crocata***	7	1230	*Stachys sylvatica*	8
1172	*Persicaria maculosa*	7	1235	***Symphytum officinale***	8
1173	***Petasites hybridus***	7	1244	***Urtica dioica***	8
1175	***Phalaris arundinacea***	7	1211	*Rumex obtusifolius*	9

Table A10.5 cont. Lowland *Alnus glutinosa* woodland species associated with each soil fertility condition derived from the Ellenberg indicator values

APPENDIX 11: DEVELOPMENT & DEFINING NICHES OF A HABITAT, LOWLAND *ALNUS GLUTINOSA* WOODLAND

In all Tables in this Appendix, species high-lighted in bold text have the potential to form (in some situations) extensive, near monoculture stands with only a few other species associated within them.

A11.1 Unique Combinations of CoaHs in Lowland *Alnus glutinosa* Groundflora

Out of the 672 possible combinations of CoaHs (see Section 5.3), 129 can be derived from the 269 groundflora species found to be associated with lowland *Alnus glutinosa* woodland. These are summarised in Table A11.1.

CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility	No. of species
competitor-ruderal	semi-shade	Drier	neutral	intermediate	1
competitor-ruderal	semi-shade	moist-damp	acidic	intermediate	1
competitor-ruderal	semi-shade	moist-damp	neutral	intermediate	1
competitor-ruderal	semi-shade	moist-damp	neutral	high fertility	5
competitor-ruderal	semi-shade	wet	acidic	low fertility	1
competitor-ruderal	semi-shade	wet	neutral	high fertility	1
competitor-ruderal	semi-shade	wet	neutral	intermediate	1
competitor-ruderal	shade	moist-damp	neutral	intermediate	1
competitor-ruderal	very well lit	moist-damp	neutral	high fertility	1
competitor-ruderal	very well lit	moist-damp	neutral	intermediate	1
competitor-ruderal	very well lit	wet	acidic	low fertility	1
competitor-ruderal	very well lit	wet	neutral	high fertility	1
competitor-ruderal	well lit	moist-damp	acidic	low fertility	1
competitor-ruderal	well lit	moist-damp	neutral	high fertility	3
competitor-ruderal	well lit	moist-damp	neutral	intermediate	7
competitor-ruderal	well lit	very wet	basic	intermediate	1
competitor-ruderal	well lit	very wet	neutral	high fertility	3
competitor-ruderal	well lit	very wet	neutral	intermediate	3
competitor-ruderal	well lit	wet	acidic	intermediate	1
competitor-ruderal	well lit	wet	acidic	low fertility	3
competitor-ruderal	well lit	wet	neutral	low fertility	1
competitor-ruderal	well lit	wet	neutral	high fertility	3
competitor-ruderal	well lit	wet	neutral	intermediate	3
competitors	semi-shade	moist-damp	acidic	intermediate	1
competitors	semi-shade	moist-damp	acidic	low fertility	2
competitors	semi-shade	moist-damp	neutral	high fertility	4
competitors	semi-shade	moist-damp	neutral	intermediate	7
competitors	semi-shade	wet	neutral	intermediate	4
competitors	very well lit	moist-damp	neutral	intermediate	1
competitors	very well lit	very wet	neutral	high fertility	1
competitors	well lit	moist-damp	acidic	low fertility	1
competitors	well lit	moist-damp	neutral	high fertility	3
competitors	well lit	moist-damp	neutral	intermediate	4
competitors	well lit	very wet	neutral	high fertility	2
competitors	well lit	very wet	neutral	intermediate	2
competitors	well lit	wet	neutral	low fertility	2
competitors	well lit	wet	neutral	high fertility	6
competitors	well lit	wet	neutral	intermediate	10
CSR	semi-shade	moist-damp	acidic	low fertility	1
CSR	semi-shade	moist-damp	acidic	intermediate	4

Table A11.1 Unique combinations and number of species of CoaHs derived from the 269 groundflora species found to be associated with lowland *Alnus glutinosa* woodland (table continues)

CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility	No. of species
CSR	semi-shade	moist-damp	neutral	low fertility	2
CSR	semi-shade	moist-damp	neutral	intermediate	3
CSR	semi-shade	moist-damp	neutral	high fertility	5
CSR	semi-shade	wet	neutral	high fertility	1
CSR	semi-shade	wet	neutral	intermediate	2
CSR	semi-shade	wet	acidic	intermediate	3
CSR	shade	moist-damp	neutral	high fertility	1
CSR	shade	moist-damp	neutral	intermediate	3
CSR	shade	wet	neutral	intermediate	1
CSR	very well lit	moist-damp	neutral	intermediate	2
CSR	very well lit	wet	neutral	low fertility	2
CSR	well lit	moist-damp	acidic	low fertility	2
CSR	well lit	moist-damp	neutral	intermediate	2
CSR	well lit	moist-damp	neutral	low fertility	4
CSR	well lit	wet	neutral	intermediate	1
CSR	well lit	wet	neutral	low fertility	2
no value	no value	no value	no value	no value	
no value	semi-shade	Drier	neutral	intermediate	1
no value	semi-shade	moist-damp	neutral	intermediate	1
no value	semi-shade	moist-damp	neutral	low fertility	1
no value	semi-shade	wet	acidic	low fertility	1
no value	semi-shade	wet	neutral	intermediate	2
no value	very well lit	wet	acidic	low fertility	1
no value	well lit	wet	basic	low fertility	1
no value	well lit	wet	neutral	intermediate	2
ruderals	semi-shade	Drier	neutral	high fertility	1
ruderals	semi-shade	moist-damp	basic	high fertility	1
ruderals	semi-shade	moist-damp	neutral	intermediate	4
ruderals	very well lit	moist-damp	neutral	intermediate	1
ruderals	very well lit	moist-damp	neutral	low fertility	1
ruderals	very well lit	wet	basic	high fertility	1
ruderals	well lit	Drier	neutral	low fertility	2
ruderals	well lit	moist-damp	acidic	low fertility	1
ruderals	well lit	moist-damp	neutral	high fertility	5
ruderals	well lit	moist-damp	neutral	intermediate	7
ruderals	well lit	very wet	neutral	high fertility	1
ruderals	well lit	very wet	neutral	intermediate	2
ruderals	well lit	wet	acidic	low fertility	1
ruderals	well lit	wet	neutral	intermediate	2
stress competitors	no value	no value	no value	no value	1
stress competitors	semi-shade	moist-damp	acidic	low fertility	3
stress competitors	semi-shade	moist-damp	acidic	intermediate	4
stress competitors	semi-shade	moist-damp	neutral	intermediate	3
stress competitors	semi-shade	wet	acidic	low fertility	1
stress competitors	semi-shade	wet	neutral	intermediate	1
stress competitors	shade	moist-damp	acidic	intermediate	1
stress competitors	shade	moist-damp	basic	intermediate	1
stress competitors	shade	moist-damp	neutral	high fertility	1
stress competitors	shade	moist-damp	neutral	intermediate	4
stress competitors	very well lit	very wet	acidic	low fertility	1
stress competitors	very well lit	very wet	neutral	low fertility	1
stress competitors	very well lit	wet	acidic	low fertility	1

Table A11.1 cont. Unique combinations and number of species of CoaHs derived from the 269 groundflora species found to be associated with lowland *Alnus glutinosa* woodland (table continues)

CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility	No. of species
stress competitors	very well lit	wet	neutral	low fertility	1
stress competitors	very well lit	wet	basic	low fertility	1
stress competitors	well lit	moist-damp	neutral	intermediate	2
stress competitors	well lit	very wet	neutral	intermediate	1
stress competitors	well lit	wet	acidic	low fertility	1
stress ruderals	semi-shade	Drier	neutral	intermediate	1
stress ruderals	semi-shade	moist-damp	acidic	low fertility	1
stress ruderals	semi-shade	moist-damp	acidic	intermediate	3
stress ruderals	semi-shade	wet	acidic	low fertility	1
stress ruderals	shade	moist-damp	neutral	high fertility	2
stress ruderals	shade	moist-damp	neutral	intermediate	2
stress ruderals	very well lit	moist-damp	neutral	intermediate	1
stress ruderals	very well lit	moist-damp	neutral	low fertility	1
stress ruderals	well lit	Drier	neutral	low fertility	1
stress ruderals	well lit	moist-damp	acidic	low fertility	1
stress tolerators	semi-shade	Drier	acidic	low fertility	1
stress tolerators	semi-shade	Drier	neutral	intermediate	1
stress tolerators	semi-shade	moist-damp	acidic	intermediate	1
stress tolerators	semi-shade	moist-damp	acidic	low fertility	8
stress tolerators	semi-shade	moist-damp	basic	low fertility	1
stress tolerators	semi-shade	moist-damp	neutral	low fertility	3
stress tolerators	semi-shade	moist-damp	neutral	intermediate	5
stress tolerators	semi-shade	wet	acidic	low fertility	1
stress tolerators	semi-shade	wet	neutral	intermediate	1
stress tolerators	shade	moist-damp	acidic	low fertility	1
stress tolerators	shade	moist-damp	neutral	high fertility	1
stress tolerators	shade	moist-damp	neutral	low fertility	1
stress tolerators	shade	moist-damp	neutral	intermediate	6
stress tolerators	very well lit	Drier	neutral	low fertility	1
stress tolerators	very well lit	moist-damp	neutral	intermediate	1
stress tolerators	very well lit	very wet	acidic	low fertility	1
stress tolerators	very well lit	wet	neutral	low fertility	1
stress tolerators	very well lit	wet	acidic	low fertility	3
stress tolerators	well lit	moist-damp	basic	intermediate	1
stress tolerators	well lit	moist-damp	neutral	low fertility	1
stress tolerators	well lit	moist-damp	acidic	low fertility	5
stress tolerators	well lit	very wet	neutral	high fertility	1
stress tolerators	well lit	wet	neutral	low fertility	2
stress tolerators	well lit	wet	acidic	low fertility	3

Table A11.1 cont. Unique combinations and number of species of CoaHs derived from the 269 groundflora species found to be associated with lowland *Alnus glutinosa* woodland

A11.2 Output Species Groups from TWINSPAN Analysis

Tables A11.2 to A11.13 list the species and the CoaHs which they represent occurring in each TWINSPAN Group summarised in Table 5.3, Section 5.3.1.

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Alopecurus pratensis	competitors	well lit	moist-damp	neutral	high fertility
Callitriche stagnalis	ruderals	well lit	very wet	neutral	intermediate
Campanula trachelium	CSR	shade	moist-damp	neutral	intermediate
Chenopodium album	ruderals	well lit	moist-damp	neutral	high fertility
Cirsium vulgare	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Dactylis glomerata	competitors	well lit	moist-damp	neutral	intermediate
Galeopsis tetrahit	ruderals	well lit	moist-damp	neutral	intermediate
Glyceria fluitans	competitor-ruderal	well lit	very wet	neutral	intermediate
Heracleum sphondylium	competitor-ruderal	well lit	moist-damp	neutral	high fertility
Plantago major	ruderals	well lit	moist-damp	neutral	high fertility
Rumex obtusifolius	competitor-ruderal	well lit	moist-damp	neutral	high fertility
Senecio vulgaris	ruderals	well lit	moist-damp	neutral	high fertility
Sonchus asper	ruderals	well lit	moist-damp	neutral	intermediate
Stellaria media	ruderals	well lit	moist-damp	neutral	high fertility
Taraxacum officinale	ruderals	well lit	moist-damp	neutral	intermediate
Trifolium repens	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Veronica beccabunga	competitor-ruderal	well lit	very wet	neutral	intermediate

Table A11.2 TWINSPAN group: 0000

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Apium nodiflorum	competitor-ruderal	well lit	very wet	neutral	high fertility
Arrhenatherum elatius	competitors	well lit	moist-damp	neutral	high fertility
Berula erecta	competitor-ruderal	well lit	very wet	neutral	high fertility
Callitriche obtusangula	ruderals	well lit	very wet	neutral	intermediate
Glyceria maxima	competitors	well lit	very wet	neutral	high fertility
Lamium album	competitor-ruderal	well lit	moist-damp	neutral	high fertility
Lemna minor	competitor-ruderal	well lit	very wet	neutral	intermediate
Phragmites australis	competitors	well lit	very wet	neutral	intermediate
Ranunculus lingua	competitors	well lit	very wet	neutral	high fertility
Rorippa nasturtium-aquaticum	competitor-ruderal	well lit	very wet	neutral	high fertility
Rumex hydrolapathum	competitors	well lit	very wet	neutral	intermediate
Veronica angallis-aquatica	ruderals	well lit	very wet	neutral	high fertility

Table A11.3 TWINSPAN group: 0001

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Aegopodium podagraria	competitor-ruderal	semi-shade	moist-damp	neutral	high fertility
Agrostis stolonifera	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Anthriscus sylvestris	competitor-ruderal	semi-shade	moist-damp	neutral	high fertility
Arum maculatum	stress ruderals	shade	moist-damp	neutral	high fertility
Bromopsis ramosa	CSR	shade	moist-damp	neutral	high fertility
Calystegia sepium	competitors	well lit	wet	neutral	high fertility
Carex hirta	competitors	well lit	moist-damp	neutral	intermediate
Carex pseudocyperus	competitors	well lit	wet	neutral	intermediate
Carex remota	CSR	shade	wet	neutral	intermediate
Circaea lutetiana	competitor-ruderal	shade	moist-damp	neutral	intermediate
Conium maculatum	competitor-ruderal	very well lit	moist-damp	neutral	high fertility
Cynosaurus cristatus	CSR	well lit	moist-damp	neutral	low fertility
Epilobium hirsutum	competitors	well lit	wet	neutral	high fertility
Equisetum arvense	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Eranthis hyemalis	stress ruderals	shade	moist-damp	neutral	intermediate
Eupatorium cannabinum	competitors	well lit	wet	neutral	high fertility
Galium odoratum	stress competitors	shade	moist-damp	neutral	intermediate
Geranium endressii	competitors	semi-shade	moist-damp	neutral	intermediate
Hedera helix	stress competitors	shade	moist-damp	neutral	intermediate
Lycopus europaeus	competitor-ruderal	well lit	wet	neutral	intermediate
Mycelis muralis	CSR	shade	moist-damp	neutral	intermediate
Myosotis arvensis	ruderals	well lit	moist-damp	neutral	intermediate
Myosotis scorpioides	competitor-ruderal	well lit	wet	neutral	intermediate
Oenanthe crocata	competitor-ruderal	well lit	wet	neutral	high fertility
Persicaria hydropiper	ruderals	well lit	moist-damp	neutral	intermediate
Persicaria maculosa	ruderals	well lit	moist-damp	neutral	high fertility
Phalaris arundinacea	competitors	well lit	wet	neutral	high fertility
Phleum pratense	CSR	very well lit	moist-damp	neutral	intermediate
Plantago lanceolata	CSR	well lit	moist-damp	neutral	low fertility
Poa pratensis	CSR	well lit	moist-damp	neutral	intermediate
Poa trivialis	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Potentilla reptans	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Prunella vulgaris	CSR	well lit	moist-damp	neutral	low fertility
Scrophularia auriculata	competitor-ruderal	well lit	wet	neutral	high fertility
Solanum dulcamara	competitors	well lit	wet	neutral	high fertility
Sparganium erectum	stress tolerators	well lit	very wet	neutral	high fertility
Stachys palustris	competitor-ruderal	well lit	wet	neutral	high fertility
Stellaria holostea	CSR	semi-shade	moist-damp	neutral	intermediate
Symphytum officinale	competitors	well lit	moist-damp	neutral	high fertility
Tamus communis	competitors	semi-shade	moist-damp	neutral	intermediate
Tussilago farfara	competitor-ruderal	well lit	moist-damp	neutral	intermediate
Typha latifolia	competitors	very well lit	very wet	neutral	high fertility
Veronica serpyllifolia	ruderals	well lit	moist-damp	neutral	intermediate
Vicia sepium	competitors	semi-shade	moist-damp	neutral	intermediate
Vicia sylvatica	competitors	well lit	moist-damp	neutral	intermediate
Viola odorata	CSR	semi-shade	moist-damp	neutral	high fertility

Table A11.4 TWINSPAN group: 001

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Allium vineale	stress tolerators	well lit	moist-damp	basic	intermediate
Angelica sylvestris	competitors	well lit	wet	neutral	intermediate
Bellis perennis	ruderals	very well lit	moist-damp	neutral	low fertility
Carex disticha	competitors	well lit	wet	neutral	low fertility
Cerastium fontanum	ruderals	well lit	moist-damp	acidic	low fertility
Equisetum palustre	competitor-ruderal	well lit	wet	neutral	low fertility
Helleborus viridis	stress competitors	shade	moist-damp	basic	intermediate
Hypericum tetrapterum	CSR	well lit	wet	neutral	low fertility
Iris pseudacorus	competitors	well lit	wet	neutral	intermediate
Lotus pedunculatus	competitors	well lit	wet	neutral	low fertility
Myosotis laxa caespitosa	ruderals	well lit	wet	neutral	intermediate
Potentilla anserina	competitor-ruderal	very well lit	moist-damp	neutral	intermediate
Rumex crispus	ruderals	very well lit	moist-damp	neutral	intermediate
Scutellaria galericulata	competitor-ruderal	well lit	wet	neutral	intermediate
Senecio aquaticus	ruderals	well lit	wet	neutral	intermediate
Senecio jacobaea	ruderals	well lit	Drier	neutral	low fertility
Veronica hederifolia	ruderals	semi-shade	moist-damp	neutral	intermediate
Vicia sativa	ruderals	well lit	Drier	neutral	low fertility

