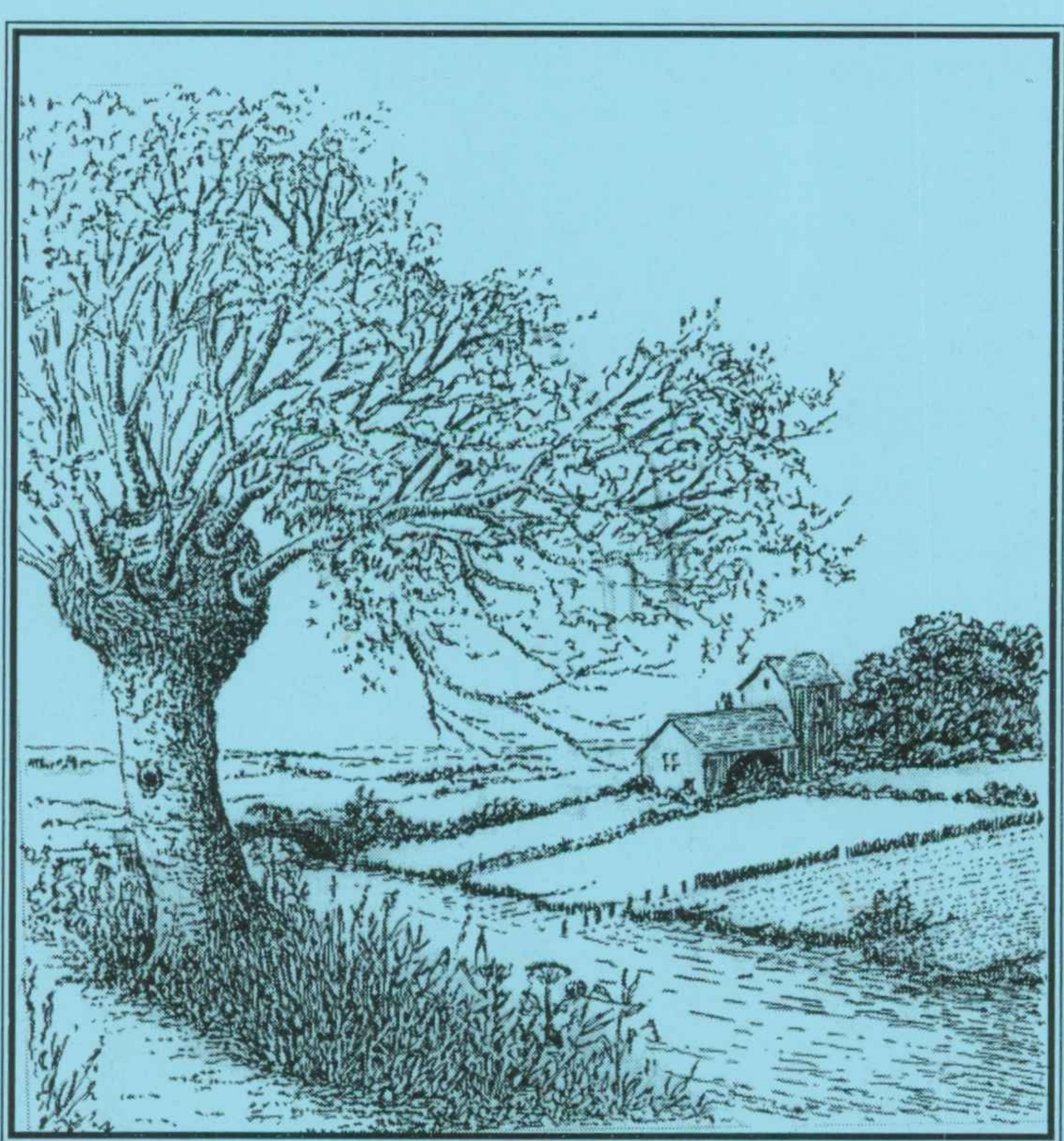
Department of the Environment



Current status and prospects for threatened habitats in England

Part 5

Waterside landscapes

ITE/ERM/UCPE contract report
to the
Department of the Environment

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CONTRACT

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EXECUTIVE SUMMARY

Survey

1. In 1992, the Department of the Environment commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme, of which rivers and watersides was one. The general aim of the project was to build on the work of the Countryside Survey 1990 and examine in more detail the distribution and quality of these habitats within the landscape types in England. This examination forms a basis against which future ecological changes, resulting from changing policies or specific initiatives, may be compared and measured.

2. The first step was to define the current geographical extent, and potential future extent, of the waterside landscape type. The broad geographical extent of the existing and potential areas was determined by soil type characteristics (acid, sand or peat soils) and altitude. The 150 m waterside zone within these 1 km squares was called the 'waterside mask'.

3. The next step was to characterise the waterside mask in terms of ecology and landscape features. The 1 km squares were stratified according to the ITE Land Classification groups (arable, pastural and upland) and designation status (designated or non-designated). Data for the squares in these six strata were taken from the CS1990 database, and land cover, vegetation in quadrats and landscape features were recorded.

Current status

4. The waterside mask comprised a range of land cover types, from built and recreational land, through agricultural crops and improved grassland, to 'core' wetland vegetation types. Only 3% of the mask was covered by core waterside vegetation types, and 57% contained one or more designation type. There was a slightly higher occurrence of the core vegetation types in the non-designated strata, and a higher proportion in the upland strata.

5. In addition to the core wetland vegetation, 24% of the mask comprised other semi-natural vegetation, such as unmanaged grassland, moorland grass, heath and woodland.

	Area (ha)
Core wetland vegetation types	46 600
Other semi-natural vegetation types	428 900
Wetland heath mask (total)	1 773 000

6. Objective measures of vegetation (recorded in quadrats) have been related to quality criteria, to provide an empirical evaluation of the quality of waterside vegetation in different parts of the waterside landscape. Using at least two separate measures of each of the quality criteria, the six survey strata were ranked. The pastural strata had the highest scores, followed by the arable and then upland landscapes. Although there were inconsistencies within the strata, the non-designated strata consistently had more high-ranking vegetation quality criteria than their designated equivalents.

7. It was recognised that, without time-series data, it was difficult to assess the effect of designation. It was not known, for example, whether correlations between 'good' areas of waterside habitat and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the waterside vegetation. However, this study provides for the first time an essential baseline, necessary to conduct future monitoring of the effectiveness of designations.

Threats

8. The key threats to waterside habitats were identified as being the management of watercourses themselves, land uses on river banks and, most importantly, the management of the wider catchment area (especially in relation to agriculture and forestry). Other major threats are associated with hydroelectric schemes (especially in the uplands), gravel extraction and new road building.

9. In the future, *climate change* is expected to be a major factor, leading to temperature and water level rise and changes in rainfall and drought.

10. Airborne pollution is not considered to have a wide impact on waterside habitats overall.

Prospects

11. To consider what vegetation changes may take place under different scenarios of perceived threats, the study has made use of the 'Competitors: Stress-tolerators: Ruderals' (C–S–R) classification of functional types, and the TRISTAR2 model which predicts vegetation change in response to environmental and/or management change scenarios.

12. Most of the core waterside vegetation was composed of competitor and competitor/ ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types

13. The TRISTAR2 model calculated the predicted change in abundance of the functional types under each of the six specimen change scenarios, and an index of vulnerability was produced. The waterside mask includes a heterogeneous grouping of wetlands, grassland and tall herb vegetation, and woodlands. The vulnerability of all habitat groupings to the change scenarios was low, with only one plot class reaching even moderate vulnerability. Vulnerability of different habitat types differed only slightly according to scenario.

14. Watersides comprise a potentially valuable landscape, but are currently dominated by managed and developed land use types. The survey results indicate that the core waterside vegetation amounts to only about 466 km^2 (<3% of the mask) and most of the rest is unmanaged grassland.

15. Working from existing knowledge and planning initiatives for waterside areas as a starting point, it would appear feasible to establish the following objectives:
    - to protect existing waterside landscapes of high value by maintaining traditional water levels and meadow management practices (eg ditch and dyke systems);
    - to restore or enhance diversity across a wider area by reinstating landscape infrastructure (planting willows, creating ponds and meanders, etc);
    - to re-create lost fens, carrs and reedbeds on selected areas of arable land, and restore a few selected rivers by removing hard engineering features and drainage systems.

16. Nature conservation designation and a number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. However, survey results suggest that the remaining areas of semi-natural habitat are limited and fragmented, and that the habitats in the designated areas are of lower quality than in the non-designated parts of the mask. If further work indicates that the above objectives are justifiable, then opportunities do exist for improvement of habitat, especially through river corridor and catchment planning initiatives.

17. To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches continue to be identified and publicised.

Chapter 1 INTRODUCTION: PURPOSE AND CONTEXT OF THE REPORT

1.1 Policy background

1.1.1 Despite much concern over the loss of semi-natural habitats in recent decades, there are inadequate levels of information as to the location and status of some rare and important habitats on a national scale. This information is becoming available through thematic and local surveys and is essential if assessments are to be made of the likely impacts of changing policies (eg Common Agricultural Policy, Habitats Directive, Biodiversity Action Plan) or of current incentive schemes (eg Countryside Stewardship) on the distribution and quality of these habitats.