Table A11.5 TWINSPAN group: 0100

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Adoxa moschatellina	stress ruderals	shade	moist-damp	neutral	intermediate
Cardamine hirsuta	stress ruderals	very well lit	moist-damp	neutral	intermediate
Carex sylvatica	stress tolerators	shade	moist-damp	neutral	intermediate
Chamerion angustifolium	competitors	semi-shade	moist-damp	neutral	intermediate
Chrysosplenium alternifolium	CSR	semi-shade	wet	neutral	intermediate
Epilobium montanum	CSR	semi-shade	moist-damp	neutral	intermediate
Festuca arundinacea	CSR	very well lit	moist-damp	neutral	intermediate
Fragaria vesca	CSR	semi-shade	moist-damp	neutral	low fertility
Geranium robertianum	ruderals	semi-shade	moist-damp	neutral	intermediate
Holcus lanatus	CSR	well lit	moist-damp	neutral	intermediate
Lychnis flos-cuculi	CSR	well lit	wet	neutral	low fertility
Persicaria bistorta	competitors	semi-shade	moist-damp	neutral	intermediate
Polystichum setiferum	stress competitors	shade	moist-damp	acidic	intermediate
Potamogetum coloratus	competitor-ruderal	well lit	very wet	basic	intermediate
Ranunculus acris	CSR	well lit	moist-damp	neutral	low fertility
Ribes uva-crispa	stress competitors	semi-shade	moist-damp	neutral	intermediate
Rumex acetosa	CSR	well lit	moist-damp	acidic	low fertility
Silene dioica	CSR	semi-shade	moist-damp	neutral	high fertility
Veronica chamaedrys	CSR	semi-shade	moist-damp	neutral	intermediate
Veronica montana	stress tolerators	shade	moist-damp	neutral	intermediate

Table A11.6 TWINSPAN group: 0101

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Aconitum napellus	competitors	semi-shade	moist-damp	neutral	intermediate
Allium ursinum	stress ruderals	shade	moist-damp	neutral	high fertility
Carex acutiformis	competitors	well lit	wet	neutral	intermediate
Carex riparia	competitors	well lit	wet	neutral	high fertility
Epipactia helleborine	stress tolerators	shade	moist-damp	neutral	low fertility
Equisetum telmateia	competitors	semi-shade	wet	neutral	intermediate
Geum urbanum	stress tolerators	shade	moist-damp	neutral	high fertility
Glechoma hederacea	CSR	semi-shade	moist-damp	neutral	high fertility
Lamiastrum galeobdolon	stress tolerators	shade	moist-damp	neutral	intermediate
Lapsana communis	ruderals	semi-shade	Drier	neutral	high fertility
Lythrum salicaria	competitors	well lit	wet	neutral	intermediate
Mentha aquatica	competitors	well lit	wet	neutral	intermediate
Mercurialis perennis	stress competitors	shade	moist-damp	neutral	high fertility
Petasites hybridus	competitors	semi-shade	moist-damp	neutral	high fertility
Rumex sanguineus	CSR	semi-shade	moist-damp	neutral	high fertility
Stachys sylvatica	competitors	semi-shade	moist-damp	neutral	high fertility
Thalictrum flavum	competitors	well lit	wet	neutral	intermediate
Vicia cracca	competitors	well lit	moist-damp	neutral	intermediate

Table A11.7 TWINSPAN group: 0110

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Cardamine amara	competitor-ruderal	semi-shade	wet	neutral	intermediate
Cirsium arvense	competitors	very well lit	moist-damp	neutral	intermediate
Epilobium parviflorum	CSR	well lit	wet	neutral	intermediate
Epilobium roseum	CSR	semi-shade	wet	neutral	high fertility
Impatiens capensis	no value	well lit	wet	neutral	intermediate
Impatiens glandulifera	competitor-ruderal	semi-shade	wet	neutral	high fertility
Ranunculus repens	competitor-ruderal	semi-shade	moist-damp	neutral	high fertility
Rumex conglomeratus	competitor-ruderal	very well lit	wet	neutral	high fertility

Table A11.8 TWINSPAN group: 0111

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Alliaria petiolata	competitor-ruderal	semi-shade	moist-damp	neutral	high fertility
Anisantha sterilis	ruderals	semi-shade	moist-damp	basic	high fertility
Calamagrostis canescens	competitors	well lit	wet	neutral	intermediate
Carex elata	stress competitors	well lit	very wet	neutral	intermediate
Daphne laureola	stress competitors	shade	moist-damp	neutral	intermediate
Equisetum hyemale	no value	semi-shade	moist-damp	neutral	intermediate
Festuca gigantea	CSR	semi-shade	moist-damp	neutral	high fertility
Filipendula ulmaria	competitors	well lit	wet	neutral	intermediate
Galium aparine	competitor-ruderal	semi-shade	moist-damp	neutral	high fertility
Humulus lupulus	competitors	semi-shade	moist-damp	neutral	high fertility
Hypericum hirsutum	stress tolerators	semi-shade	moist-damp	neutral	intermediate
Juncus inflexus	stress competitors	well lit	moist-damp	neutral	intermediate
Listera ovata	stress tolerators	semi-shade	moist-damp	neutral	intermediate
Lysimachia vulgaris	competitors	well lit	wet	neutral	intermediate
Melica uniflora	stress tolerators	shade	moist-damp	neutral	intermediate
Paris quadrifolia	stress competitors	shade	moist-damp	neutral	intermediate
Phyllitis scolopendrium	stress tolerators	shade	moist-damp	neutral	intermediate
Polystichum aculeatum	stress competitors	semi-shade	moist-damp	neutral	intermediate
Ribes rubrum	stress competitors	semi-shade	moist-damp	neutral	intermediate
Rubus caesius	stress competitors	well lit	moist-damp	neutral	intermediate
Sanicula europaea	stress tolerators	shade	moist-damp	neutral	intermediate
Scrophularia nodosa	competitor-ruderal	semi-shade	moist-damp	neutral	intermediate
Urtica dioica	competitors	semi-shade	moist-damp	neutral	high fertility
Vinca major	competitors	semi-shade	moist-damp	neutral	intermediate

Table A11.9 TWINSPAN group: 100

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Achillea ptarmica	competitor-ruderal	well lit	moist-damp	acidic	low fertility
Agrostis canina	CSR	well lit	moist-damp	acidic	low fertility
Agrostis capillaris	CSR	semi-shade	moist-damp	acidic	low fertility
Arctium minus	competitor-ruderal	semi-shade	Drier	neutral	intermediate
Caltha palustris	stress tolerators	well lit	wet	neutral	low fertility
Cardamine flexuosa	ruderals	semi-shade	moist-damp	neutral	intermediate
Cardamine pratensis	ruderals	well lit	wet	acidic	low fertility
Carex elongata	no value	semi-shade	wet	neutral	intermediate
Carex paniculata	competitors	semi-shade	wet	neutral	intermediate
Centaurium erythraea	stress ruderals	very well lit	moist-damp	neutral	low fertility
Cirsium palustre	competitor-ruderal	well lit	wet	acidic	low fertility
Crepis paludosa	CSR	semi-shade	moist-damp	neutral	low fertility
Dryopteris affinis ssp. *borreri*	stress competitors	no value	no value	no value	no value
Equisetum fluviatile	stress competitors	very well lit	very wet	neutral	low fertility
Festuca ovina	stress tolerators	well lit	moist-damp	acidic	low fertility
Galium palustre	competitor-ruderal	well lit	wet	acidic	low fertility
Galium uliginosum	stress tolerators	well lit	wet	neutral	low fertility
H. non-scripta	stress ruderals	semi-shade	moist-damp	acidic	intermediate
Hyacinthoides hispanica	stress ruderals	semi-shade	Drier	neutral	intermediate
Hydrocotyle vulgaris	CSR	very well lit	wet	neutral	low fertility
Juncus articulatus	CSR	very well lit	wet	neutral	low fertility
Juncus bufonius	ruderals	well lit	moist-damp	neutral	intermediate
Peucedanum palustre	no value	well lit	wet	neutral	intermediate
Primula vulgaris	stress tolerators	semi-shade	moist-damp	neutral	low fertility
Pteridium aquilinum	competitors	semi-shade	moist-damp	acidic	low fertility
Ranunculus bulbosus	stress ruderals	well lit	Drier	neutral	low fertility
Ranunculus ficaria	ruderals	semi-shade	moist-damp	neutral	intermediate
Ranunculus flammula	competitor-ruderal	well lit	wet	acidic	low fertility
Ribes nigrum	stress competitors	semi-shade	wet	neutral	intermediate
Scirpus sylvaticus	competitors	semi-shade	wet	neutral	intermediate
Stachys officinalis	stress tolerators	well lit	moist-damp	acidic	low fertility
Stellaria uliginosa	competitor-ruderal	well lit	wet	acidic	intermediate
Valeriana officinalis	CSR	semi-shade	wet	neutral	intermediate

Table A11.10 TWINSPAN group: 101

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Ajuga reptans	CSR	semi-shade	moist-damp	acidic	intermediate
Anemone nemorosa	stress ruderals	semi-shade	moist-damp	acidic	low fertility
Anthoxanthum odoratum	stress ruderals	well lit	moist-damp	acidic	low fertility
Aquilegia vulgaris	stress tolerators	semi-shade	Drier	neutral	intermediate
Athyrium filix-femina	competitors	semi-shade	moist-damp	acidic	intermediate
Blechnum spicant	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Brachypodium sylvaticum	stress tolerators	semi-shade	moist-damp	neutral	intermediate
Carex distans	stress tolerators	very well lit	moist-damp	neutral	intermediate
Carex laevigata	stress tolerators	semi-shade	wet	acidic	low fertility
Carex nigra	stress tolerators	well lit	wet	acidic	low fertility

Table A11.11 TWINSPAN group: 110 (Table continues)

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Carex pallescens	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Carex pendula	stress tolerators	semi-shade	wet	neutral	intermediate
Ceratocapnos claviculata	stress ruderals	semi-shade	moist-damp	acidic	intermediate
Chrysosplenium oppositifolium	CSR	semi-shade	wet	acidic	intermediate
Colchium autumnale	no value	semi-shade	moist-damp	neutral	low fertility
Conopodium majus	stress ruderals	semi-shade	moist-damp	acidic	intermediate
Convallaria majalis	stress tolerators	semi-shade	moist-damp	neutral	intermediate
Cystopteris fragilis	stress tolerators	semi-shade	moist-damp	basic	low fertility
Deschampsia cespitosa cespitosa	stress competitors	semi-shade	moist-damp	acidic	low fertility
Deschampsia. flexuosa	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Digitalis purpurea	competitor-ruderal	semi-shade	moist-damp	acidic	intermediate
Dryopteris affinis	stress competitors	semi-shade	moist-damp	acidic	intermediate
Dryopteris carthusiana	stress competitors	semi-shade	wet	acidic	low fertility
Dryopteris cristata	no value	semi-shade	wet	acidic	low fertility
Dryopteris dilatata	stress competitors	semi-shade	moist-damp	acidic	intermediate
Dryopteris filix-mas	stress competitors	semi-shade	moist-damp	acidic	intermediate
Epilobium obscurum	CSR	semi-shade	wet	acidic	intermediate
Epilobium tetragonum	CSR	semi-shade	moist-damp	acidic	intermediate
Equisetum sylvaticum	CSR	semi-shade	wet	acidic	intermediate
Galium saxatile	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Geum rivale	stress tolerators	semi-shade	moist-damp	neutral	low fertility
Gymnadenia conopsea	stress tolerators	well lit	moist-damp	neutral	low fertility
Hypericum androsaemum	stress tolerators	semi-shade	moist-damp	neutral	intermediate
Juncus effusus	competitors	well lit	moist-damp	acidic	low fertility
Luzula pilosa	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Luzula sylvatica	stress competitors	semi-shade	moist-damp	acidic	low fertility
Lysimachia nemorum	CSR	semi-shade	moist-damp	acidic	intermediate
Lysimachia nummularia	CSR	semi-shade	moist-damp	acidic	intermediate
Menyanthes trifoliata	stress tolerators	very well lit	very wet	acidic	low fertility
Myosotis secunda	competitor-ruderal	semi-shade	wet	acidic	low fertility
Orchis mascula	stress tolerators	semi-shade	moist-damp	neutral	low fertility
Oreopteris limbosperma	stress competitors	semi-shade	moist-damp	acidic	low fertility
Oxalis acetosella	stress tolerators	shade	moist-damp	acidic	low fertility
Polypodium vulgare	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Potentilla pulsutris	stress tolerators	very well lit	wet	acidic	low fertility
Potentilla sterilis	stress tolerators	semi-shade	moist-damp	acidic	intermediate
Pulmonaria longifolia	no value	semi-shade	Drier	neutral	intermediate
Rubus idaeus	stress competitors	semi-shade	moist-damp	acidic	intermediate
Solidago virgaurea	stress tolerators	semi-shade	moist-damp	acidic	low fertility
Succisa pratensis	stress tolerators	well lit	moist-damp	acidic	low fertility
Teucrium scorodonia	stress tolerators	semi-shade	Drier	acidic	low fertility
Viola riviniana	stress tolerators	semi-shade	moist-damp	acidic	low fertility

Table A11.11 cont. TWINSPAN group: 110

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Carex appropinquata	no value	well lit	wet	basic	low fertility
Carex rostrata	stress competitors	very well lit	very wet	acidic	low fertility
Epilobium palustre	stress tolerators	well lit	wet	acidic	low fertility
Holcus mollis	competitors	semi-shade	moist-damp	acidic	low fertility
Luzula multiflora	stress tolerators	well lit	moist-damp	acidic	low fertility
Molinia caerulea	stress competitors	well lit	wet	acidic	low fertility
Plantago media	stress tolerators	very well lit	Drier	neutral	low fertility
Potentilla erecta	stress tolerators	well lit	moist-damp	acidic	low fertility
Ranunculus sceleratus	ruderals	very well lit	wet	basic	high fertility
Schoenus nigricans	stress competitors	very well lit	wet	neutral	low fertility
Thelypteris palustris	no value	semi-shade	wet	neutral	intermediate
Valeriana dioica	stress tolerators	very well lit	wet	neutral	low fertility
Veronica scutellata	competitor-ruderal	very well lit	wet	acidic	low fertility
Viola palustris	stress tolerators	well lit	wet	acidic	low fertility

Table A11.12 TWINSPAN group: 1110

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Carex echinata	stress tolerators	very well lit	wet	acidic	low fertility
Carex panicea	stress tolerators	very well lit	wet	acidic	low fertility
Juncus acutiflorus	stress competitors	very well lit	wet	acidic	low fertility
Juncus subnodulosus	stress competitors	very well lit	wet	basic	low fertility
Lathraea clandestina	no value	no value	no value	no value	no value
Myrica gale	no value	very well lit	wet	acidic	low fertility
Wahlenbergia hederacea	stress ruderals	semi-shade	wet	acidic	low fertility

Table A11.13 TWINSPAN group: 1111

APPENDIX 12: LOWLAND *ALNUS GLUTINOSA* WOODLAND GROUNDFLORA SPECIES THAT DEFINE THE NICHES OF THE HABITAT

In all Tables in this Appendix, species high-lighted in bold text have the potential to form (in some situations) extensive, near monoculture stands with only a few other species associated within them.