1.1.2 To add to knowledge and understanding in these areas, the Department of Environment (DOE) commissioned a research project to investigate the threatened habitats occurring within the landscape types included in the original Countryside Stewardship Scheme. These are:

i. lowland heath landscapes
ii. chalk and limestone grasslands landscapes
iii. upland landscapes
iv. coastal landscapes
v. river valleys and waterside landscapes

1.1.3 These landscape types, together with their constituent habitats (see Box 1), are seen as areas which have suffered serious losses and degradation of habitats in the past and appear to be still under threat. They are perceived as having great value for wildlife, landscape, history and amenity/public enjoyment.

1.1.4 The general aim of the project was to build on the work of the Countryside Survey 1990 and examine in more detail the distribution and quality of threatened habitats within the landscape types in England. This examination forms a basis against which future scenarios of change, resulting from changing policies or specific initiatives, may be measured and compared. The project has also attempted to develop a methodology for measuring change at the national level; it reviews current policy instruments affecting threatened habitats and considers prospects for the future.

1.2 Research context

1.2.1 Countryside Survey 1990 (CS1990), a project carried out by ITE, jointly funded by NERC, DOE and the former Nature Conservancy Council, was developed from earlier surveys of GB and included field surveys of land cover, landscape features and vegetation quadrats. It also included soil surveys of all sample squares and was linked to a project mapping the land cover of GB using satellite imagery (Barr *et al.* 1993).

1.2.2 For the Countryside Survey 1990 fieldwork, a standard sample unit of 1 km x 1 km square has been used. Squares visited in the earlier surveys (1978 and 1984) were surveyed in 1990 and an additional 124 squares were added to the sample, giving a total of 508 squares.

1.2.3 Although the 1978, 1984 and 1990 Countryside Surveys provide comparatively

Box 1.1

In the context of this project, the waterside **landscape type** is a conceptual term for geographical area(s) in which water features (such as rivers and lakes) occur or have occurred, historically, and includes other land cover types (eg farmland) which form mosaics with waterside habitats. The **mask** is a cartographic term which, in this project, is a map which includes both the waterside landscape type and areas which have the potential to be included in the landscape type. Individual **habitats**, such as fens, reedbeds, inundated grassland, occur within the landscape type.

up-to-date information on general changes in the British countryside, the sample-based system was not designed to yield data on rarer, or localised, habitats. Thus, there was a need for information about these habitats which are perceived to be under threat, or which represent areas of concern to the Department. This Report describes work undertaken on the waterside landscape type.

1.3 Objectives

1.3.1 The objectives for each landscape type were to:

i. determine the distribution of the landscape type in England;
ii. survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type;
iii determine, on a regional basis and in relation to current designations, the composition of each landscape type in terms of the quantity and quality of the surveyed features;
iv. develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats;
v. in the light of the above, make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish the habitats which characterise each landscape type; and
vi. establish a baseline and develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies, at a national (England) scale.

1.4 General approach

1.4.1 To meet the objectives of this project, a consortium was assembled which brought together the ecological and modelling knowledge and skills ITE and the NERC Unit of Comparative Plant Ecology (UCPE) with the policy-related expertise of Environmental Resources Management (ERM).

1.4.2 The general approach used by the research team can be summarised in Figure 1.1.

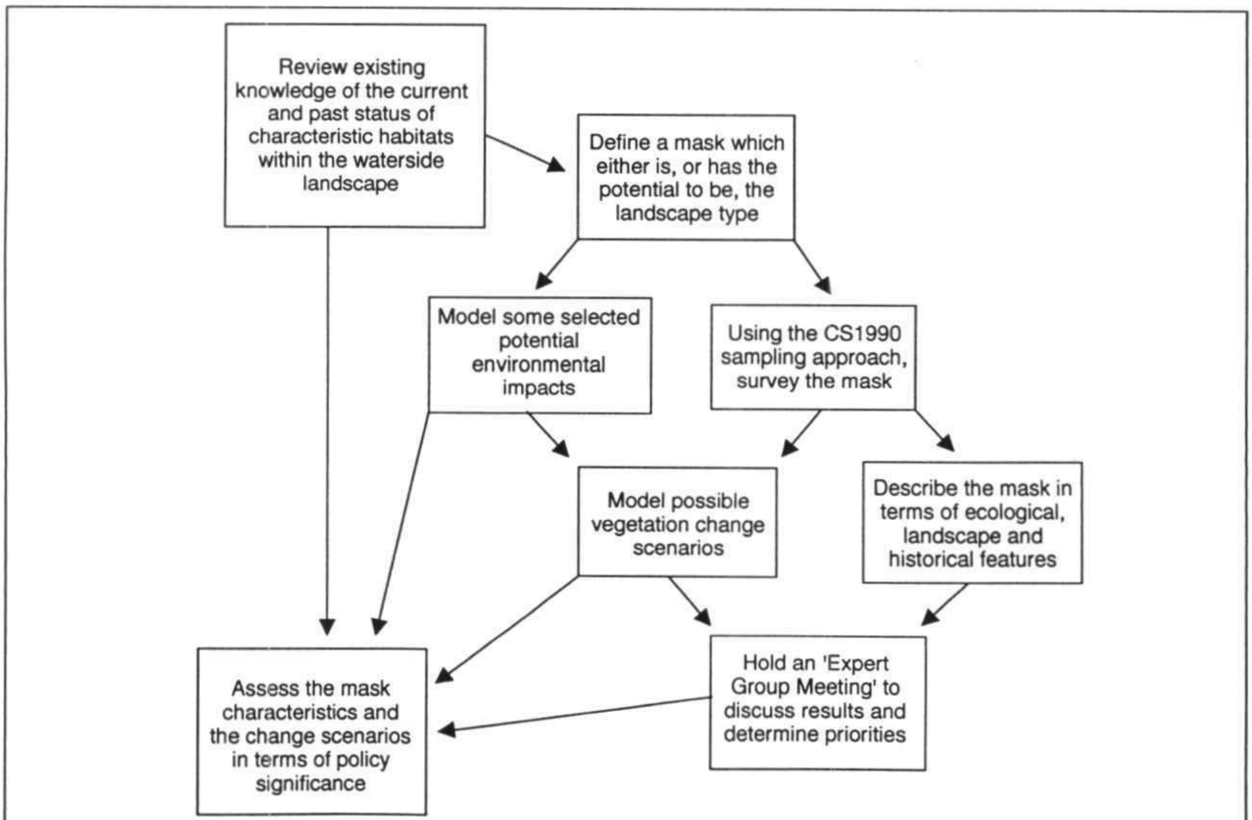

Figure 1.1 General approach used by the research team

1.5 Structure of the Report

1.5.1 The task of compiling this Report was undertaken jointly by members of the research team. The structure of the Report reflects the overall approach, as shown in Figure 1.1, with steps in the research being reported as separate Chapters. The final Chapter brings together the main conclusions from each phase of the work and gives a summary of the project, in relation to the objectives.

Chapter 2 BACKGROUND: THE IMPORTANCE OF THE WATERSIDE LANDSCAPE

2.1 Introduction

2.1.1 This Chapter is based on a review of existing literature and gives a general definition of the waterside landscape and its distribution within England. It describes its distinctive ecological, scenic, recreational and historical characteristics, and explains why waterside habitats are important in a national and international context. Trends for change and threats to the waterside habitat resource are briefly reviewed and the need for conservation and enhancement is highlighted.

2.2 The waterside landscape – a general definition

2.2.1 The waterside landscape in England consists of a network of rivers together with associated wetlands (eg lakes, mires, swamps) and other non-wetland habitats which may not be peculiar to watersides (eg woodlands). These diverse habitats may be connected by their aquatic components, and should be considered as a unit because changes in one area can affect others. The waterside landscape supports nationally and internationally important plants and animals, and provides special scenic and recreational resources. Waterways also provide drainage and act as wildlife corridors. Distinctive landscape forms associated with rivers include broad floodplains with meanders, narrow streams in steep-sided valleys fringed by trees, canalised major rivers, rivers on soft soils, and rivers on chalk. Rivers form central features in many large conurbations and, for this reason, they are popular as walking routes. The waterside landscape contains many types of designation.

2.2.2 The waterside landscape therefore includes the river corridor beyond the river channel and those areas and habitats which are an integral part of the river. However, these landscapes are widely dispersed and varied, which makes the precise definition of the landscape type difficult. A key consideration is the width of the river corridor or buffer zone around waterways that should be considered as part of the landscape.

2.2.3 The Countryside Stewardship Scheme uses a general definition of the waterside landscape: river valley land which is affected by the floodplain together with areas adjoining lakes and canals and areas of other wetland.

2.2.4 Although the definition of a river corridor is always likely to be somewhat arbitrary, there have been some recent attempts to define a standard survey width. In its early river corridor surveys, the Nature Conservancy Council used a minimum 50 m from the river and this has been adopted by others including the National Rivers Authority (NRA) and Scottish Natural Heritage (SNH). NRA river corridor surveys define the term as follows.