Species	Species
Angelica sylvestris	*Lotus pedunculatus*
Calamagrostis canescens	*Lychnis flos-cuculi*
Caltha palustris	*Lysimachia vulgaris*
Cardamine pratensis	*Lythrum salicaria*
Carex appropinquata	*Mentha aquatica*
Carex disticha	*Menyanthes trifoliata*
Carex nigra	***Molinia caerulea***
Carex rostrata	*Myosotis laxa caespitosa*
Cirsium palustre	*Peucedanum palustre*
Crepis paludosa	*Plantago media*
Epilobium palustre	*Potentilla palustris*
Epilobium parviflorum	*Ranunculus flammula*
Equisetum fluviatile	*Schoenus nigricans*
Equisetum palustre	*Scutellaria galericulata*
Filipendula ulmaria	*Senecio aquaticus*
Galium palustre	*Stellaria uliginosa*
Galium uliginosum	*Thalictrum flavum*
Geum rivale	*Thelypteris palustris*
Hydrocotyle vulgaris	*Valeriana dioica*
Hypericum tetrapterum	*Valeriana officinalis*
Juncus articulatus	*Veronica scutellata*
Juncus subnodulosus	

Table A12.1 NoaH-1 species

Species	Species
Apium nodiflorum	*Potamogetum coloratus*
Berula erecta	*Ranunculus lingua*
Callitriche obtusangula	***Rorippa nasturtium-aquaticum***
Callitriche stagnalis	*Rumex hydrolapathum*
Carex elata	***Sparganium erectum***
Glyceria fluitans	***Typha latifolia***
Glyceria maxima	*Veronica anagllis-aquatica*
Lemna minor	*Veronica beccabunga*
Phragmites australis	

Table A12.2 NoaH-2 species

Species	Species
Alliaria petiolata	*Persicaria bistorta*
Anisantha sterilis	***Petasites hybridus***
Anthriscus sylvestris	*Ranunculus repens*
Athyrium filix-femina	*Ribes rubrum*
Cardamine flexuosa	*Scrophularia nodosa*
Carex remota	*Silene dioica*
Equisetum hyemale	*Stachys sylvatica*
Festuca gigantea	*Tamus communis*
Galium aparine	***Urtica dioica***
Geranium endressii	*Veronica hederifolia*
Geranium robertianum	*Vicia sepium*
Glechoma hederacea	*Vinca major*
Humulus lupulus	

Table A12.3 NoaH-3 species

Species	Species
Aegopodium podagraria	*Heracleum sphondylium*
Alopecurus pratensis	*Phleum pratense*
Arrhenatherum elatius	*Plantago major*
Cardamine hirsuta	*Rumex crispus*
Chenopodium album	*Senecio vulgaris*
Cirsium vulgare	*Sonchus asper*
Dactylis glomerata	*Stellaria media*
Festuca arundinacea	*Taraxacum officinale*
Galeopsis tetrahit	*Trifolium repens*

Table A12.4 NoaH-4 species

Species	Species
Aconitum napellus	*Helleborus viridis*
Adoxa moschatellina	***Lamiastrum galeobdolon***
Allium ursinum	*Melica uniflora*
Arum maculatum	***Mercurialis perennis***
Bromopsis ramosa	*Mycelis muralis*
Campanula trachelium	*Paris quadrifolia*
Carex sylvatica	*Phyllitis scolopendrium*
Chamerion angustifolium	*Polystichum aculeatum*
Circaea lutetiana	*Polystichum setiferum*
Daphne laureola	*Ribes uva-crispa*
Epilobium montanum	*Rumex sanguineus*
Epipactia helleborine	*Sanicula europaea*
Eranthis hyemalis	*Stellaria holostea*
Galium odoratum	*Veronica chamaedrys*
Geum urbanum	*Veronica montana*
Hedera helix	*Viola odorata*

Table A12.5 NoaH-5 species

Species	Species
Aquilegia vulgaris	*Hypericum androsaemum*
Arctium minus	*Hypericum hirsutum*
Bellis perennis	*Lapsana communis*
Brachypodium sylvaticum	*Listera ovata*
Carex distans	*Orchis mascula*
Centaurium erythraea	*Plantago lanceolata*
Cerastium fontanum	*Primula vulgaris*
Colchium autumnale	*Prunella vulgaris*
Conopodium majus	***Pulmonaria longifolia***
Convallaria majalis	*Ranunculus acris*
Cynosaurus cristatus	*Ranunculus bulbosus*
Cystopteris fragilis	*Rubus idaeus*
Fragaria vesca	*Rumex acetosa*
Gymnadenia conopsea	*Senecio jacobaea*
Holcus lanatus	*Vicia sativa*
Hyacinthoides hispanica	*Viola riviniana*

Table A12.6 NoaH-6 species

Species	**Species**
Agrostis stolonifera	*Poa pratensis*
Allium vineale	*Poa trivialis*
Carex hirta	*Potentilla anserina*
Cirsium arvense	*Potentilla reptans*
Conium maculatum	*Ranunculus ficaria*
Dryopteris affinis ssp. *borreri*	*Ranunculus sceleratus*
Equisetum arvense	*Rubus caesius*
Juncus bufonius	*Rumex obtusifolius*
Juncus inflexus	***Symphytum officinale***
Lamium album	***Tussilago farfara***
Myosotis arvensis	*Veronica serpyllifolia*
Persicaria hydropiper	*Vicia cracca*
Persicaria maculosa	*Vicia sylvatica*

Table A12.7 NoaH-7 species

Species	**Species**
Calystegia sepium	*Impatiens capensis*
Cardamine amara	***Impatiens glandulifera***
Carex acutiformis	***Iris pseudacorus***
Carex elongata	*Lycopus europaeus*
Carex paniculata	*Myosotis scorpioides*
Carex pendula	***Oenanthe crocata***
Carex pseudocyperus	***Phalaris arundinacea***
Carex riparia	*Ribes nigrum*
Chrysosplenium alternifolium	*Rumex conglomeratus*
Epilobium hirsutum	*Scirpus sylvaticus*
Epilobium roseum	*Scrophularia auriculata*
Equisetum telmateia	*Solanum dulcamara*
Eupatorium cannabinum	*Stachys palustris*

Table A12.8 NoaH-8 species

Species	**Species**
Achillea ptarmica	*Holcus mollis*
Agrostis canina	***Hyacinthoides non-scripta***
Agrostis capillaris	*Juncus effusus*
Ajuga reptans	*Luzula multiflora*
Anemone nemorosa	*Luzula pilosa*
Anthoxanthum odoratum	*Luzula sylvatica*
Blechnum spicant	*Lysimachia nemorum*
Carex pallescens	***Lysimachia nummularia***
Ceratocapnos claviculata	*Oreopteris limbosperma*
Deschampsia cespitosa cespitosa	*Oxalis acetosella*
Deschampsia flexuosa	*Polypodium vulgare*
Digitalis purpurea	*Potentilla erecta*
Dryopteris affinis	*Potentilla sterilis*
Dryopteris dilatata	*Pteridium aquilinum*
Dryopteris filix-mas	*Solidago virgaurea*
Epilobium tetragonum	*Stachys officinalis*
Festuca ovina	*Succisa pratensis*
Galium saxatile	*Teucrium scorodonia*

Table A12.9 NoaH-9 species

Species	**Species**
Carex echinata	*Equisetum sylvaticum*
Carex laevigata	*Juncus acutiflorus*
Carex panicea	*Lathraea clandestina*
Chrysosplenium oppositifolium	*Myosotis secunda*
Dryopteris carthusiana	*Myrica gale*
Dryopteris cristata	*Viola palustris*
Epilobium obscurum	*Wahlenbergia hederacea*

Table A12.10 NoaH-10 species

APPENDIX 13: SPECIES OCCURRING IN STONEBRIDGE MEADOWS *ALNUS GLUTINOSA* WOODLANDS

Species	**1992[1]**	**1996[1]**	**25/04/04**			**31/05/04**			**30/08/04**			**02/12/04**		
			A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Adoxa moschatellina				4	3		3							
Aegopodium podagraria					3			3			4			
Agrostis capillaris														
Agrostis stolonifera														
Ajuga reptans														
Alliaria petiolata				2	3		3	5			3			
Alnus glutinosa		*	9	9	8	9	9	9	10	9	8	10	9	8
Alopecurus pratensis						5								
Anemone nemorosa														
Angelica sylvestris					1					2	1		1	
Anthoxanthum odoratum														
Anthriscus sylvestris				1	2		2	3		3			2	2
Arctium sp.							1	1						
Arrhenatherum elatius										4				
Arum maculatum					1									
Athyrium filix-femina							1							
Brachypodium sylvaticum							4							
Callitriche stagnalis														
Caltha palustris		*		5			5			3			1	
Calystegia sepium							1							
Cardamine amara														
Cardamine flexuosa													2	
Carex acutiformis				3			5			5			5	
Carex remota								3		1	4			
Cerastium fontanum														
Chamerion angustifolium			2	2		1								
Chenopodium album						4			3					
Circaea lutetiana					3			3	1	1	2			
Cirsium palustre						1								
Conopodium majus														
Corylus avellana					1								1	
Crataegus monogyna			2	1	1		3	2	1	2	4		1	
Dactylis glomerata														
Deschampsia cespitosa cespitosa			1			1						1		1
Digitalis purpurea						1						1		
Dryopteris carthusiana				1?						1				
Dryopteris dilatata			1						1	1		1		
Dryopteris filix-mas			1		1						1			
Epilobium hirsutum							4							
Epilobium montanum									2					
Epilobium tetragonum						4								
Equisetum arvense						1								
Festuca arundinacea			9				9	9						
Festuca gigantea														
Filipendula ulmaria					1		2	2		4	1			
Fraxinus excelsior			1	1	1		4	5		4	4		4	
Galeopsis tetrahit									1	1				

Table A13.1 Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated) (Table continues)

Species	1992[1]	1996[1]	25/04/04			31/05/04			30/08/04			02/12/04		
			A	B	C	A	B	C	A	B	C	A	B	C
Galium aparine			3	5	7	3	8	7						
Galium palustre													3	
Geranium robertianum														
Geum urbanum				1	1	1	4	3	1	3	4		4	4
Glechoma hederacea							2				4			
Glyceria fluitans														
Glyceria maxima														
Glyceria notata														
Hedera helix													1	
Heracleum sphondylium				1			4	3			1		1	
Holcus lanatus														
Holcus mollis														
Hyacinthoides non-scripta			4	3	1	3								
Ilex aquifolium														1
Impatiens capensis		*								3				
Impatiens glandulifera					3		4	4			3			
Iris pseudacorus		*					3			2				
Juncus bufonius														
Juncus effusus												1		
Lapsana communis											1			
Lonicera periclymenum				1										
Moehringia trinervia														
Myosotis scorpioides		*		4										
Persicaria hydropiper														
Persicaria maculosa									1					
Phalaris arundinacea							3			3			2	
Phleum pratensis							1							
Plantago lanceolata														
Poa trivialis														
Potentilla erecta														
Potentilla reptans										1				
Ranunculus acris				2		1	4	3						
Ranunculus bulbosus														
Ranunculus ficaria			3	6	5			4						
Ranunculus flammula														
Ranunculus repens			2		3	3	4	3	5	5	4	4	4	3
Ranunculus sceleratus														
Ribes rubrum					1									
Rorippa nasturtium-aquaticum				1			3			3				
Rosa canina							1				1		1	
Rubus fruticosus agg.			2	1		4	3		4	2	4	1	3	4
Rumex acetosa						1			2					
Rumex obtusifolius			2	3	2	3			2	1			1	
Rumex sanguineus						2	4	4	2	1	2			
Salix fragilis				1	2		1	1		4	4			
Sambucus nigra			2	1	4	2	2	5	4	2	4		4	4
Scirpus sylvaticus	*													
Scrophularia nodosa									1		1			
Scutellaria galericulata														

Table A13.1 cont. Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated) (Table continues)

Species	1992[1]	1996[1]	25/04/04			31/05/04			30/08/04			02/12/04		
			A	B	C	A	B	C	A	B	C	A	B	C
Senecio jacobaea														
Senecio vulgaris														
Silene dioica			3	4	3	3	4	4	2	3	3	3	3	
Solanum dulcamara														
Stachys officinalis							2							
Stellaria graminea														
Stellaria media				3	1			3	4	3	3			
Taraxacum officinale														
Urtica dioica			4	6	8	5	9	9	7	8	8	4	6	6
Valeriana officinalis				2			4			3				
Veronica beccabunga														
Veronica chamaedrys			1				4							
Veronica hederifolia														
Veronica scutellata	*													
Viola arvensis														
TOTAL SPECIES (111)	**2**	**5**	**18**	**27**	**26**	**21**	**36**	**24**	**19**	**30**	**25**	**9**	**21**	**9**

Table A13.1 cont. Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated) (Table continues)

Species	26/03/05			April 08[1]			June 08[1]			31/05/09[2]		
	A	B	C	A	B	C	A	B	C	A	B	C
Adoxa moschatellina		4	2	*	*	*	*	*	*			
Aegopodium podagraria				*		*	*		*			R
Agrostis capillaris							*	*		O		
Agrostis stolonifera				*			*			O		
Ajuga reptans												
Alliaria petiolata		1		*	*	*	*	*	*	R	O	LA
Alnus glutinosa	9	9	8							D	D	D
Alopecurus pratensis							*			R		
Anemone nemorosa											R	
Angelica sylvestris		3	1	*	*	*	*	*	*		R	O
Anthoxanthum odoratum							*			O	R	
Anthriscus sylvestris		1	1		*	*		*	*		L	L
Arctium sp.												
Arrhenatherum elatius								*	*			
Arum maculatum		1	2									
Athyrium filix-femina												
Brachypodium sylvaticum				*		*	*		*		R	
Callitriche stagnalis							*		*			
Caltha palustris		4			*	*		*	*		LA	R
Calystegia sepium								*				
Cardamine amara				*			*					
Cardamine flexuosa				*	*	*	*	*	*		F	
Carex acutiformis					*			*			LD	
Carex remota		1		*	*	*	*	*	*	R	O	LF
Cerastium fontanum				*		*	*		*	R		R

Table A13.1 cont. Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated) (Table continues)

Species	26/03/05			April 08[1]			June 08[1]			31/05/09[2]		
	A	B	C	A	B	C	A	B	C	A	B	C
Chamerion angustifolium												
Chenopodium album												
Circaea lutetiana				*	*	*	*	*	*	R	R	R
Cirsium palustre				*	*		*	*			R	
Conopodium majus										R/L		R
Corylus avellana												
Crataegus monogyna	1	2	3							R	R	R
Dactylis glomerata							*			L		
Deschampsia cespitosa cespitosa	1			*			*			O		
Digitalis purpurea				*	*		*	*		R	R	
Dryopteris carthusiana												
Dryopteris dilatata	1			*	*		*	*		R	R	
Dryopteris filix-mas	1			*	*	*	*	*	*		R	
Epilobium hirsutum					*			*			R	
Epilobium montanum				*	*		*	*		R	R	R
Epilobium tetragonum												
Equisetum arvense				*			*			R		
Festuca arundinacea												
Festuca gigantea					*	*		*	*			
Filipendula ulmaria		1	2	*	*	*	*	*	*	R	R	R
Fraxinus excelsior	1	1	1							R	R	R
Galeopsis tetrahit							*	*				
Galium aparine		4	4	*	*	*	*	*	*	R	R	R
Galium palustre				*	*	*	*	*	*			R
Geranium robertianum									*			
Geum urbanum	2	2	3	*	*	*	*	*	*	R	R	O
Glechoma hederacea					*	*		*	*		R	L
Glyceria fluitans				*			*			L		
Glyceria maxima					*			*				
Glyceria notata						*			*			
Hedera helix				*		*	*		*			
Heracleum sphondylium		1			*	*		*	*		L	L
Holcus lanatus				*	*	*	*	*	*	L	L	L
Holcus mollis							*					
Hyacinthoides non-scripta		1		*	*	*	*	*	*	L	L	L
Ilex aquifolium			1									
Impatiens capensis								*	*		R	R
Impatiens glandulifera					*	*	*	*	*		R	O
Iris pseudacorus		1			*			*				
Juncus bufonius							*					
Juncus effusus	1									O	R	
Lapsana communis				*	*	*	*	*	*	R		
Lonicera periclymenum		1										
Moehringia trinervia					*							
Myosotis scorpioides		2						*				R
Persicaria hydropiper							*		*	R		LA
Persicaria maculosa												
Phalaris arundinacea		1			*			*				
Phleum pratensis											LA	

Table A13.1 cont. Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated) (Table continues)

Species	26/03/05			April 08[1]			June 08[1]			31/05/09[2]		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Plantago lanceolata				*								
Poa trivialis				*	*	*	*	*	*	A	LD	LD
Potentilla erecta							*					
Potentilla reptans												
Ranunculus acris				*	*		*	*				
Ranunculus bulbosus												
Ranunculus ficaria		4	4	*	*	*	*	*	*	R	O	L
Ranunculus flammula							*			R		
Ranunculus repens	2	3	1	*	*	*	*	*	*	O	O	R
Ranunculus sceleratus									*			
Ribes rubrum			1		*	*		*	*			R
Rorippa nasturtium-aquaticum		4			*			*			LF	
Rosa canina											R	R
Rubus fruticosus agg.	1	1	1							R	R	R
Rumex acetosa				*			*					
Rumex obtusifolius		3		*	*	*	*	*	*	R	R	O
Rumex sanguineus	1	1	1				*	*	*	R	R	O
Salix fragilis											R	R
Sambucus nigra	1		3							R	R	O
Scirpus sylvaticus												
Scrophularia nodosa		1						*			R	
Scutellaria galericulata					*			*				
Senecio jacobaea							*			R		
Senecio vulgaris						*			*			
Silene dioica		3	2							L	O	L
Solanum dulcamara								*				
Stachys officinalis					*	*						
Stellaria graminea							*			R		
Stellaria media				*	*	*	*	*	*	LA	R	R
Taraxacum officinale					*	*		*	*			
Urtica dioica	3	5	7	*	*	*	*	*	*	R	LD	LD
Valeriana officinalis		3			*			*			R	
Veronica beccabunga												
Veronica chamaedrys				*	*	*	*	*	*	R	R	LA
Veronica hederifolia				*	*	*						
Veronica scutellata												
Viola arvensis								*				
TOTAL SPECIES (111)	**13**	**29**	**19**	**38**	**45**	**37**	**51**	**52**	**42**	**41**	**47**	**39**

Notes
1. Presence
2. DAFOR

Table A13.1 cont. Species recorded at Stonebridge Meadows *Alnus glutinosa* woodlands (values DOMIN unless otherwise stated)

APPENDIX 14: OUTPUT SPECIES GROUPS FROM TWINSPAN ANALYSIS: STONEBRIDGE SUMMER 2008 DATA

In all Tables in this Appendix, species high-lighted in bold text have the potential to form (in some situations) extensive, near monoculture stands with only a few other species associated within them.

Tables A14.1 to A14.9 list the species and the CoaHs which they represent occurring in each TWINSPAN Group summarised in Table 7.1, Section 7.2.

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Conopodium majus	Stress-ruderal	semi-shade	Drier	acidic	intermediate
Dryopteris filix-mas	Stress-competitor	semi-shade	moist-damp	acidic	intermediate
Galium palustre	Competitor-ruderal	well lit	wet	acidic	infertile
Poa trivialis	Competitor-ruderal	well lit	moist-damp	neutral	intermediate
Rumex obtusifolius	Competitor-ruderal	well lit	Drier	neutral	richly
Silene dioica	CSR	semi-shade	moist-damp	neutral	richly
Stellaria media	Ruderal	well lit	Drier	neutral	richly

Table A14.1 TWINSPAN group: 01

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Caltha palustris	**Stress**	**well lit**	**wet**	**neutral**	**infertile**
Calystegia sepium	Competitor	well lit	wet	neutral	richly
Cardamine flexuosa	Ruderal	semi-shade	moist-damp	neutral	intermediate
Carex acutiformis	**Competitor**	**well lit**	**wet**	**neutral**	**intermediate**
Epilobium hirsutum	Competitor	well lit	wet	neutral	richly
Glyceria maxima	**Competitor**	**well lit**	**very wet**	**neutral**	**richly**
Impatiens capensis		well lit	wet	neutral	intermediate
Iris pseudacorus	Competitor	well lit	wet	neutral	intermediate
Myosotis scorpioides	Competitor-ruderal	well lit	wet	neutral	intermediate
Phalaris arundinacea	**Competitor**	**well lit**	**wet**	**neutral**	**richly**
Ribes rubrum	Stress-competitor	semi-shade	moist-damp	neutral	intermediate
Rorippa nasturtium-aquaticum	**Competitor-ruderal**	**well lit**	**very wet**	**neutral**	**richly**
Scutellaria galericulata	Competitor-ruderal	well lit	wet	neutral	intermediate
Solanum dulcamara	Competitor	well lit	wet	neutral	richly
Valeriana officinalis	CSR	semi-shade	wet	neutral	intermediate

Table A14.2 TWINSPAN group: 0000

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Angelica sylvestris	Competitor	well lit	wet	neutral	intermediate
Filipendula ulmaria	Competitor	well lit	wet	neutral	intermediate
Impatiens glandulifera	**Competitor-ruderal**	**semi-shade**	**wet**	**neutral**	**richly**

Table A14.3 TWINSPAN group: 0001

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Adoxa moschatellina	stress-ruderal	Shade	Drier	neutral	intermediate
Anthriscus sylvestris	Competitor-ruderal	semi-shade	Drier	neutral	richly
Carex remota	CSR	Shade	wet	neutral	intermediate
Epilobium tetragonum	CSR	semi-shade	moist-damp	acidic	intermediate
Galium aparine	Competitor-ruderal	semi-shade	moist-damp	neutral	richly
Geranium robertianum	Ruderal	semi-shade	moist-damp	neutral	intermediate
Glechoma hederacea	**CSR**	**semi-shade**	**moist-damp**	**neutral**	**richly**
Glyceria notata	Competitor-ruderal	well lit	very wet	neutral	richly
Heracleum sphondylium	Competitor-ruderal	well lit	Drier	neutral	richly
Ranunculus sceleratus	Ruderal	very well lit	wet	neutral	richly
Taraxacum officinale	Ruderal	well lit	Drier	neutral	intermediate
Urtica dioica	**Competitor**	**semi-shade**	**moist-damp**	**neutral**	**richly**

Table A14.4 TWINSPAN group: 0010

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Aegopodium podagraria	Competitor-ruderal	semi-shade	Drier	neutral	richly
Alliaria petiolata	Competitor-ruderal	semi-shade	moist-damp	neutral	richly
Arrhenatherum elatius	Competitor	well lit	Drier	neutral	richly
Festuca gigantea	CSR	semi-shade	moist-damp	neutral	richly
Geum urbanum	Stress	Shade	moist-damp	neutral	richly
Senecio vulgaris	Ruderal	well lit	Drier	neutral	richly

Table A14.5 TWINSPAN group: 0011

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Brachypodium sylvaticum	Stress	semi-shade	Drier	neutral	intermediate
Circaea lutetiana	Competitor-ruderal	Shade	moist-damp	neutral	intermediate
Dryopteris dilatata	stress-competitor	semi-shade	moist-damp	acidic	intermediate
Galeopsis tetrahit	Ruderal	well lit	Drier	neutral	intermediate
Hyacinthoides non-scripta	Stress-ruderal	semi-shade	Drier		intermediate
Persicaria hydropiper	Ruderal	well lit	moist-damp	neutral	intermediate
Ranunculus ficaria	Ruderal	semi-shade	moist-damp	neutral	intermediate

Table A14.6 TWINSPAN group: 10

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Lapsana communis	Ruderal	semi-shade	Drier	neutral	richly
Ranunculus repens	Competitor-ruderal	semi-shade	moist-damp	neutral	richly
Rumex sanguineus	CSR	semi-shade	moist-damp	neutral	richly
Veronica chamaedrys	CSR	semi-shade	Drier	neutral	intermediate

Table A14.7 TWINSPAN group: 110

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Callitriche stagnalis	Ruderal	well lit	very wet	neutral	intermediate
Cerastium fontanum	Ruderal	well lit	Drier	acidic	infertile
Digitalis purpurea	Competitor-ruderal	semi-shade	moist-damp	acidic	intermediate
Epilobium montanum	CSR	semi-shade	moist-damp	neutral	intermediate
Holcus lanatus	CSR	well lit	moist-damp	neutral	intermediate
Holcus mollis	Competitor	semi-shade	moist-damp	acidic	infertile
Juncus bufonius	Ruderal	well lit	moist-damp	neutral	intermediate
Juncus effusus	Competitor	well lit	moist-damp	acidic	infertile
Potentilla erecta	Stress	well lit	moist-damp	acidic	infertile
Ranunculus flammula	Competitor-ruderal	well lit	wet	acidic	infertile
Scrophularia nodosa	Competitor-ruderal	semi-shade	moist-damp	neutral	intermediate
Senecio jacobaea	Ruderal	well lit	Drier	neutral	infertile
Stellaria graminea	CSR	well lit	moist-damp	acidic	infertile

Table A14.8 TWINSPAN group: 1110

Species	CoaH-CSR	CoaH-Light	CoaH-Moisture	CoaH-Acidity	CoaH-Fertility
Agrostis capillaris	CSR	semi-shade	Drier	acidic	infertile
Agrostis stolonifera	Competitor-ruderal	well lit	moist-damp	neutral	intermediate
Alopecurus pratensis	Competitor	well lit	Drier	neutral	richly
Anthoxanthum odoratum	stress-ruderal	well lit	moist-damp	acidic	infertile
Cardamine amara	Competitor-ruderal	semi-shade	wet	neutral	intermediate
Cirsium palustre	Competitor-ruderal	well lit	wet	acidic	infertile
Dactylis glomerata	Competitor	well lit	Drier	neutral	intermediate
Deschampsia cespitosa cespitosa	Stress-competitor	semi-shade	moist-damp	acidic	infertile
Equisetum arvense	Competitor-ruderal	well lit	moist-damp	neutral	intermediate
Glyceria fluitans	Competitor-ruderal	well lit	very wet	neutral	intermediate
Ranunculus acris	CSR	well lit	moist-damp	neutral	infertile
Rumex acetosa	CSR	well lit	Drier	acidic	infertile
Viola arvense	Ruderal	very well lit	Drier	neutral	intermediate

Table A14.9 TWINSPAN group: 1111

APPENDIX 15: SPATIAL DISTRIBUTION OF SPECIES IN COAHS AND NOAHS IN *ALNUS GLUTINOSA* WOODLAND AT STONEBRIDGE (SITES A & C)

Figures A15.1 to A15.12 graphically represent the transects and constituent quadrats sampled in Sites A and C, Stonebridge, in relation to the CoaHs and NoaHs of the component species. For each quadrat, the component species (and % cover) occurring in each quadrat are depicted and coded by their associated CoaH or NoaH. In these Figures, columns represent quadrat composition while rows represent occurrence of species in the quadrats (see Figure 3.2 for explanation).

Fig. A15.1 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

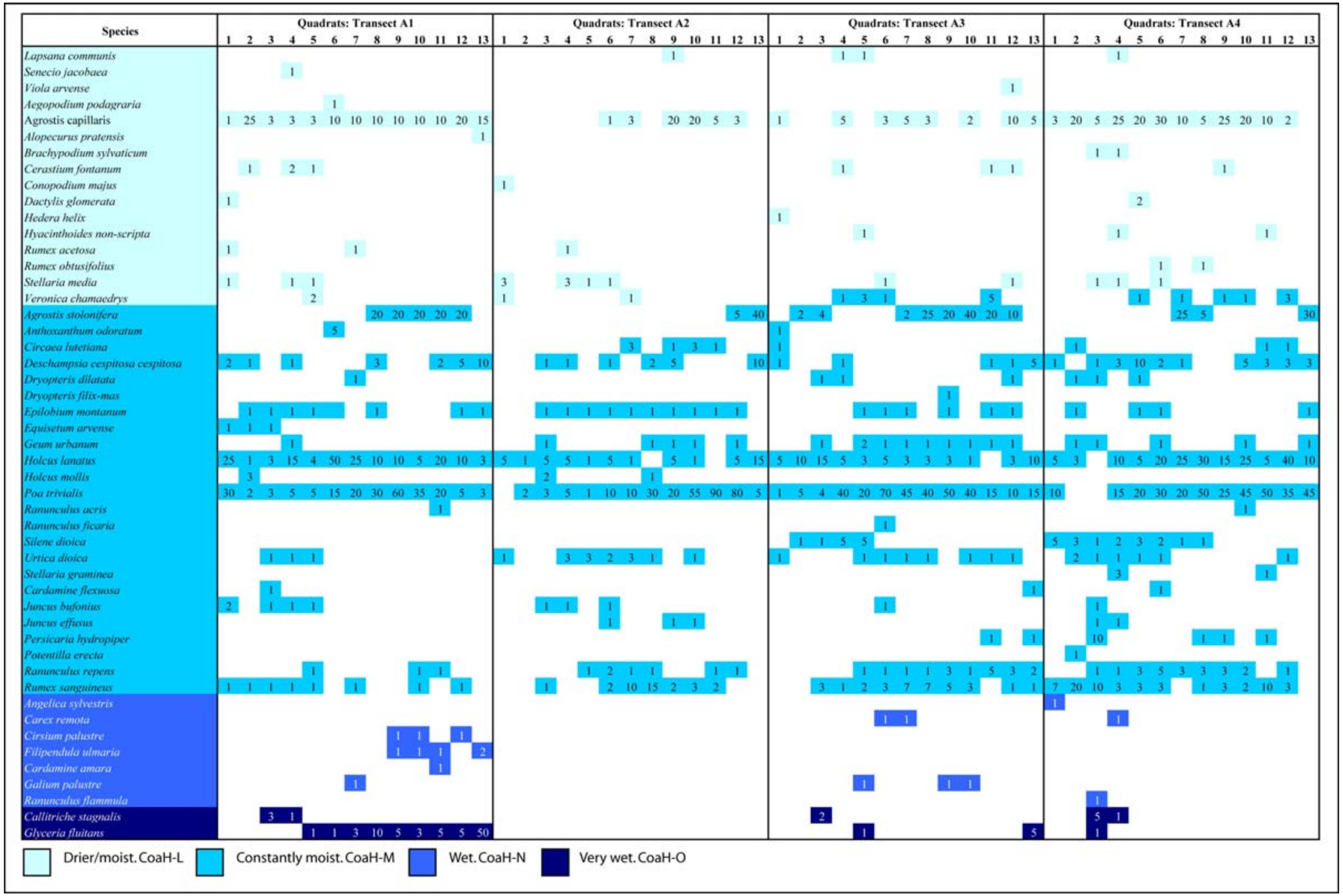

Fig. A15.2 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

Fig. A15.3 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to CoaH –Acidity (summer 2008 data)

Species	Quadrats: Transect A1													Quadrats: Transect A2												
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13
Potentilla erecta																										
Anthoxanthum odoratum						5																				
Holcus mollis		3														2					1					
Ranunculus flammula																										
Agrostis capillaris	1	25	3	3	3	10	10	10	10	10	10	20	15						1	3		20	20	5	3	
Cerastium fontanum		1		2	1																					
Cirsium palustre									1	1		1														
Deschampsia cespitosa cespitosa	2	1		1				3			2	5	10			1	1		1		2	5				10
Galium palustre							1																			
Juncus effusus																			1			1	1			
Ranunculus acris											1															
Rumex acetosa	1						1										1									
Senecio jacobaea				1																						
Stellaria graminea																										
Angelica sylvestris																										
Brachypodium sylvaticum																										
Conopodium majus														1												
Dryopteris dilatata							1																			
Dryopteris filix-mas																										
Filipendula ulmaria									1	1	1		2													
Holcus lanatus	25	1	3	15	4	50	25	10	10	5	20	10	3	5	1	5	5	1	5	1		5	1		5	15
Juncus bufonius	2		1	1	1											1	1		1							
Veronica chamaedrys					2									1						1						
Agrostis stolonifera								20	20	20	20	20													5	40
Callitriche stagnalis			3	1																						
Cardamine amara											1															
Cardamine flexuosa			1																							
Carex remota																										
Circaea lutetiana																				3		1	3	1		
Dactylis glomerata	1																									
Epilobium montanum		1	1	1	1			1				1	1			1	1	1	1	1	1	1	1	1	1	
Equisetum arvense	1	1	1																							
Glyceria fluitans					1	1	3	10	5	3	5	5	50													
Hedera helix																										
Hyacinthoides non-scripta																										
Persicaria hydropiper																										
Poa trivialis	30	2	3	5	5	15	20	30	60	35	20	5	3		2	3	5	1	10	10	30	20	55	90	80	5
Ranunculus ficaria																										
Viola arvense																										
Aegopodium podagraria						1																				
Alopecurus pratensis													1													
Geum urbanum				1												1					1	1	1		1	
Lapsana communis																						1				
Ranunculus repens					1					1	1							1	2	1	1			1	1	
Rumex sanguineus	1	1	1	1	1		1			1		1				1			2	10	15	2	3	2		
Silene dioica																										
Stellaria media	1			1	1									3			3	1	1							
Urtica dioica			1	1	1									1			3	3	2	3	1		1			
Rumex obtusifolius																										