> "'River corridor" is a term generally used to described a stretch of river, its banks and the land close by. The width of the corridor depends on how much the nearby land is affected by the river and *vice versa*. Usually the river

Table 2.1 Examples of waterside communities in the National Vegetation Classification

AQUATIC	A6	*Ceratophyllum submersum* community	SE coasts England
	A21	*Ranunculus baudotii* community	Coasts England
SWAMP	S20	*Scirpus lacustris* spp. *tabernaemontani* swamp	Coasts England
	S21	*Scirpus maritimus* swamp	Coasts England
GRASSLAND	MG11	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* subcommunity	
		MG11b *Atriplex prostrata*	W Coast England

corridor includes land and vegetation within 50 metres of the river bank, but, where there are extensive water meadows, marshes or other wetland areas, the corridor may be wider to include these other associated features.'

2.2.5 SNH has devised the SERCON (System for Evaluating Rivers for Conservation) project, which defines river valleys as:

'... the channel and its banks together with the adjacent flood plain habitats such as wet meadows or marshland; where rivers lack flood plains, a 50 m zone on either side of the river will be included.'

2.2.6 The definition of the waterside landscape in this Report is described in Chapter 3; it involves a wider zone on either side of the river than the two above definitions and, in contrast to the Countryside Stewardship Scheme, it includes river landscapes in the uplands.

2.3 The waterside as an ecological resource

2.3.1 Almost all waterside landscapes support aquatic plant and animal communities, water margin communities, and swamps. Some support other wetland habitats including tall herb fens, sedge fens (in base-poor waters), fen meadows and carrs, various mires, wet grasslands and rush pastures, wetland scrub, and riparian woodlands. Some of these are nationally and internationally important, especially fens and mires.

2.3.2 Upland and lowland rivers tend to support different plants and animals, eg bog vegetation and breeding waders on upland rivers, reedbeds and warblers on lowland rivers.

2.3.3 Bogs and fens are both peat-forming systems which develop in waterlogged sites. Bogs develop in acid conditions, and tend to be dominated by *Sphagnum* mosses, ericaceous shrubs, and purple moor-grass (*Molinia caerulea*), while fens develop in alkaline conditions and tend to be dominated by taller grasses, sedges and broadleaved herbs. Swamps are tall grass and herb communities which form on waterlogged mineral soils. Wet grasslands and woodlands develop in areas which are periodically but not permanently inundated by flooding, or where water tables are permanently high.

2.3.4 Stewart, Pearman and Preston (1994) estimate that, of all the 'Nationally scarce' plants in Britain (species confined to less than 100 10 km grid squares), at least 14% occur in habitats usually associated with watersides. The largest single group of wetland rarities in Britain are the fen species. The great majority of these species have become rare through habitat loss since the 17th century.

2.3.5 A wide range of National Vegetation Classification classes could potentially be present in the English waterside landscape, mainly from the aquatic and swamp series of communities (most of which are lowland types), but also from the mire, grassland and woodland series (examples in Table 2.1).

2.3.6 Waterside habitats are important for a range of fauna. The British Isles have large numbers of otters (*Lutra lutra*) – an international *Red Data Book* species. Rivers are important for water vole (*Arvicola terrestris*) – a declining species according to Strachan and Jefferies (1993) – and water shrew (*Neomys fodiens*) which use the water and bankside vegetation. Wet areas also provide feeding areas for some species of bat because of the presence of large numbers of invertebrates. Many birds are closely associated with wet habitats. Waterfowl need to be on or near water, but several other species are also confined to these habitats, including grasshopper warbler (*Locustella naevia*), bearded tit (*Panurus biarmicus*), kingfisher (*Alcedo atthis*), heron (*Ardea cinerea*), dipper (*Cinclus cinclus*), grey wagtail (*Motacilla cinerea*) and Cetti's warbler (*Cettia cetti*). Many of these birds have low and declining populations in England.

2.3.7 There are six native species of amphibian in England, including the great crested newt (*Triturus cristatus*) (which is protected under European Community Habitats and Species Directive). Others are palmate and smooth newts (*Triturus helveticus* and *T. vulgaris*), common frog (*Rana temporaria*) and common and natterjack toads (*Bufo bufo* and *B. calamita*). Of these, all but the natterjack toad (now confined to coastal habitats) are strongly associated with waterside and wetland habitats.

2.3.8 Many nationally rare or important invertebrates are associated with wet areas, including dragonflies and damselflies. Different species have different waterside habitat requirements, but many artificial habitats, eg canals and dykes, are especially important. There are two species of stonefly found exclusively in dykes.

2.3.9 Rivers and wetlands are also important areas for rare native species of fish, such as whitefish (*Coregonus* spp.), vendace (*Coregonus albula*), smelt (*Osmerus eperlanus*), charr (*Salvelinus alpinus*), allis shad (*Alosa alosa*) and the twaite shad (*Alosa fallax*). Such habitats also support more common fish species, such as salmon (*Salmo salar*), trout (*Salmo trutta*), roach (*Rutilus rutilus*), pike (*Esox lucius*) and perch (*Perca fluviatilis*).

2.4 The waterside as a scenic resource

2.4.1 The types of landscape associated with watersides range from steep upland streams to lowland rivers with wide meandering channels; they include canals, waterfalls, lakes, fens and mires. Large waterside areas may constitute important scenic areas, as does the Lake District which is popular for its mix of mountain and water; small water features such as streams and ponds may for similar reasons be important to local people in local contexts. Although there is a tremendous diversity within the landscape forms, most waterside environments are restful and peaceful places. Views associated with waterside landscapes can be diverse, ranging from wide views in flat valleys, fringed with hills, to dramatic waterfalls over steep cliffs.

2.4.2 An important aspect of many waterside landscapes is their associated vegetation and the focus of water for local wildlife. The presence of water provides a sense of natural fertility in areas that would otherwise be bare or barren.

2.5 The waterside as a recreational resource

2.5.1 The waterside landscape provides a valuable resource for recreation. Linear paths along rivers and canals provide places for walking and often run through towns and cities, thus providing a valuable urban recreational resource. Rivers and wetlands provide quiet places for picnics and rest. Many scenic drives follow routes along or around lakes and rivers, as in the Lake District. Water channels provide navigable routes through which to explore the countryside on boats, canoes or barges, and these pastimes are becoming increasingly popular along canals and in the Broads. Fishing is a popular sport and, with the return of fish populations to many previously polluted rivers, is likely to increase.

2.5.2 Wetland features provide a valuable educational resource, and ponds and other water features are popular places for children to learn about natural history. Old disused gravel pits also provide good resources for a variety of watersports, although there may be a conflict with nature conservation objectives.

2.5.3 Wetland areas provide a good place to watch birds in winter and summer.

2.6 The waterside as an historical resource

2.6.1 Waterside landscapes are generally ancient in origin, shaped by river flows and sometimes by man. They are important archaeologically because of the types of site preserved and the preservation of organic materials.

2.6.2 Remains special to waterside sites are likely to be linked to the special functions of rivers. Rivers provide natural resources (such as food and building materials) and communication channels. In more recent times, they have provided sources of power. Bank and shoreline features commonly found include settlements, crossings, religious sites, quays and jetties, locks and mills. Rivers themselves often contain a great variety of objects, and historic remains are likely to be well preserved in waterside landscapes, whether they are of organic or inorganic material, owing to the deposition of fine silts and the maintenance of anaerobic conditions. Patterns of land use may also be preserved where they have been buried under alluvial deposits.

2.6.3 Waterside landscapes are also likely to contain waterlogged soils where vastly reduced rates of aerobic decomposition lead to the preservation of plant and animal remains, eg in peat bogs. These remains are invaluable indicators of past environmental conditions, especially in accumulating deposits, eg peats and lake sediments, which can be analysed stratigraphically. Pollen deposits have proved especially informative in researching the post-glacial period.

2.6.4 Remains in rivers and their valleys are amongst the least well-documented types because, until discovered, they are often hidden and protected by alluvial deposits. As a result, there is little evidence of their presence prior to excavation. East Anglia has been well studied and finds here indicate that much is likely to remain undiscovered in other areas.

2.7 The waterside as an economic resource

2.7.1 Few water channels are now used for transportation, although many are used for recreational navigation. However, rivers and the dykes and canals which feed into them have an important role in draining the land for agricultural production and urban development. They are also used to transport water (and sewage waste) from one area to another so that it can be abstracted for use. Possibilities for long-distance transfers using rivers and canals are being investigated in several areas.

2.8 The dynamics of waterside landscapes

2.8.1 The retreating ice of 12 000 years ago left behind a network of rivers and associated wetlands draining from the uplands to the lowlands and out to sea. Over a quarter of the British Isles is or was associated with fresh water at one time.