Species	Quadrats: Transect A3													Quadrats: Transect A4												
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13
Potentilla erecta															1											
Anthoxanthum odoratum	1																									
Holcus mollis																										
Ranunculus flammula																1										
Agrostis capillaris	1			5		3	5	3		2		10	5	3	20	5	25	20	30	10	5	25	20	10	2	
Cerastium fontanum				1							1	1										1				
Cirsium palustre																										
Deschampsia cespitosa cespitosa	1			1							1	1	5	1		1	3	10	2	1			5	3	3	3
Galium palustre					1				1	1																
Juncus effusus																1	1									
Ranunculus acris																							1			
Rumex acetosa																										
Senecio jacobaea																										
Stellaria graminea																	3							1		
Angelica sylvestris														1												
Brachypodium sylvaticum																1	1									
Conopodium majus																										
Dryopteris dilatata			1	1								1			1	1		1								
Dryopteris filix-mas									1																	
Filipendula ulmaria																										
Holcus lanatus	5	10	15	5	3	5	3	3	3	1		3	10	5	3		10	5	20	25	30	15	25	5	40	10
Juncus bufonius						1										1										
Veronica chamaedrys				1	3	1					5							1		1		1	1		3	
Agrostis stolonifera		2	4				2	25	20	40	20	10								25	5					30
Callitriche stagnalis			2													5	1									
Cardamine amara																										
Cardamine flexuosa													1						1							
Carex remota						1	1										1									
Circaea lutetiana	1														1									1	1	
Dactylis glomerata																		2								
Epilobium montanum					1	1	1		1		1	1			1			1	1							1
Equisetum arvense																										
Glyceria fluitans					1								5			1										
Hedera helix	1																									
Hyacinthoides non-scripta					1												1							1		
Persicaria hydropiper											1		1			10					1	1		1		
Poa trivialis	1	5	4	40	20	70	45	40	50	40	15	10	15	10			15	20	30	20	50	25	45	50	35	45
Ranunculus ficaria						1																				
Viola arvense												1														
Aegopodium podagraria																										
Alopecurus pratensis																										
Geum urbanum			1		2	1	1	1	1	1	1	1			1	1			1				1			1
Lapsana communis				1	1												1									
Ranunculus repens					1	1	1	1	3	1	5	3	2			1	1	3	5	3	3	3	2		1	
Rumex sanguineus			3	1	2	3	7	7	5	3		1	1	7	20	10	3	3	3		1	3	2	10	3	
Silene dioica		1	1	5	5									5	3	1	2	3	2	1	1					
Stellaria media						1						1				1	1		1							
Urtica dioica	1				1	1	1	1		1	1	1			2	1	1	1	1						1	
Rumex obtusifolius																			1		1					

Low fertility. CoaH-R
Intermediate fertility. CoaH-S
High fertility. CoaH-T

Fig. A15.4 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

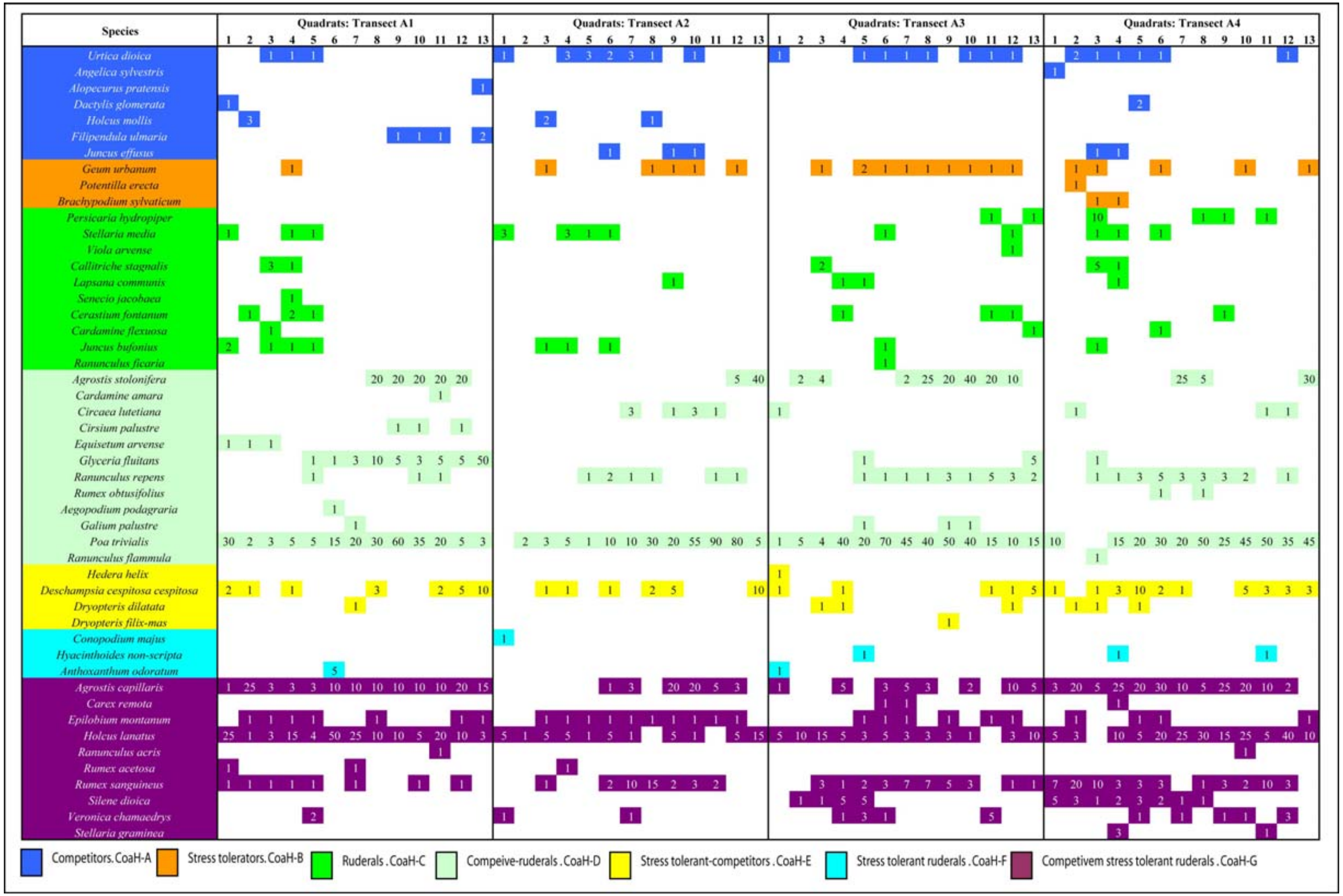

Fig. A15.5 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

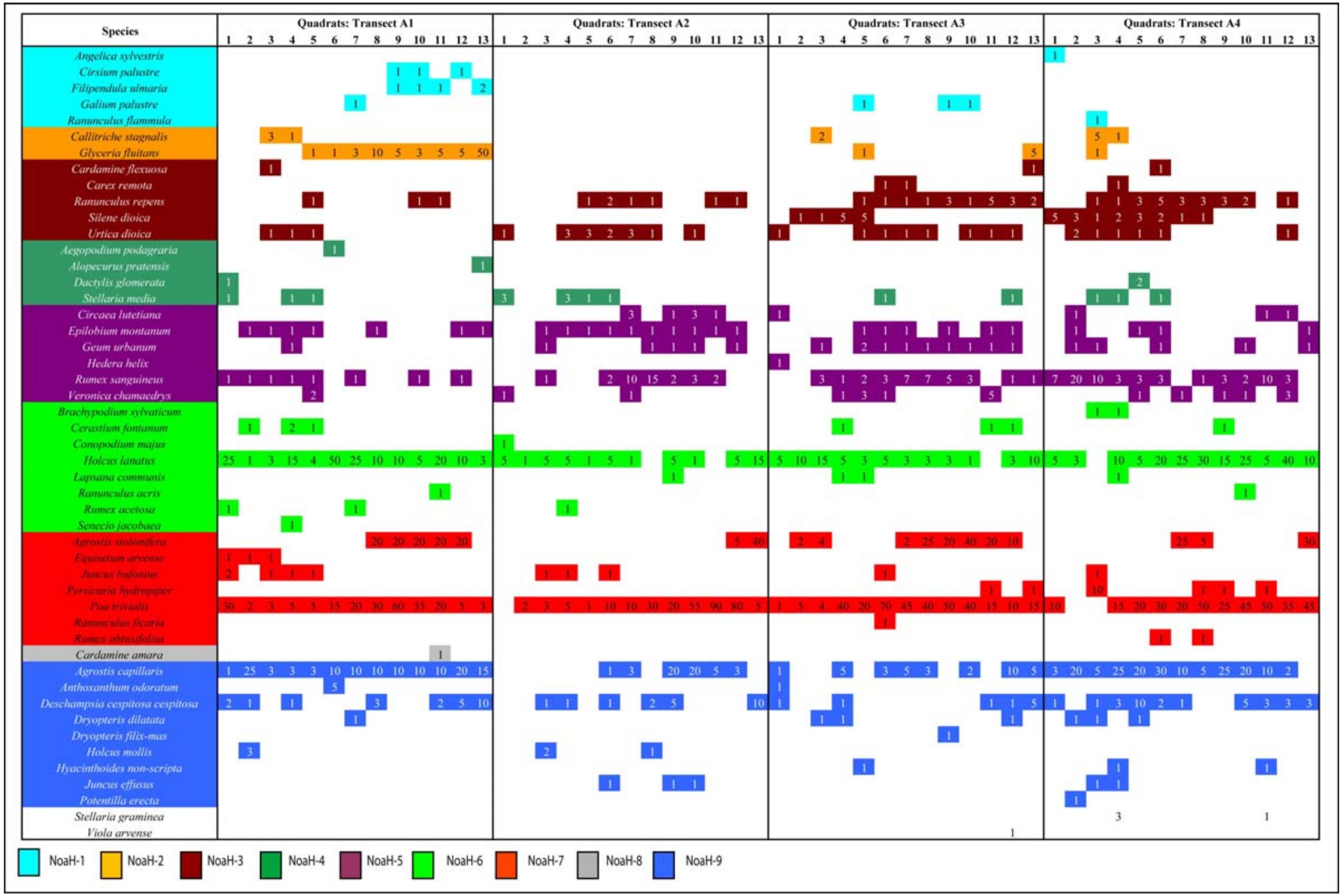

Fig. A15.6 Distribution & percentage cover of species in each quadrat along transects (1-4) in Site A *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)

Species	Quadrats: Transect C1																																						
	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
Adoxa moschatellina						2																																		
Carex remota						1	25	20	2	1									1	1	5																			
Circaea lutetiana				1					1			1		1													1	1												
Geum urbanum	1		3	5	5	25	4	1	5	5	1	1	5	5	1	1	1		3	1	3	2		1	2	25	10		10	5	1	1	2	3	3	3	3	1		1
Hedera helix																																								
Alliaria petiolata			1		1	5	1	1	4	2								3			2			3	3	3	2	1		4	2	2	3	4	3	2	1	1		
Cardamine flexuosa																																								
Dryopteris filix-mas																																								
Festuca gigantea																																								
Geranium robertianum																																								
Hyacinthoides non-scripta	1	1	1	2																																				
Rumex sanguineus								1	1			1				1			1							1				1							1			
Silene dioica	10			40	15	1	1																																	
Aegopodium podagraria																																						5	50	60
Anthriscus sylvestris																										1										1	1			1
Brachypodium sylvaticum																																								
Conopodium majus																																								
Epilobium tetragonum						1																																		
Galium aparine	4	3	3	2	1											1										1	1		1											1
Glechoma hederacea	2		3	5	4																																			
Impatiens glandulifera																1	1		1																					
Lapsana communis																																		2						
Ranunculus ficaria							1																																	
Ranunculus repens							1																								1			1						
Urtica dioica	25	25	25	5	1	1			1		2							15	5	10	10	30	40	40	10	1	25	6	40	10			2	2	1					
Veronica chamaedrys	1																																							
Angelica sylvestris																							1			1														
Arrhenatherum elatius																																								
Callitriche stagnalis																																								
Caltha palustris																																								
Filipendula ulmaria							1	1									1									1	3					1								
Heracleum sphondylium																												1	1											
Holcus lanatus																																								
Impatiens capensis																																								
Persicaria hydropiper							1																																	
Poa trivialis	2	1	3		3	5	40	20	40	75	95	95	95	95	100	70	75	25	40	60	60	30	1	1	10	25	25	2	10	10	90	95	10	40	70	95	98	95	50	10
Rumex obtusifolius							1	1	1							1																								
Senecio vulgaris																																		1						
Stellaria media	5	1	3	5	20	3		1	1																															
Taraxacum officinale																																								
Glyceria notata																																								
Ranunculus sceleratus																																								

Shade. CoaH-H   Semi-shade. CoaH-I   Well lit. CoaH-J   Very well lit. CoaH-K

Fig. A15.7a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

Species	Quadrats: Transect C2																																		
	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
Adoxa moschatellina					1																															
Carex remota								10	40	5	1	3	1		1		1	1																		
Circaea lutetiana																								2						1						
Geum urbanum	5	5	1		4	2	2	2		3										1	1	1	3	1			1	3	1	1	2	3	25	5	15	5
Hedera helix				1																																
Alliaria petiolata		1	2		2	1				2											1	1							1	1	3	1		1	1	
Cardamine flexuosa																																				
Dryopteris filix-mas																																				
Festuca gigantea		1	25	1																																
Geranium robertianum																																				
Hyacinthoides non-scripta	1	3	1	1																																
Rumex sanguineus		5	2																																	
Silene dioica	15	40	5	5	7	1			2	3																										
Aegopodium podagraria																																				
Anthriscus sylvestris																																				
Brachypodium sylvaticum	1	1																																		
Conopodium majus	1	1		1																																
Epilobium tetragonum					1																															
Galium aparine	3	1	1							1														1	1				1			1		1		
Glechoma hederacea	4	3	2		1	2																														
Impatiens glandulifera																																				
Lapsana communis																																				
Ranunculus ficaria																																				
Ranunculus repens							1	1	1																											
Urtica dioica	3	4	3	5		1		1	3	3	30	40	40	50	50	60	60	40	30	20	15	20	10	5	10	15	5	3	1						2	5
Veronica chamaedrys		1	1		1																															
Angelica sylvestris							1				1		2	1																						
Arrhenatherum elatius	5	3																																		
Callitriche stagnalis																																				
Caltha palustris									1																											
Filipendula ulmaria							1		1	1														1	1											
Heracleum sphondylium																																				
Holcus lanatus	10	3																																		
Impatiens capensis																																				
Persicaria hydropiper									1																											
Poa trivialis	15	3	1		10	50	80	60	1	5	1	1		1					5	2	3	3	10	75	25	1	3	95	60	90	20	60	15		5	15
Rumex obtusifolius	1																																			
Senecio vulgaris																																				
Stellaria media	1	1			7	1																								1						
Taraxacum officinale									1																											
Glyceria notata								1																												
Ranunculus sceleratus																																				

Shade. CoaH-H   Semi-shade. CoaH-I   Well lit. CoaH-J   Very well lit. CoaH-K

Fig. A15.7b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

Species	Quadrats: Transect C3																																				
	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
Adoxa moschatellina				1			1			1	1									1	2																
Carex remota					2	15	10	5	1	10	20	10	30	4	40	40	35	5	1	1		10	4	10	4	5	5	1			1						
Circaea lutetiana											1	1		1														1									
Geum urbanum	3	2	1	1	1	4	4	1	1	1	1	1		1	1			1		1		1	1				1	1	1				1		1	1	1
Hedera helix																																					
Alliaria petiolata							1	1		1	1	2						1	2	3			1	1		1	1	3				1	3	1	2		
Cardamine flexuosa																			1		5																
Dryopteris filix-mas		1																																			
Festuca gigantea																																					
Geranium robertianum					1																																
Hyacinthoides non-scripta																																					
Rumex sanguineus	1						1						1	1	1	1	1	1		1	1		2					1									
Silene dioica	40	2		1																1													3				
Aegopodium podagraria																																					
Anthriscus sylvestris																															1	1					
Brachypodium sylvaticum																																					
Conopodium majus																																					
Epilobium tetragonum													1	1					1										1								
Galium aparine		1	2	1	1		1	1	1	1	1					1										1	1	1			1		1	1			
Glechoma hederacea		1	2	1																																	
Impatiens glandulifera						1	3	3	1	1	1			1			1	1			1							1									
Lapsana communis																																					
Ranunculus ficaria																																					
Ranunculus repens						1		1								1	1							1													
Urtica dioica	1	25	15	40	10	15	2	4	15	15	20	40	10	3	1	5	5	3	1	3	2	2	2	5	15	10	3	3	5	7	30	30	5	1	3	3	20
Veronica chamaedrys		5		10	3																																
Angelica sylvestris				3		1	2	1	1			1							1	1		1	1	1													1
Arrhenatherum elatius																																					
Callitriche stagnalis															1																						
Caltha palustris															1																						
Filipendula ulmaria						1	1			3			2	1	1	1	2	1		1		1	1	1	1		1	1						1			
Heracleum sphondylium																																				1	1
Holcus lanatus																					1																
Impatiens capensis								2						1			1		1																		
Persicaria hydropiper													1		1	3	15		1			2															
Poa trivialis	1			1	3	3	10	1	4	3	1	5	2	2	1	2	15	10	1	5	70	30	40	40	4	2	40	1	1		1		60	95	70	90	70
Rumex obtusifolius																																					
Senecio vulgaris																																					
Stellaria media				1			1	1										1																			
Taraxacum officinale																			1																		
Glyceria notata																																					
Ranunculus sceleratus															1			1	1																		

Shade. CoaH-H   Semi-shade. CoaH-I   Well lit. CoaH-J   Very well lit. CoaH-K

Fig. A15.7c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Light (summer 2008 data)

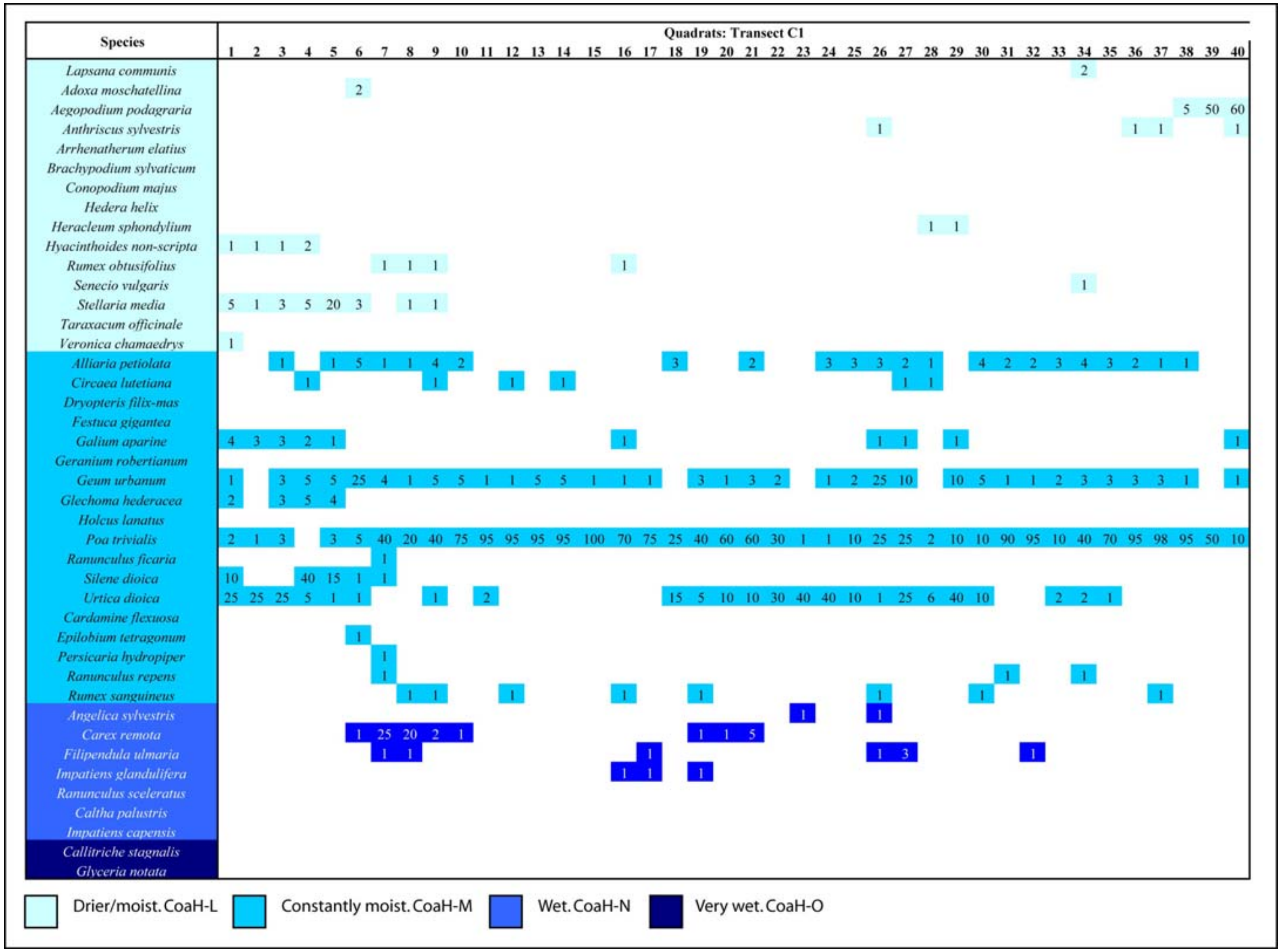

Fig. A15.8a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

Species	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
Lapsana communis																																				
Adoxa moschatellina					1																															
Aegopodium podagraria																																				
Anthriscus sylvestris																																				
Arrhenatherum elatius	5	3																																		
Brachypodium sylvaticum	1	1																																		
Conopodium majus	1	1		1																																
Hedera helix				1																																
Heracleum sphondylium																																				
Hyacinthoides non-scripta	1	3	1	1																																
Rumex obtusifolius	1																																			
Senecio vulgaris																																				
Stellaria media	1	1			7	1																								1						
Taraxacum officinale									1																											
Veronica chamaedrys		1	1		1																															
Alliaria petiolata		1	2		2	1				2											1	1							1	1	3	1		1	1	
Circaea lutetiana																								2						1						
Dryopteris filix-mas																																				
Festuca gigantea		1	25	1																																
Galium aparine	3	1	1							1														1	1				1			1		1		
Geranium robertianum																																				
Geum urbanum	5	5	1		4	2	2	2		3										1	1	1	3	1			1	3	1	1	2	3	25	5	15	5
Glechoma hederacea	4	3	2		1	2																														
Holcus lanatus	10	3																																		
Poa trivialis	15	3	1		10	50	80	60	1	5	1	1		1					5	2	3	3	10	75	25	1	3	95	60	90	20	60	15		5	15
Ranunculus ficaria																																				
Silene dioica	15	40	5	5	7	1			2	3																										
Urtica dioica	3	4	3	5		1		1	3	3	30	40	40	50	50	60	60	40	30	20	15	20	10	5	10	15	5	3	1						2	5
Cardamine flexuosa																																				
Epilobium tetragonum					1																															
Persicaria hydropiper									1																											
Ranunculus repens							1	1	1																											
Rumex sanguineus		5	2																																	
Angelica sylvestris							1				1		2	1																						
Carex remota								10	40	5	1	3	1		1		1	1																		
Filipendula ulmaria							1		1	1														1	1											
Impatiens glandulifera																																				
Ranunculus sceleratus																																				
Caltha palustris									1																											
Impatiens capensis																																				
Callitriche stagnalis																																				
Glyceria notata								1																												

Quadrats: Transect C2

Drier/moist. CoaH-L | Constantly moist. CoaH-M | Wet. CoaH-N | Very wet. CoaH-O

Fig. A15.8b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

Species	Quadrats: Transect C3																																			
	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
Lapsana communis																																					
Adoxa moschatellina				1			1			1	1									1	2																
Aegopodium podagraria																																					
Anthriscus sylvestris																															1	1					
Arrhenatherum elatius																																					
Brachypodium sylvaticum																																					
Conopodium majus																																					
Hedera helix																																					
Heracleum sphondylium																																				1	1
Hyacinthoides non-scripta																																					
Rumex obtusifolius																																					
Senecio vulgaris																																					
Stellaria media				1			1	1										1																			
Taraxacum officinale																			1																		
Veronica chamaedrys		5		10	3																																
Alliaria petiolata							1	1		1	1	2						1	2	3			1	1		1	1	3				1	3	1	2		
Circaea lutetiana											1	1		1														1									
Dryopteris filix-mas		1																																			
Festuca gigantea																																					
Galium aparine		1	2	1	1		1	1	1	1	1					1										1	1	1			1		1	1			
Geranium robertianum					1																																
Geum urbanum	3	2	1	1	1	4	4	1	1	1	1	1		1	1			1		1		1	1				1	1	1				1		1	1	1
Glechoma hederacea		1	2	1																																	
Holcus lanatus																					1																
Poa trivialis	1			1	3	3	10	1	4	3	1	5	2	2	1	2	15	10	1	5	70	30	40	40	4	2	40	1	1		1		60	95	70	90	70
Ranunculus ficaria																																					
Silene dioica	40	2		1																1													3				
Urtica dioica	1	25	15	40	10	15	2	4	15	15	20	40	10	3	1	5	5	3	1	3	2	2	2	5	15	10	3	3	5	7	30	30	5	1	3	3	20
Cardamine flexuosa																			1		5																
Epilobium tetragonum													1	1					1										1								
Persicaria hydropiper													1		1	3	15		1			2															
Ranunculus repens						1		1								1	1							1													
Rumex sanguineus	1						1						1	1	1	1	1	1		1	1		2					1									
Angelica sylvestris				3		1	2	1	1			1							1	1		1	1	1													1
Carex remota					2	15	10	5	1	10	20	10	30	4	40	40	35	5	1	1		10	4	10	4	5	5	1			1						
Filipendula ulmaria						1	1			3			2	1	1	1	2	1		1		1	1	1	1		1	1						1			
Impatiens glandulifera						1	3	3	1	1	1			1			1	1			1							1									
Ranunculus sceleratus															1			1	1																		
Caltha palustris															1																						
Impatiens capensis								2						1			1		1																		
Callitriche stagnalis															1																						
Glyceria notata																																					

Drier/moist. CoaH-L · Constantly moist. CoaH-M · Wet. CoaH-N · Very wet. CoaH-O

Fig. A15.8c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Moisture (summer 2008 data)

Species	Quadrats: Transect C1																																							
	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
Conopodium majus																																								
Dryopteris filix-mas																																								
Epilobium tetragonum						1																																		
Hyacinthoides non-scripta	1	1	1	2																																				
Adoxa moschatellina						2																																		
Aegopodium podagraria																																						5	50	60
Angelica sylvestris																							1			1														
Brachypodium sylvaticum																																								
Callitriche stagnalis																																								
Caltha palustris																																								
Cardamine flexuosa																																								
Carex remota						1	25	20	2	1									1	1	5																			
Filipendula ulmaria							1	1									1									1	3					1								
Geranium robertianum																																								
Holcus lanatus																																								
Persicaria hydropiper							1																																	
Poa trivialis	2	1	3		3	5	40	20	40	75	95	95	95	95	100	70	75	25	40	60	60	30	1	1	10	25	25	2	10	10	90	95	10	40	70	95	98	95	50	10
Ranunculus ficaria							1																																	
Ranunculus repens							1																								1			1						
Silene dioica	10			40	15	1	1																																	
Stellaria media	5	1	3	5	20	3		1	1																															
Veronica chamaedrys	1																																							
Glyceria notata??																																								
Alliaria petiolata			1		1	5	1	1	4	2								3			2			3	3	3	2	1		4	2	2	3	4	3	2	1	1		
Anthriscus sylvestris																										1										1	1			1
Arrhenatherum elatius																																								
Circaea lutetiana				1					1			1		1													1	1												
Festuca gigantea																																								
Galium aparine	4	3	3	2	1											1										1	1		1											1
Geum urbanum	1		3	5	5	25	4	1	5	5	1	1	5	5	1	1	1		3	1	3	2		1	2	25	10		10	5	1	1	2	3	3	3	3	1		1
Glechoma hederacea	2		3	5	4																																			
Hedera helix																																								
Heracleum sphondylium																												1	1											
Impatiens capensis																																								
Impatiens glandulifera																1	1		1																					
Lapsana communis																																		2						
Rumex obtusifolius							1	1	1							1																								
Rumex sanguineus								1	1			1				1			1							1				1							1			
Senecio vulgaris																																		1						
Taraxacum officinale																																								
Urtica dioica	25	25	25	5	1	1			1		2							15	5	10	10	30	40	40	10	1	25	6	40	10			2	2	1					
Ranunculus sceleratus																																								

Acidic. CoaH-P

Near neutral. CoaH-Q

Fig. A15.9a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH –Acidity (summer 2008 data)

Species	Group	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
Conopodium majus	Acidic. CoaH-P	1	1		1																																
Dryopteris filix-mas	Acidic. CoaH-P																																				
Epilobium tetragonum	Acidic. CoaH-P					1																															
Hyacinthoides non-scripta	Acidic. CoaH-P	1	3	1	1																																
Adoxa moschatellina	Near neutral. CoaH-Q					1																															
Aegopodium podagraria	Near neutral. CoaH-Q																																				
Angelica sylvestris	Near neutral. CoaH-Q							1				1		2	1																						
Brachypodium sylvaticum	Near neutral. CoaH-Q	1	1																																		
Callitriche stagnalis	Near neutral. CoaH-Q																																				
Caltha palustris	Near neutral. CoaH-Q									1																											
Cardamine flexuosa	Near neutral. CoaH-Q																																				
Carex remota	Near neutral. CoaH-Q								10	40	5	1	3	1		1		1	1																		
Filipendula ulmaria	Near neutral. CoaH-Q							1		1	1														1	1											
Geranium robertianum	Near neutral. CoaH-Q																																				
Holcus lanatus	Near neutral. CoaH-Q	10	3																																		
Persicaria hydropiper	Near neutral. CoaH-Q									1																											
Poa trivialis	Near neutral. CoaH-Q	15	3	1		10	50	80	60	1	5	1	1		1					5	2	3	3	10	75	25	1	3	95	60	90	20	60	15		5	15
Ranunculus ficaria	Near neutral. CoaH-Q																																				
Ranunculus repens	Near neutral. CoaH-Q							1	1	1																											
Silene dioica	Near neutral. CoaH-Q	15	40	5	5	7	1			2	3																										
Stellaria media	Near neutral. CoaH-Q	1	1			7	1																								1						
Veronica chamaedrys	Near neutral. CoaH-Q		1	1		1																															
Glyceria notata??	Near neutral. CoaH-Q								1																												
Alliaria petiolata	Near neutral. CoaH-Q		1	2		2	1				2											1	1							1	1	3	1		1	1	
Anthriscus sylvestris	Near neutral. CoaH-Q																																				
Arrhenatherum elatius	Near neutral. CoaH-Q	5	3																																		
Circaea lutetiana	Near neutral. CoaH-Q																								2						1						
Festuca gigantea	Near neutral. CoaH-Q		1	25	1																																
Galium aparine	Near neutral. CoaH-Q	3	1	1							1														1	1				1			1		1		
Geum urbanum	Near neutral. CoaH-Q	5	5	1		4	2	2	2		3										1	1	1	3	1			1	3	1	1	2	3	25	5	15	5
Glechoma hederacea	Near neutral. CoaH-Q	4	3	2		1	2																														
Hedera helix	Near neutral. CoaH-Q				1																																
Heracleum sphondylium	Near neutral. CoaH-Q																																				
Impatiens capensis	Near neutral. CoaH-Q																																				
Impatiens glandulifera	Near neutral. CoaH-Q																																				
Lapsana communis	Near neutral. CoaH-Q																																				
Rumex obtusifolius	Near neutral. CoaH-Q	1																																			
Rumex sanguineus	Near neutral. CoaH-Q		5	2																																	
Senecio vulgaris	Near neutral. CoaH-Q																																				
Taraxacum officinale	Near neutral. CoaH-Q									1																											
Urtica dioica	Near neutral. CoaH-Q	3	4	3	5		1		1	3	3	30	40	40	50	50	60	60	40	30	20	15	20	10	5	10	15	5	3	1						2	5
Ranunculus sceleratus	Near neutral. CoaH-Q																																				

Quadrats: Transect C2

Acidic. CoaH-P
Near neutral. CoaH-Q

Fig. A15.9b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH –Acidity (summer 2008 data)