2.8.2 Water falling on a land mass gathers into streams and then rivers, cutting a system of dendritic channels, which lead to the sea. The course of these channels is determined by the movements of the earth's crust, the potential for erosion of rocks, glaciation and human activity, and, as a result, many rivers take circuitous routes to the sea (Haslam 1987). Most lowland river channels are essentially man-made and placed according to preferences related to agriculture, land drainage and navigation (Haslam 1987).

2.8.3 The type of landform and vegetation in the waterside landscape is largely determined by water flow speeds and volume, sediment distribution patterns, water quality and underlying soil type.

2.8.4 Both standing and flowing water bodies are subject to physical and chemical modification by natural and artificial disturbance within their catchments. This disturbance will affect waterside habitats and fauna. Much of the ecological and landscape interest of the waterside landscape is associated with periodic flooding of the land, especially in the water meadows.

2.8.5 The majority of waterside vegetation types are subject to successional change, and successions beginning in open water habitats (hydroseres) have been widely described. Traditional descriptions of succession started with the colonisation of open water by floating aquatic plants, leading to an accumulation of deposits of plant remains which allow rooted aquatics with floating leaves to establish. The continued and accelerating accumulation of plant remains eventually leads to invasion by scrub and succession to wet woodland.

2.8.6 However, in a study of published records of post-glacial hydroseres in Britain, Walker (1970) has shown that changes have in fact been very diverse, frequently failing to conform to the traditional pattern described above and, in about 15% of cases, the expected trend has been reversed. The commonest long-term outcome has not been a development towards wetland scrub and wet woodland, but towards *Sphagnum* bog. Sometimes wetland scrub colonised briefly before being overwhelmed by the development of *Sphagnum* carpets (which prevent tree regeneration).

2.9 Loss of waterside landscapes

2.9.1 Loss of habitats and communities characteristic of watersides has probably been concentrated in extensive wetland areas where land has been drained for agriculture. In the East Anglian fens, only about 10 km^2 of semi-natural vegetation now survives out of 3380 km^2 existing in 1637 AD (Rackham 1986). Losses on a similar scale have most probably occurred in the Somerset Levels and elsewhere. Most surviving fens in these areas are nature reserves, though in the Somerset Levels peat extraction remains a threat. Other serious losses relate to the agricultural improvement of wet grasslands, especially neutral unimproved grasslands (water meadows and similar meadows managed for hay and light grazing); English Nature estimates that only 2% of such areas existing in 1945 now survive.

2.9.2 By contrast, many riverside habitats have suffered less severe losses, partly because rivers cannot be completely removed, and partly because these communities are strongly successional, so that they are better able to recover from damage and to colonise new sites as they become available.

2.9.3 From a scenic and recreational standpoint, however, the loss of riverside landscapes has been as marked as the loss of other wetlands. Canalisation and the loss of bankside vegetation can reduce the visual appeal of these landscapes.

2.10 Causes of loss

Physical alterations to river channels

2.10.1 Many river channels have been straightened for the purposes of improved drainage, the removal of flood waters, and navigation. In addition to affecting riparian vegetation directly, these practices often lead to decreased winter flooding of adjacent fields, with consequent deterioration of wet grassland, and to incentives for the agricultural improvement of such fields. Such straightening reduces the scenic appeal of lowland rivers which would naturally meander and create riffles and wetlands. It reduces their recreational appeal as both navigation and walking become monotonous. Engineering works undertaken on rivers also include the building of reservoirs, generally by blocking the river channel and flooding the surrounding land.

2.10.2 The dredging of watercourses can disturb historical remains within and alongside the river course, although it can also lead to their exposure and discovery.

Water abstraction

2.10.3 Low flows due to abstraction of groundwater are a serious issue on most English lowland rivers. In some cases, rivers completely disappear in summer, especially in dry weather. This has obvious implications for ecological and scenic values, but also affects historical features through desiccation and shrinkage.

Agricultural activity

2.10.4 There are several factors which lead to the loss or deterioration of wetland habitats, including agricultural improvement of wet grasslands, invasion of fens by scrub following the cessation of management, eutrophication leading to increased dominance of competitive species, and water abstraction for irrigation causing drying out.

2.10.5 Large areas of land in the waterside zone have also been drained for agriculture. This has been a major cause of the loss of wetland habitats and plant species, and the associated animal, bird and insect life, although there are no definitive figures available on the magnitude of the total loss or on the rate. The most widespread drainage is in connection with the conversion of land to intensive grassland or arable. In these latter cases, the agricultural drainage is usually associated with increased applications of fertilizers and pesticides whicn will also lead to the loss of plant species of conservation interest. Drainage usually involves both under-drainage and linked surface ditches. Riparian plant species can persist along the open ditches; indeed, the ditches may represent the creation of new habitats with some species being encouraged, but the net effect of the agricultural land drainage is a loss of waterside habitats and species.

Grazing pressures

2.10.6 Though necessary to maintain ecological integrity in some wetland habitats, such as water meadows, grazing can be damaging when wet soils are poached by the hooves of grazing animals; closed stands of vegetation are liable to be destroyed. On stream and river banks this may lead to increased sediment loadings, with potential adverse effects on aquatic macrophytes and fish, especially in clear-water streams, such as the chalk streams of southern Hampshire and Dorset (Summers 1994). On peat bogs, grazing is especially damaging. Here, poaching simultaneously causes local drainage of the peat surface and aerates it, so that the aerobic decay of the peat can proceed.

2.10.7 Conversely, the trampled water margin habitat is essential to the survival of a wide range of small water margin species, eg water forget-me-not (*Myosotis* spp.) and speedwells (*Veronica* spp.). Many of these species are rare and decreasing because of a general loss of this type of habitat, eg lesser marshwort (*Apium inundatum*), penny royal, (*Mentha pulegium*), and small fleabane, (*Pulicaria vulgaris*) (Prince & Hare 1981).

Peat wastage

2.10.8 Where peatlands have been reclaimed for agriculture (eg East Anglian fens), drying out and aeration of the peat lead to aerobic decay. The peat is oxidised to carbon dioxide and the surface of the land falls. This process is known as 'peat wastage'. In the drained East Anglian fens, it historically created a need for improved drainage as the land surface fell and the rivers became progressively higher than the surrounding land. Further drainage then in turn accelerated peat wastage (Darby 1983). It is now hard to maintain water tables in surviving fragments of fenland which are above the surrounding agricultural land (almost all are sites of extremely high nature conservation importance).

Pollution

2.10.9 Levels of pollution are falling in most British rivers, especially those that were once seriously polluted. Fish have been re-introduced into several rivers where they have long been absent (eg the River Rother in Yorkshire), and the return of a wide range of fish species to the River Thames is well documented. However, the few pristine rivers remaining are vulnerable to low-level sources of pollution, especially agricultural runoff which can include soil erosion; this is still a problem in some areas, especially where winter crops are sown on light soils or maize is grown close to rivers.

2.10.10 Eutrophication from sewage and agricultural runoff rich in nitrogen and phosphate affects many watercourses and lakes, reducing the oxygen in the water and favouring competitive plant species. In extreme cases, it may cause algal blooms (especially in lakes) which may totally disrupt ecosystem functioning, leading to the elimination of aquatic macrophytes and fish kills. The aquatic macrophyte flora of the Norfolk Broads has been impoverished by these causes since 1945. Isolation of individual Broads from the rivers (which supply nutrients from agricultural runoff) has been successful as a way of re-establishing aquatic macrophytes (Moss *et al.* 1986).

Atmospheric deposition

2.10.11 Atmospheric deposition is not generally noted as a problem in the lowland waterside zone. Rivers naturally collect nutrients and deposit them in lowland swamp and fen habitats, so that these are relatively eutrophic and unlikely to be affected by additional inputs of nitrogen. In the uplands, however, atmospheric deposition may be more important as these areas tend to be more nutrient-stressed.

Alien plants

2.10.12 Alien plants may have a negative influence in rivers and lakes. Alien aquatics are frequently capable of regenerating vegetatively from fragments carried by running waters, on the feet of water birds, and by anglers; and they may therefore spread rapidly and become strongly dominant in watercourses locally or even nationally. Examples include Canadian pondweed (*Elodea canadensis*), an alien pennywort (*Hydrocotyle ranunculoides*), and swamp stonecrop (*Crassula helmsii*). Other aliens are dominant on river banks, especially in the north and west, eg Himalayan balsam (*Impatiens glandulifera*) and Japanese knotweed (*Reynoutria japonica*).

Climate change

2.10.13 The effects of climate change on waterside habitats are hard to predict. On the one hand, many aquatic and wetland plants are widely distributed in Europe, so that they might be expected to tolerate a wide range of climatic conditions. On the other hand, many aquatic communities consist of just a few species, so that, if the dominant species did respond to change, the ecological impact might be large. Changes in rainfall might either reinforce or counteract the general tendency for wetlands to dry out under modern land management regimes.

Development

2.10.14 Development is a major issue in some waterside areas. Many transport links and conurbations are centred on river valleys, and industrial development has traditionally taken place on rivers because of the historic reliance on water power. Development within or near the floodplain can increase runoff, and hence flood risk and river channel erosion. It therefore tends to be controlled in the planning process.