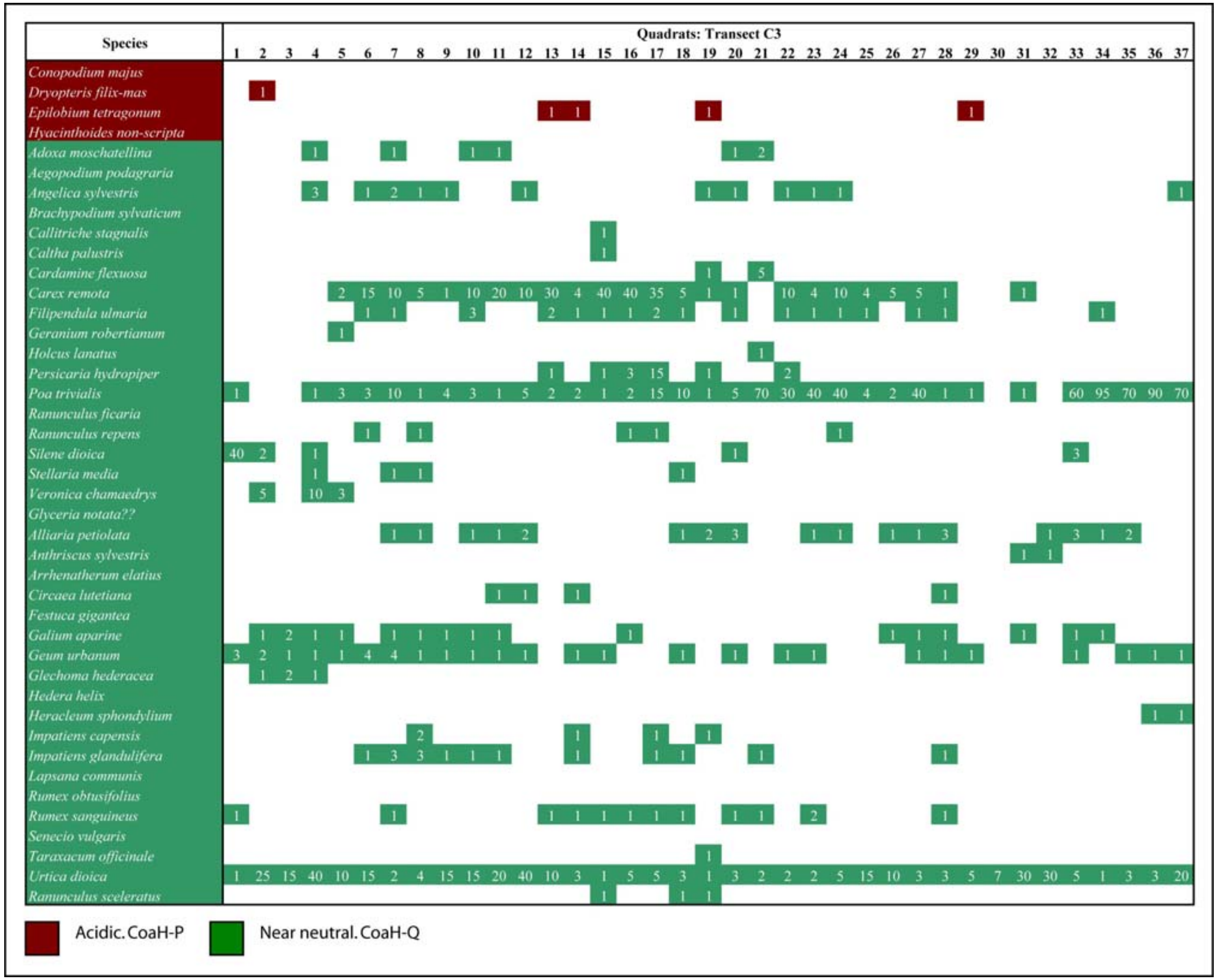

Fig. A15.9c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH –Acidity (summer 2008 data)

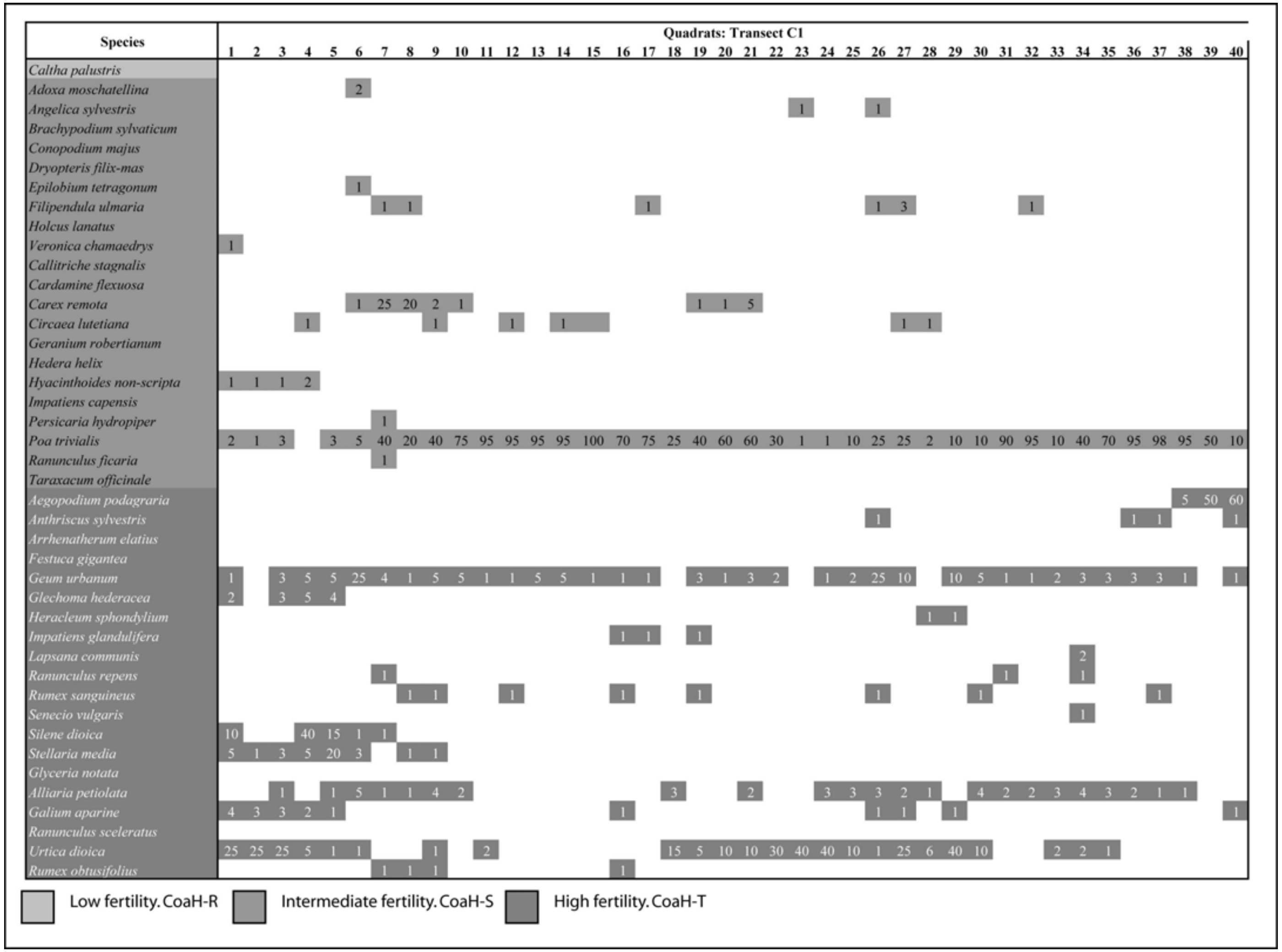

Fig. A15.10a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

Species	Quadrats: Transect C2																																			
	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
Caltha palustris									1																											
Adoxa moschatellina					1																															
Angelica sylvestris							1				1		2	1																						
Brachypodium sylvaticum	1	1																																		
Conopodium majus	1	1		1																																
Dryopteris filix-mas																																				
Epilobium tetragonum					1																															
Filipendula ulmaria							1		1	1														1	1											
Holcus lanatus	10	3																																		
Veronica chamaedrys		1	1		1																															
Callitriche stagnalis																																				
Cardamine flexuosa																																				
Carex remota								10	40	5	1	3	1		1		1	1																		
Circaea lutetiana																								2						1						
Geranium robertianum																																				
Hedera helix				1																																
Hyacinthoides non-scripta	1	3	1	1																																
Impatiens capensis																																				
Persicaria hydropiper									1																											
Poa trivialis	15	3	1		10	50	80	60	1	5	1	1		1					5	2	3	3	10	75	25	1	3	95	60	90	20	60	15		5	15
Ranunculus ficaria																																				
Taraxacum officinale									1																											
Aegopodium podagraria																																				
Anthriscus sylvestris																																				
Arrhenatherum elatius	5	3																																		
Festuca gigantea		1	25	1																																
Geum urbanum	5	5	1		4	2	2	2		3										1	1	1	3	1			1	3	1	1	2	3	25	5	15	5
Glechoma hederacea	4	3	2		1	2																														
Heracleum sphondylium																																				
Impatiens glandulifera																																				
Lapsana communis																																				
Ranunculus repens							1	1	1																											
Rumex sanguineus		5	2																																	
Senecio vulgaris																																				
Silene dioica	15	40	5	5	7	1			2	3																										
Stellaria media	1	1			7	1																								1						
Glyceria notata								1																												
Alliaria petiolata		1	2		2	1				2											1	1							1	1	3	1		1	1	
Galium aparine	3	1	1							1														1	1				1			1		1		
Ranunculus sceleratus																																				
Urtica dioica	3	4	3	5		1		1	3	3	30	40	40	50	50	60	60	40	30	20	15	20	10	5	10	15	5	3	1						2	5
Rumex obtusifolius	1																																			

Low fertility. CoaH-R — Intermediate fertility. CoaH-S — High fertility. CoaH-T

Fig. A15.10b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

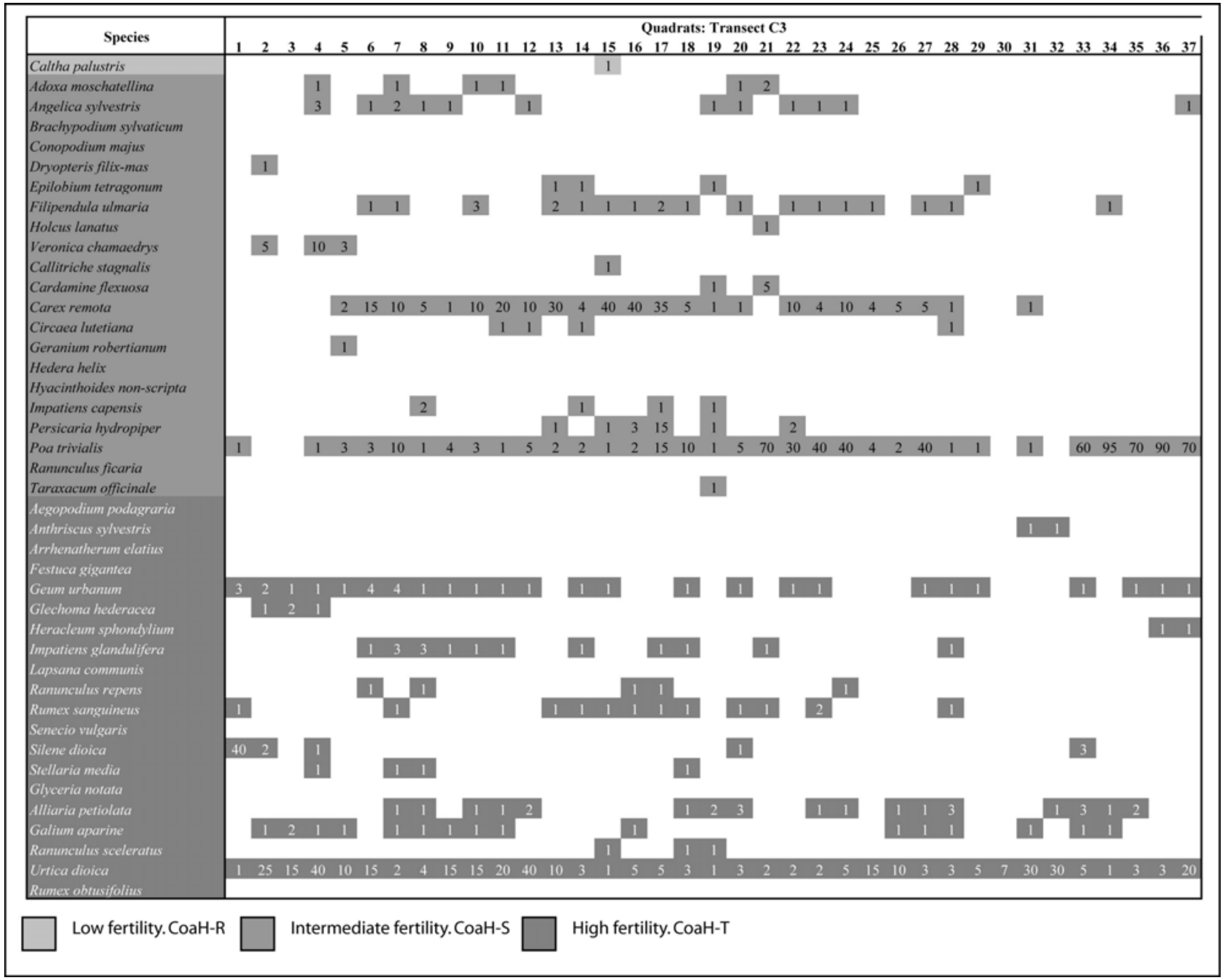

Fig. A15.10c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-Fertility (summer 2008 data)

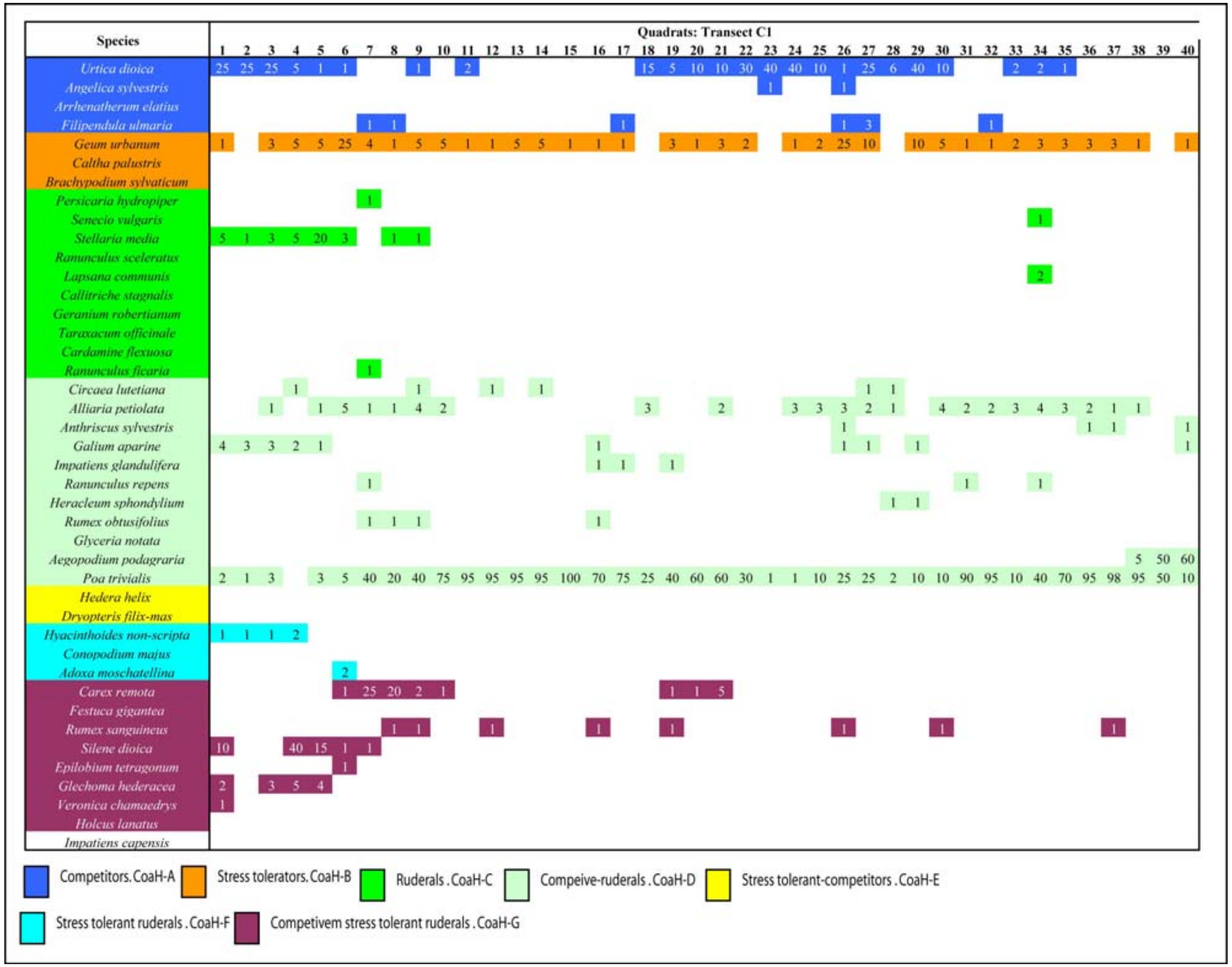

Fig. A15.11a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

Species	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
Urtica dioica	3	4	3	5		1		1	3	3	30	40	40	50	50	60	60	40	30	20	15	20	10	5	10	15	5	3	1						2	5
Angelica sylvestris							1				1		2	1																						
Arrhenatherum elatius	5	3																																		
Filipendula ulmaria							1		1	1														1	1											
Geum urbanum	5	5	1		4	2	2	2		3										1	1	1	3	1			1	3	1	1	2	3	25	5	15	5
Caltha palustris									1																											
Brachypodium sylvaticum	1	1																																		
Persicaria hydropiper									1																											
Senecio vulgaris																																				
Stellaria media	1	1			7	1																								1						
Ranunculus sceleratus																																				
Lapsana communis																																				
Callitriche stagnalis																																				
Geranium robertianum																																				
Taraxacum officinale									1																											
Cardamine flexuosa																																				
Ranunculus ficaria																																				
Circaea lutetiana																								2						1						
Alliaria petiolata		1	2		2	1				2											1	1							1	1	3	1		1	1	
Anthriscus sylvestris																																				
Galium aparine	3	1	1							1														1	1				1			1		1		
Impatiens glandulifera																																				
Ranunculus repens							1	1	1																											
Heracleum sphondylium																																				
Rumex obtusifolius	1																																			
Glyceria notata								1																												
Aegopodium podagraria																																				
Poa trivialis	15	3	1		10	50	80	60	1	5	1	1		1					5	2	3	3	10	75	25	1	3	95	60	90	20	60	15		5	15
Hedera helix				1																																
Dryopteris filix-mas																																				
Hyacinthoides non-scripta	1	3	1	1																																
Conopodium majus	1	1		1																																
Adoxa moschatellina					1																															
Carex remota								10	40	5	1	3	1		1		1	1																		
Festuca gigantea		1	25	1																																
Rumex sanguineus		5	2																																	
Silene dioica	15	40	5	5	7	1			2	3																										
Epilobium tetragonum					1																															
Glechoma hederacea	4	3	2		1	2																														
Veronica chamaedrys		1	1		1																															
Holcus lanatus	10	3																																		
Impatiens capensis																																				