Recreation

2.10.15 Recreation is a major issue in the waterside landscape. Many different types of activity are involved. Their effects may be summarised as follows.

- Water sports (yachting, sail-boarding, motor-boating) mainly affect habitats in the waterside zone through landtake for marinas and related facilities, erosion of channel edges by motor-boat washes, and damage to sensitive habitats caused by landing.
- Angling may encourage conservation management on many rivers. There may be trampling damage to waterside vegetation in popular sites, but this is not a major issue unless rare species are present.
- The sheer weight of public access has large effects in waterside areas. These range from trampling of botanically important communities to disturbance of animals.
- Wildfowling generally protects sites, as wildfowling organisations require sites capable of supporting birds.

Afforestation

2.10.16 This is not generally a threat to the lowland waterside landscape, though poplar (*Populus* spp.) plantations are sometimes developed close to lowland rivers. However, in the uplands there are major concerns relating to the role of conifer plantations in acidifying catchments. Some data suggest that the severity of watercourse acidification may be ameliorated by leaving unplanted buffer zones alongside upland streams (Ormerod *et al.* 1993).

2.11 Conservation and restoration

2.11.1 Where rivers, canals or dykes are in equilibrium, dynamically self-sustaining and of high ecological interest, no management is the best prescription from an ecological, scenic and historical perspective. However, most management of watercourses is carried out for reasons other than nature conservation, most notably to maintain a channel which acts as a drain or navigation route. Nevertheless, with appropriate knowledge and techniques such management can have minimal or even beneficial impacts for wildlife, scenic and archaeological features.

2.11.2 Dredging and weed cutting are two common activities with potential to impact on waterside resources. However, if carried out sensitively, in stages, dredging only the channel needed and leaving sections to provide cover, then impacts can be minimised. The impacts of mowing bank vegetation can also be reduced by sensitive timing which allows seed to set and animals to reproduce. Such sensitive management approaches can be outlined in a river catchment plan which considers the management of the catchment as a whole, rather than in disparate sections. Bogs are another example of a waterside habitat which requires no management if it is in equilibrium.

2.11.3 However, some habitats in the wetland landscape were traditionally subject to distinctive agricultural management practices that determined their vegetational characteristics, and, as such, need to be managed to maintain their interest. The main managed habitats may be summarised as follows.

- Tall herb fens, especially East Anglian sedge fens (dominated by great fen-sedge (*Cladium mariscus*)), were frequently managed by mowing for 'litter' which was used for poor-quality thatching, animal bedding, and similar purposes. In addition, peat was often cut for fuel, especially where fens were in common ownership, eg the Waveney Valley fens. These practices led to the maintenance of a structurally diverse habitat ranging from bare peat and pools associated with turbary, through various regrowth stages in mowing fens, to tall herb fen and perhaps carr in neglected areas. Many rare plant (and invertebrate) species were formerly associated with pools and bare peat created by peat digging, rather than with closed fen vegetation (eg bog violet (*Viola stagnina*) in the Cambridgeshire fens, fen orchid (*Liparis loeselii*) in the Suffolk/Norfolk Valley fens). Such practices are now undertaken for conservation purposes and include reed and scrub cutting in rotation in order to leave a structure of age classes and a diversity of vegetation types.

- Meadows (*sensu* Rackham 1986) were either managed for hay crops to provide food for animals during the winter, though grazing often took place on the aftermath, or for grazing all summer. Riverside water meadows were allowed to flood in winter, so that nutrients brought in with silt would support a strong flush of summer growth. To be maintained, such areas should continue to receive the same treatment, involving cutting once or twice a year when seed has set, or grazing all summer once the flood has retreated.

- Drainage ditches on drained fenland and coastal grazing marshes were kept clear for drainage purposes. Prior to the advent of mechanical methods of ditch clearance, this regime maintained a range of waterside conditions including trampled mud and emergent aquatic vegetation along dyke-sides, and open water in the centre.

2.12 Summary

2.12.1 Rivers and their associated wetlands are central to the ecology of England. Not only do they support their own special flora and fauna, but they also provide drainage and water sources for other flora and fauna. The waterside landscape is a valuable scenic resource providing rest and refreshment. These landscapes are popular for recreation in such forms as boating, fishing or simply walking. The historical importance of waterside areas is high as many special kinds of settlements and remains are found here, including remains which can supply environmental indicators.

2.12.2 There are several threats to the waterside landscape, including waterway management, water pollution, development, forestry and recreation, although wetlands appear to have suffered greater loss than the rivers themselves. It is important in the waterside landscape to remember that activities in one area can profoundly and unexpectedly affect the resources in another area. For this reason, whole-catchment management plans and tools are becoming increasingly important in the management of water and watersides.

Chapter 3 DEFINING THE WATERSIDE MASK

3.1 Introduction

3.1.1 Waterside landscapes, river corridors and valleys have been defined in a number of ways (para 2.2) but, at the outset of this project, there was no obvious existing classification which met the need of this project, ie which focused on the habitats alongside water bodies rather than aquatic habitats *per se*, and which included lowland and upland water bodies, and a wide zone of the landscape adjacent to the water bodies.

3.2 Defining the waterside mask

3.2.1 The waterside mask was defined as land within 150 m of all waterways (streams, rivers, canals and lakes) in England from the origin of the waterway as marked on the OS *Strategi* dataset (see para 3.2.3) to the high water mark.

3.2.2 The final appearance of the map of the waterside landscapes of England was determined by the definition of the

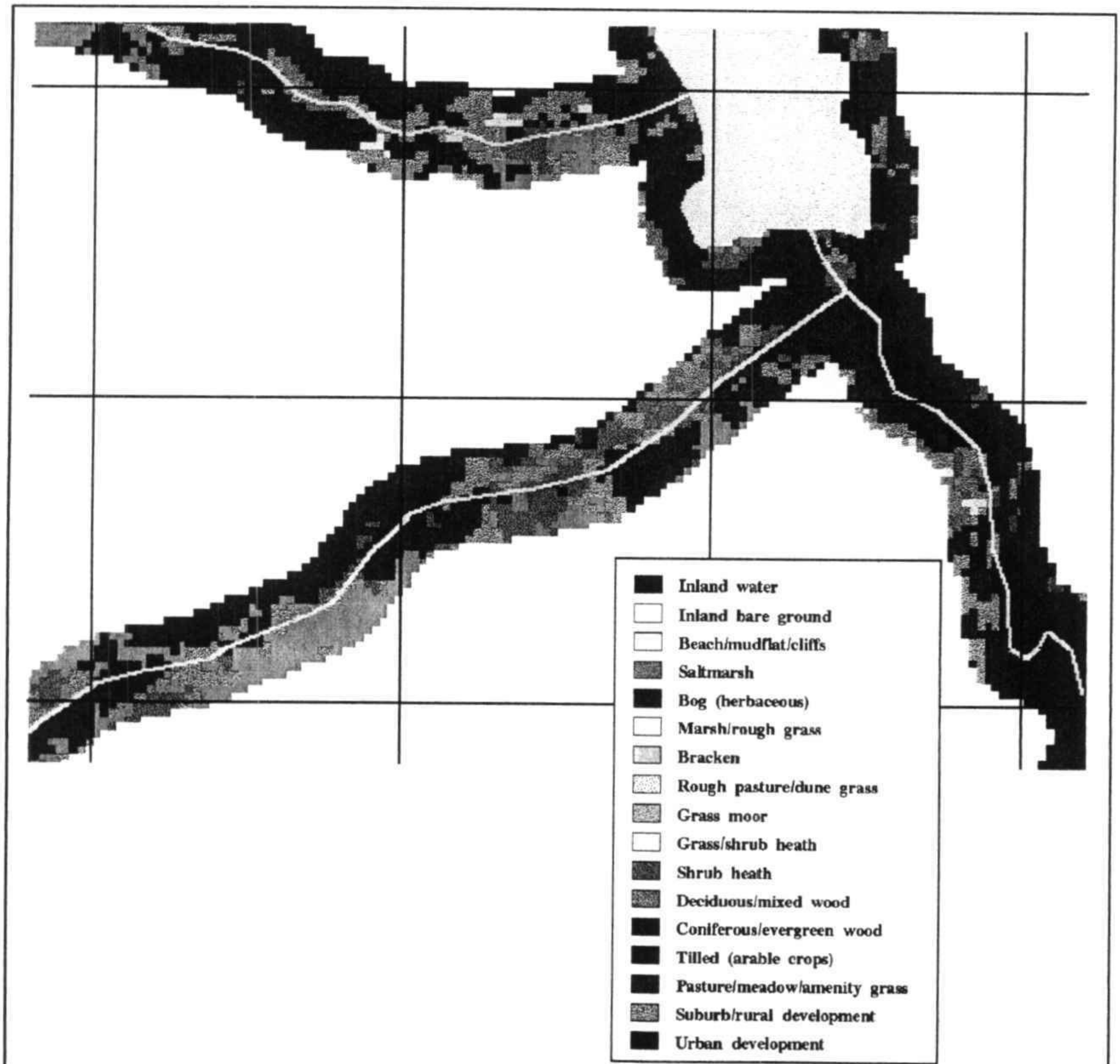

Figure 3.1 Example of the river mask at Grizedale in Cumbria, showing land cover from the ITE Land Cover Map

waterway network (and the accuracy and availability of data to describe it) and, second, by the definition and width of the adjacent waterway landscape area and the procedure used for mapping this. It was also necessary to match the approach used in Countryside Survey 1990 as closely as possible.