Quadrats: Transect C2

Competitors. CoaH-A; Stress tolerators. CoaH-B; Ruderals . CoaH-C; Compeive-ruderals . CoaH-D; Stress tolerant-competitors . CoaH-E; Stress tolerant ruderals . CoaH-F; Competivem stress tolerant ruderals . CoaH-G

Fig. A15.11b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

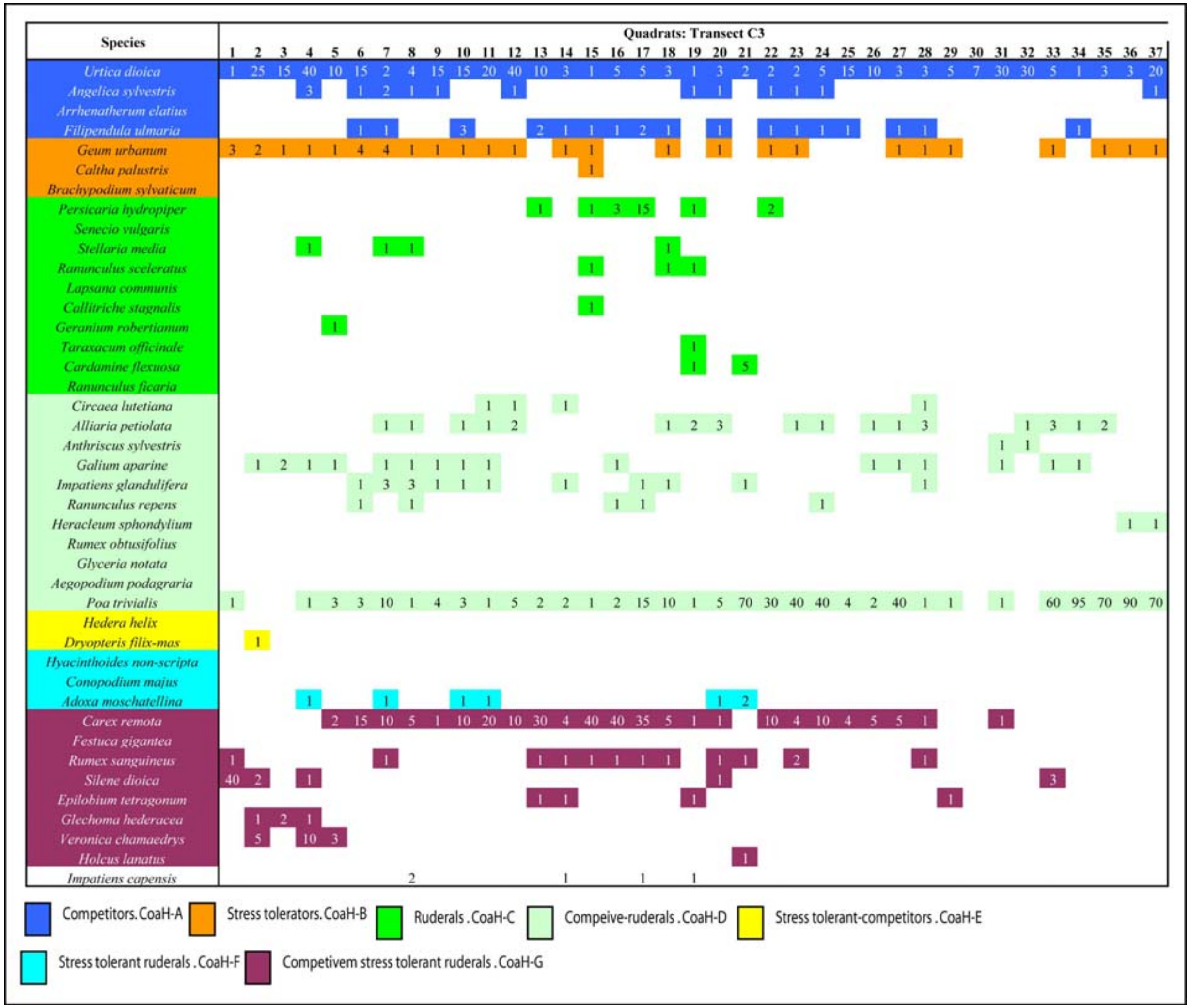

Fig. A15.11c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to CoaH-CSR (summer 2008 data)

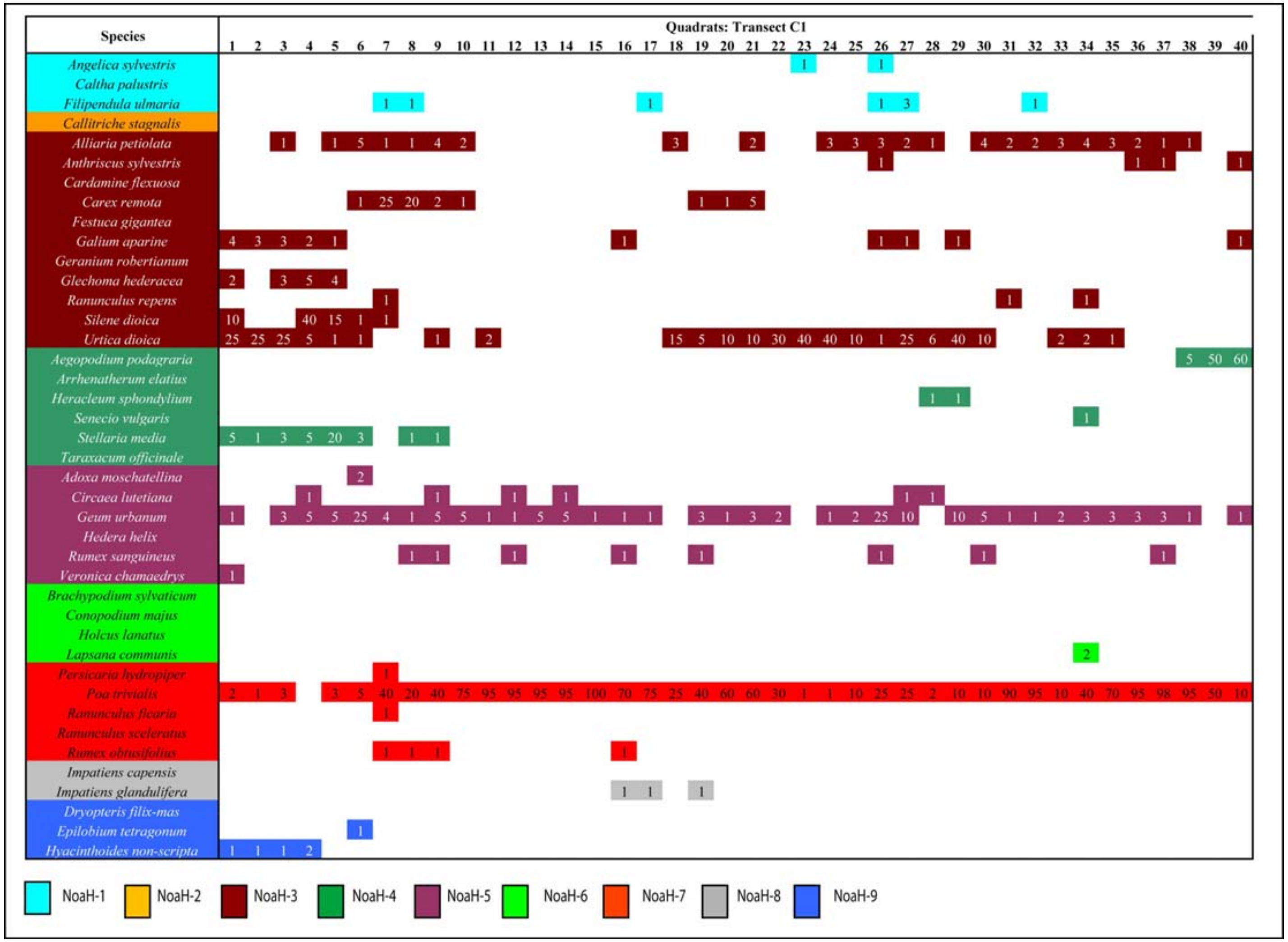

Fig. A15.12a Distribution & percentage cover of species in each quadrat along transects (1) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)

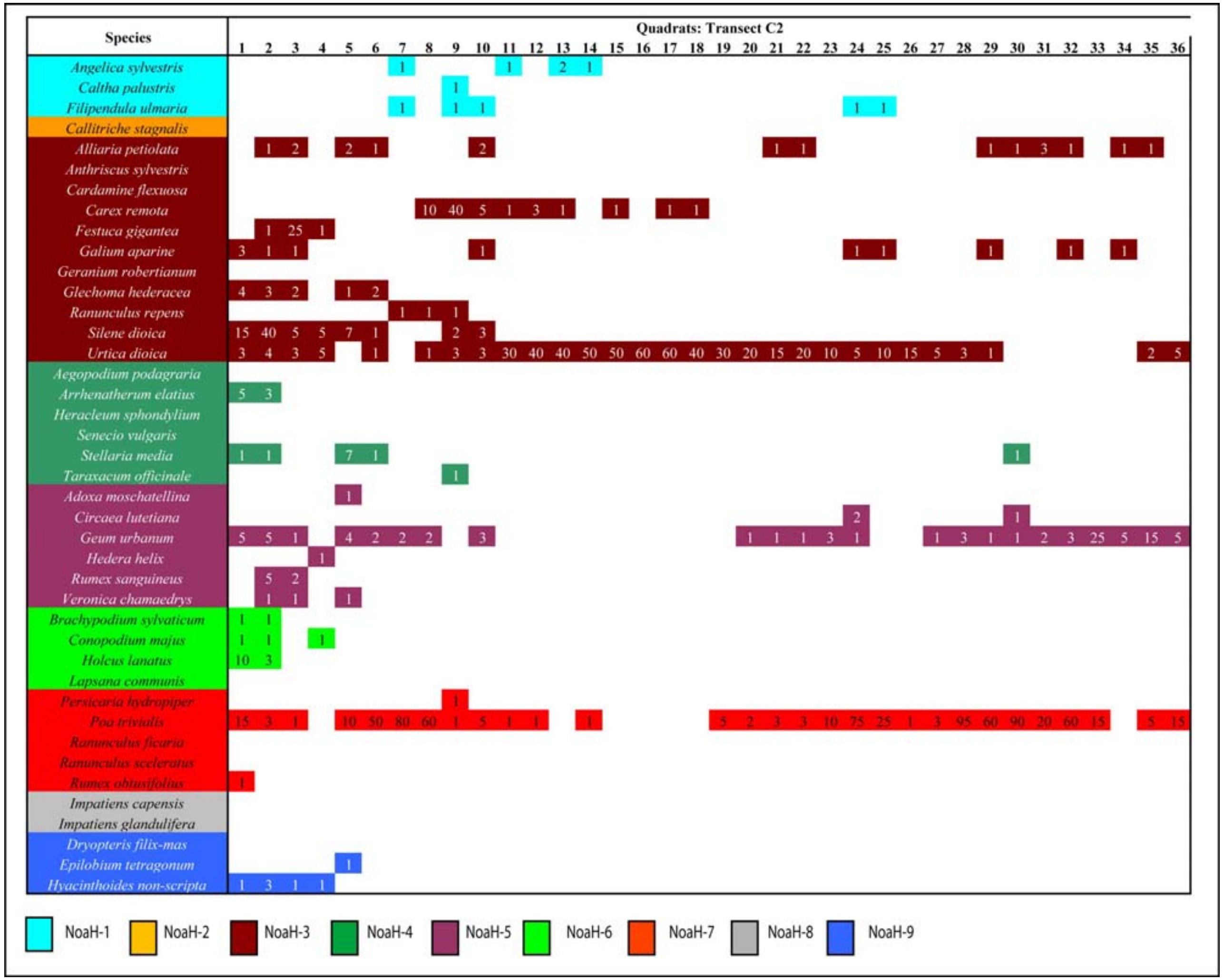

Fig. A15.12b Distribution & percentage cover of species in each quadrat along transects (2) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)

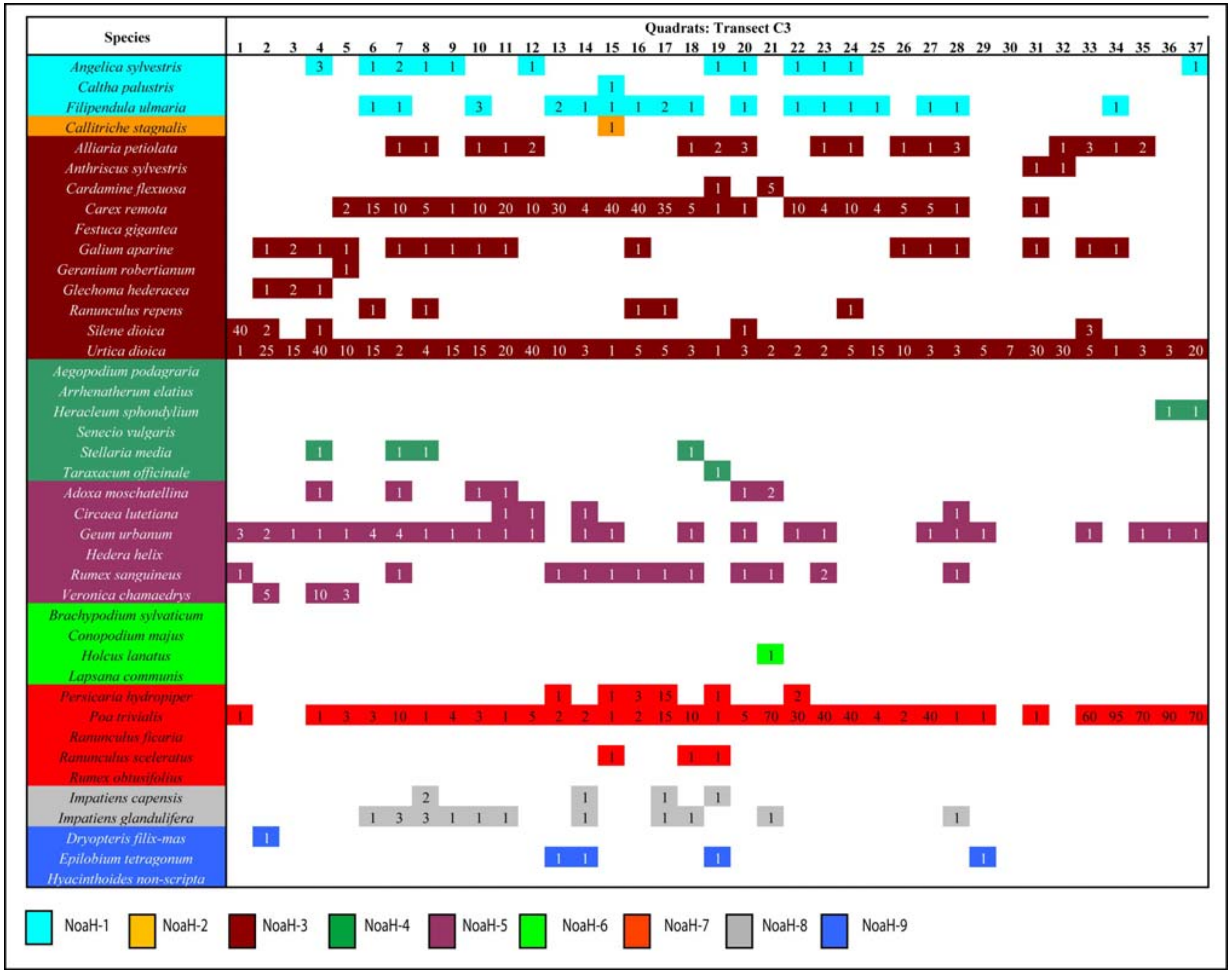

Fig. A15.12c Distribution & percentage cover of species in each quadrat along transects (3) in Site C *Alnus glutinosa* woodland at Stonebridge in relation to NoaHs (summer 2008 data)