3.2.3 Several data sources were considered (including the ITE Land Cover Map, the Ordnance Survey (OS) *Strategi* digital data and the Bartholomew digital map). These differed in terms of:
- definition – datasets were variable in terms of the order of stream/river included;
- coverage – some datasets were more comprehensive than others;
- accuracy – a comparison between two separate datasets demonstrated average shifts of 200 m eastward and northward.

3.2.4 The water feature layer from the OS *Strategi* dataset (1:250 000) was used for defining the waterway network as it provided the best coverage of the CS1990 waterways and was more accurate in its mapping of its position than the alternatives. Within *Strategi* there are three waterway types:
- rivers (6 categories),
- canals and lakes
- coastline.

The representation of rivers at the coast is dependent on cartographic considerations and so a certain amount of editing was necessary to ensure consistency. Rules were defined for reclassifying the coastline as river banks or lakes, depending on the distance between banks and shape or if they were inland of the coastal buffer.

3.2.5 A 150 m buffer was constructed around each waterway type using a procedure in an Arc/Info geographical information system. Any area of buffer lying entirely within the water area of lakes or coastal rivers, or outside the boundary of England, was removed. The separate buffers for each waterway type were then combined into a single coverage. Each polygon within the combined coverage was labelled with attributes defining presence/absence in the buffer of each waterway type. A given polygon could contain more than one waterway type, and would therefore be labelled with the attribute for each type represented. For all waterways, and then each waterway type individually, the buffer polygons were converted to a 25 m grid which was used as a mask for extracting land cover statistics. Land cover classes for sea/estuary, inland water, beach/mudflat/cliffs and saltmarsh were excluded from the buffer.

3.3 The waterside mask – outputs

3.3.1 The waterside mask (an example area is shown in Figure 3.1) occurs within a database of 77 817 1 km squares. Of these, 2065 urban squares (>75% built-up) were excluded, leaving a total of 75 752 squares. The locational data for these squares, although not the buffer zones within them (the mask), are available as a dataset for use in the DOE's Countryside Information System.

Chapter 4 ECOLOGICAL CHARACTERISTICS OF THE WATERSIDE MASK

4.1 Introduction

4.1.1 The methods used to define the waterside mask are described in Chapter 3. This Chapter goes on to describe the field survey which was completed in order to characterise the mask in terms of ecological components such as land cover, landscape features and vegetation.

4.2 Sampling strategy

4.2.1 The waterside mask was stratified to ensure that the sample of surveyed squares was representative, and to allow comparison between landscapes in different parts of England, and between waterside types in designated and non-designated areas. The six strata are:

i. arable designated watersides
ii. arable non-designated watersides
iii. pastural designated watersides
iv. pastural non-designated watersides
v. upland designated watersides
vi. upland non-designated watersides

4.2.2 'Arable', 'pastural' and 'upland' refer to the land class groups derived from the ITE Land Classification, as used in Countryside Survey 1990 (Barr *et al.* 1993). Stratification using these land class groups allows watersides in different parts of England to be compared. The arable land class group covers areas where arable farming is a dominant land use, together with intensively managed grassland; it is concentrated in East Anglia and the eastern Midlands (land classes 2, 3, 4, 9, 11, 12, 14, 25 and 26). The pastural land class group represents areas mainly in the west of lowland England, where grassland used for livestock farming is the dominant land use (land classes 1, 5, 6, 7, 8, 10, 13, 15, 16 and 27). 'Upland' is a combination of the marginal upland and true upland land class groups comprising, in England, mostly the former. The marginal upland land class group represents areas which are on the periphery of the uplands; they are dominated by mixtures of low-intensity agriculture, forestry and semi-natural vegetation (land classes 17, 18, 19, 20, 28 and 31). The true upland land class group represents areas which are largely above a height suitable for intensive farming; they are frequently dominated by sheep farming and semi-natural vegetation, and in England are largely restricted to the Pennines and Cumbrian mountains (land classes 21, 22, 23, 24, 29, 30 and 32).

4.2.3 'Designated' refers to the presence in all or part of a 1 km square of one of the following designations, according databases assembled by ITE in 1988:

Site of Special Scientific Interest (SSSI),
National Nature Reserve (NNR),
National Park (NP),
Area of Outstanding National Beauty (AONB),

Heritage Coast (HC),
Green Belt (G Belt),
Environmentally Sensitive Area (ESA).

These designations have varied objectives and were defined on the basis of different criteria, ranging from the conservation of rare species to landscape value. Some cover small homogeneous areas such as NNRs, whilst others are large and varied, like National Parks. They are administered by a range of bodies including English Nature, the Countryside Commission, the Ministry of Agriculture, Fisheries and Food (MAFF), wildlife conservation trusts and local authorities.

4.2.4 The inclusion of a 1 km square in the designated strata indicates that at least some part of the square has at least one designation – in interpreting the following results it should be remembered that not all of the square is necessarily designated (and it may not be part of the waterside buffer zone), so the area of the designated strata and areas of land cover types within it may be over-estimates. This is mainly relevant to designations which affect small areas, eg SSSIs. Further, the reasons for designation may not be related to the waterside nature of the vegetation.

4.2.5 To characterise the mask, field data were taken from the Countryside Survey 1990 dataset. Of the 264 CS1990 survey squares recorded in England, 116 contained watercourses as recorded in the OS dataset (including rivers, lakes and canals – see Chapter 3). These OS watercourses were identified in the CS1990 survey squares and a 150 m buffer was created around them, using geographical information system procedures. The land cover, boundary and quadrat data were then extracted from this buffer zone, to create a dataset for land within 150 m of selected watercourses in the CS1990 survey squares. The results are extrapolated from the sample squares to the waterside landscape as a whole. The relationship between the survey squares and the size of each stratum is shown in Table 4.1. When interpreting the results of the field survey, the small size of the sample from the non-designated upland stratum should be borne in mind. Because of the small size of the sample in this stratum, the results will not be statistically reliable and should be treated as indicative only.

4.2.6 The total mask comprises 17 730 km², which is approximately 14% of the total area of land in England.

Table 4.1 The waterside landscape stratification: area of land in mask and number of sample squares

Strata	Stratum size km²	%	Sample size km²	%
Designated arable	5169	*29*	16	*14*
Non-designated arable	2739	*15*	39	*34*
Designated pastural	4493	*25*	21	*18*
Non-designated pastural	2909	*16*	23	*20*
Designated upland	467	*3*	13	*11*
Non-designated upland	1953	*11*	4	*3*
Total	*17730*	*100*	*116*	*100*

4.2.7 Of the mask area, 57% is in 1 km squares which have a designation (which is the same for England as a whole). Few areas are designated specifically for river corridors (the programme of SSSI designation of rivers mostly occurred after 1988, and so is not included in the ITE designations database). Only 14% of the landscape occurs in upland England, and most of this (11%) is in non-designated squares. This shows that river corridors in the uplands are not targeted for designation as, in total, 81% of the English uplands are designated. In contrast, in lowland England (arable and pastural strata), more than 50% of the waterside landscape occurred in designated squares.

4.3 Field data recording

4.3.1 Land cover and boundaries were mapped in 1990 for the whole square, using a standard coding system (Barr *et al.* 1993). This spatial database is held on an Arc/Info geographical information system, and information from the 150 m buffer zone around the selected rivers, lakes and canals was extracted for this study.

4.3.2 Quadrats were recorded in 1990 to provide quantitative botanical information about vegetation in the sample squares. All the plant species present in the quadrats were recorded, together with cover estimates. These quadrats were permanently marked, to provide a baseline for future monitoring. Quadrats falling within the 150 buffer zone around the selected watercourses were extracted for this study, although quadrats in arable fields were excluded. Three different types of quadrats were included:

- **main plots**: 200 m² nested quadrats recorded at random locations within the square, to provide a representative sample; the number of main plots (from a maximum of five) included in the 150 m zone is proportional to the total area of the buffer zone;

- **habitat plots**: 4 m^2 quadrats recorded in the less common habitats which were not represented by the main plots, eg the aquatic margins of lakes;
- **waterside plots**: 10 m x 1 m plots recorded adjacent to rivers, streams, canals and ditches. The plots were placed parallel to the watercourse to record the metre strip above the running water. (Waterside plots immediately adjacent to non-selected streams, but which happened to lie within the mask, were excluded.)

4.4 Field survey results: land cover

4.4.1 Land cover in the buffer zone around each selected water feature has been used to estimate the total area of each land cover

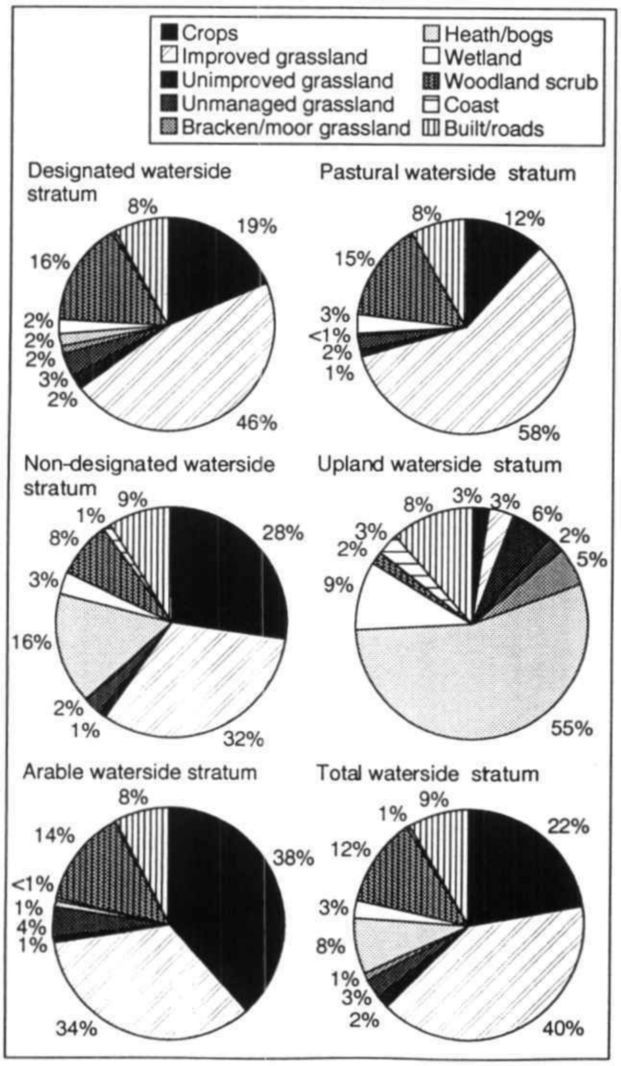

Figure 4.1 Estimates of the percentage area of each land cover type in the waterside mask

type in the six strata (Figure 4.1). More detailed information on the land cover estimates for each stratum is given in Appendix 1.

4.4.2 Wetland vegetation (including fens, marshes and flushes) has been estimated to occupy a small area of the mask and is most common in the upland strata, with less in the two lowland strata. Unmanaged grass and tall herb vegetation, which is often associated with river banks and lake margins, was most common in the arable strata. The figures shown in Figure 4.1 emphasise the scarcity of wetland vegetation, which forms only a small component even within river corridors and lake edges.

4.4.3 Improved grassland was the dominant land cover type in the pastural strata where it occupied 58% of the mask. It was also important in the arable strata (34%), where crops were the dominant land cover, occupying 38% of the mask. Woodland and scrub formed a significant component of the waterside mask, occupying 14% of the area (greater than for lowland England as a whole). In contrast, the uplands were dominated by moorland vegetation, with heath and bogs occupying 55% of the waterside zone, and bracken (*Pteridium aquilinum*) and moor-grass (*Molinia*) a further 5%. The waterside landscapes in the lowland strata contained a small proportion of semi-natural vegetation (*c* 20%) compared to the uplands (*c* 80%), but this proportion was still higher than would be expected for lowland England as a whole (*c* 10%).

4.4.4 The areas of wetland habitat in the designated and non-designated areas of the waterside landscape are very similar, but, because of the large size of the latter, the proportion of the designated area occupied by wetland vegetation is smaller (2%) than in the non-designated areas (3%). Both designated and non-designated areas are dominated by crops and improved grassland, but the non-designated area has a higher proportion of heath and bog vegetation.

4.5 Field survey results: boundaries

4.5.1 Within the waterside mask, fences were the most common boundary type (52%), followed by hedges (40%), with walls (7%) and banks (1%) forming minor components (Figure 4.2). However, there was strong regional variation, with walls being predominant in the uplands (49%), fences in the pastural strata (59%), and

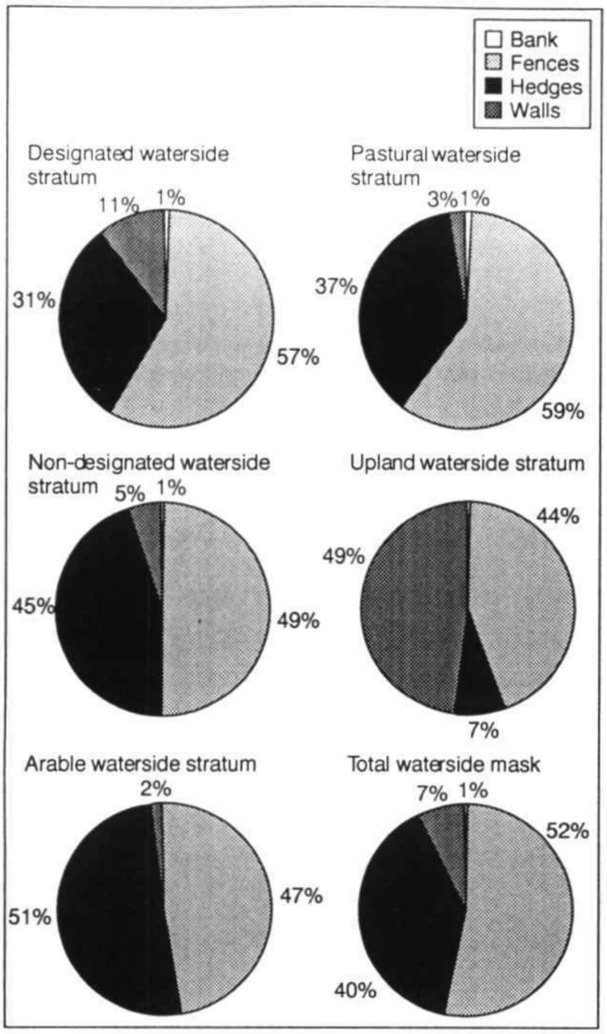

Figure 4.2 Proportion of boundary types in the waterside mask

hedges in the arable strata (51%). More detailed figures are given in Appendix 1.

4.6 Summary of land cover and boundary results

4.6.1 The waterside mask includes only a small proportion of wetland vegetation. It is most common in the uplands, but scarce in the lowlands, reflecting the extent of agricultural improvement and drainage in the lowlands, especially in arable-dominated areas. Half the area estimated to contain wetland vegetation fell in non-designated areas, mostly in the uplands, which implies a lack of targeting of wetland vegetation for designation.

4.7 Vegetation sampling and analysis

4.7.1 The land cover data (as described in Section 4.3) represents the major vegetation categories and provides a baseline against which quantitative estimates of change can be made. To examine the more subtle changes that may take place as a result of new management or changing environmental conditions, the balance of vegetation species within the major land cover types needs to be recorded. To do this, species were recorded within quadrats. Two broad types of analysis have been carried out: first, quadrats have been analysed according to the species they contain and; second, the species have been analysed according to their frequency of occurrence in quadrats.

Analysis of quadrats: 'structural types' and 'plot classes'

4.7.2 Two types of analysis have been carried out using the quadrat data: allocating the quadrats to structural vegetation types, and classifying quadrats into plot classes.

4.7.3 The quadrats have been aggregated according to vegetation type, based on quadrat descriptions, into broad groups called '**structural types**':

- Ditch-side
- Stream-side
- River-side
- Canal-side
- Aquatic margins
- Marsh
- Flush
- Acid grass/heath
- Woodland
- Managed grass
- Unmanaged grass
- Tall herb vegetation

4.7.4 The quadrats were classified statistically into '**plot classes**' based on species composition (using a multivariate statistical classification, TWINSPAN – see hierarchy diagram in Appendix 1). These plot classes have been given short descriptive names to aid interpretation (Table 4.2), and are ordered according to the principal gradient score (derived from the DECORANA analysis – see Figure 4.4). Further details of the plot classes are given in Appendix 1.

4.7.5 Plot classes F, G and H might be considered as the 'core' specialist waterside classes. The other classes are more generalist and may be found in non-waterside situations.

Analysis of species: 'habitat indicator groups' and 'species groups'

4.7.6 The species recorded have been allocated to

Table 4.2 Waterside landscape 'plot classes'. A classification derived from multivariate analysis of quadrat data (using TWINSPAN)

Plot class	Name
PCA	Woodland on heavy soils
PCB	Basic/eutrophic woodland
PCC	Open/disturbed woodland
PCD	Coarse grassland
PCE	Tall herb
PCF	Waterside tall herb
PCG	Disturbed/eutrophic water edge
PCH	Water edge/marsh
PCI	Semi-improved grassland
PCJ	Improved grassland
PCK	Neglected grassland
PCL	Damp neutral grassland
PCM	Damp acid grassland
PCN	Short-term grassland
PCO	Wet heath
PCP	Acid grassland

Shaded plot classes (F–H) are those considered to be typical of the waterside landscape = 'core' waterside vegetation; non-shaded plot classes (A–E, I–P) are other vegetation types found within the mask = 'non-core' waterside vegetation classes

'**habitat indicator groups**', based on expert knowledge, to identify the extent to which the species are associated with waterside vegetation (Box 4.1).

4.7.7 A multivariate statistical classification into '**species groups**' has been produced which groups species with similar distributions across the quadrat dataset, using DECORANA and Ward's Minimum Clustering. The rare species (frequency <2%) have been excluded from this classification. These groups are shown in Table 4.3, ordered on the principal gradient.

4.7.8 SG3, SG7 and SG8 represent the core waterside and wetland species.

Box 4.1

Waterside,
eg *Phalaris arundinacea, Myosotis scorpioides*
Wet grassland,
eg *Galium palustre, Glyceria fluitans*
Moist grassland,
eg *Agrostis stolonifera, Epilobium hirsutum*
Wet heath/bog,
eg *Polytrichum commune, Nardus stricta*
Acid grassland/dry heath,
eg *Agrostis canina, Galium saxatile*
Neutral/calc grassland,
eg *Holcus lanatus, Ranunculus repens*
Woodland edge/scrub,
eg *Rubus fruticosus, Anthriscus sylvestris*
Woodland,
eg *Hedera helix, Holcus mollis*
Ruderals,
eg *Urtica dioica, Taraxacum* agg.
Aliens,
eg *Acer pseudoplantanus, Impatiens glandulifera*

4.7.9 Species have been identified as being sensitive to particular threats (based on expert knowledge of species ecology), ie species which quickly disappear in the presence of:

i. drying out, due to drainage or climate change;
ii. canalisation and river bank maintenance;
iii. use of aquatic herbicides;
iv. eutrophication, through runoff or deposition.

The presence of species from these 'sensitivity indicator groups' implies that the vegetation in which they occur has not been subject to these pressures.

Assessment of vegetation quality

4.7.10 These classifications of quadrats and species will be used to describe the types of vegetation

Table 4.3 Waterside landscape: species groups. A classification derived from multivariate analysis of quadrat data (using DECORANA) for species present in more than 4% of quadrats

Species groups		Typical species
SG1	Eutrophic woodland species	*Geranium robertianum, Silene dioica*
SG2	Bramble/tall herb species	*Rubus fruticosus, Heracleum sphondylium*
SG3	Waterside species	*Epilobium hirsutum, Phalaris arundinacea*
SG4	Coarse grassland species	*Arrhenathrum elatius, Elymus repens*
SG5	Woodland species on heavy soils	*Dryopteris dilatata, Hyacinthoides non-scripta*
SG6	Ruderal species	*Stellaria media, Plantago major*
SG7	Moist grassland species	*Agrostis stolonifera, Filipendula ulmaria*
SG8	Impeded drainage/marsh species	*Juncus effusus, Deschampsia cespitosa*
SG9	Managed grassland species	*Dactylis glomerata, Cirsium arvense*
SG10	Acid grassland species	*Agrostis capillaris, Galium saxatile*

Shaded species groups (3, 7, 8) are those which are characteristic of the waterside landscape = 'waterside' species groups; unshaded species groups (1, 2, 4–6, 9, 10) are also found in the waterside mask = 'non-waterside' species groups in the six strata, and to compare them in terms of selected quality criteria.

4.7.11 The use of quality criteria to provide a comparative assessment of sites by other studies is discussed in Appendix 1 (Box A1.1). In this project, objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of waterside vegetation in different parts of the waterside landscape. Each criterion emphasises a particular aspect of quality, but they do inter-relate, and should not be considered as mutually exclusive. The following discussion of vegetation in terms of quality criteria is based on species information from quadrats, and makes use of the classifications described above (Section 4.4). The following quality criteria are considered in turn: size, diversity, naturalness, representativeness, rarity, fragility, potential value.

4.8 Vegetation quality: size/abundance

4.8.1 Large size is usually considered a positive quality, for a number of reasons. Each species has a minimum area (or resource) which is necessary to maintain a viable population. There is a relationship between area and species diversity affected by population size, extinction and immigration rates. Large sites provide a buffered 'edge' between the central core of the site and adjacent land which helps to protect the core from disturbance, runoff, spray drift, etc. Larger sites usually (but not always) contain a greater range of local environments, reflected in a greater diversity of species.

4.8.2 However, in the case of waterside habitats, the area of land affected by proximity to a water body will vary according to the local topography and hydrology. Because the waterside landscape has been defined as land within 150 m of a water body, the area of land falling within this buffer will be related to the total length of watercourses. The size of patches of waterside and/or wetland vegetation will therefore depend on the total length of watercourse, local topography, and the way land adjacent to the watercourse is managed. In the lowlands, wetlands may be extensive (eg Norfolk Broads) but are more usually fragmented, occupying small unmanaged patches surrounded by more intensively managed fields. In the uplands, more watercourses pass through unenclosed land and are usually grazed; frequently there is only a very narrow strip of waterside vegetation which is distinctive from the surroundings, although there may be more extensive areas of flush or bog.

Quantity of water bodies

4.8.3 Minor rivers are the most common water feature, being much more common than larger rivers, ie main and secondary rivers, which are especially scarce in the uplands (Table 4.4). Canals are less common and mostly located in the lowlands, whilst lakes/reservoirs are more common in the uplands. The total length of these features is reflected in the buffer size and, although the buffer size varies from square to square, the mean buffer size for each stratum is very similar, being smallest in the uplands (26 ha), and largest in the pastural strata (31 ha). The differences between designated and non-designated strata, in

Table 4.4 Waterside landscape – mean length of watercourse per km square (for survey squares), by strata

	Mean length per km square (m)						Mean
Strata	Main rivers	Secondary rivers	Minor rivers	Canals	Lake/ reservoir	All water bodies	buffer size (ha)
Arable designated	0	122	763	62	75	1022	28
Arable non-designated	181	251	689	54	93	1268	29
Pastural designated	96	156	869	26	21	1167	31
Pastural non-designated	106	271	743	49	0	1168	31
Upland designated	0	161	700	0	128	988	27
Upland non-designated	0	0	661	11	221	893	23
Combined designated	36	145	786	32	69	1067	29
Combined non-designated	140	248	711	50	58	1207	29
Combined arable	118	206	715	57	87	1183	29
Combined pastural	102	225	793	40	8	1168	31
Combined upland	0	131	693	2	145	971	26
Total	*95*	*203*	*744*	*42*	*63*	*1146*	*29*

Table 4.5 Mean number and percentage of waterside plot classes recorded in survey squares

Strata	Mean number of waterside plots per 1 km survey square									
	River-side		Stream-side		Ditch-side		Canal-side		All water-side plots	
	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Arable designated	0.9	*42*	0.7	*31*	0.3	*11*	0.4	*17*	2.3	*100*
Arable non-designated	0.9	*35*	0.8	*29*	0.8	*31*	0.1	*4*	2.6	*100*
Pastural designated	1.7	*61*	1.0	*39*	0.0	*0*	0.0	*0*	2.7	*100*
Pastural non-designated	0.9	*35*	1.3	*53*	0.2	*9*	0.1	*4*	2.5	*100*
Upland designated	0.5	*27*	1.5	*73*	0.0	*0*	0.0	*0*	2.0	*100*
Upland non-designated	0.8	*43*	0.8	*43*	0.3	*14*	0.0	*0*	1.8	*100*
Combined designated	1.2	*51*	0.9	*37*	0.1	*4*	0.2	*8*	2.4	*100*
Combined non-designated	0.9	*37*	1.0	*42*	0.4	*17*	0.1	*4*	2.3	*100*
Combined arable	0.9	*38*	0.7	*29*	0.5	*21*	0.3	*12*	2.4	*100*
Combined pastural	1.4	*51*	1.2	*45*	0.1	*4*	0.0	*0*	2.6	*100*
Combined upland	0.7	*39*	0.9	*50*	0.2	*11*	0.0	*0*	1.8	*100*
Total	*1.1*	*45*	*0.9*	*38*	*0.3*	*13*	*0.1*	*4*	*2.4*	*100*

overall buffer size and mean length of water body, are small. Although the absence of main rivers from the arable designated stratum is an exception, this suggests that few large rivers have been included in designated areas in the arable strata.

4.8.4 The mean number of waterside plots recorded per square, for each stratum, gives an indication of the relative abundance of rivers, streams, canals and ditches, which were included in the OS dataset. This shows that only a few waterside plots were recorded alongside canals and ditches, and most plots were recorded beside rivers and streams (Table 4.5). The exception is the wide drains, classed here as ditches because they are man-made, which form a significant component in the arable land class. Waterside plots were recorded beside running water; the aquatic margins of still water bodies were recorded by the habitat plots (see below).

Relative abundance of structural types

4.8.5 Most of the main plots are in managed grassland, some are in woodland, especially in the arable strata, and some in acid grassland or heath, particularly in the uplands (Table 4.6 & Figure 4.3). The main plots were randomly located, so are representative of the relative abundance of the most common structural types, even though they actually contain a very limited range of habitats.

4.8.6 In contrast, the habitat plots (which were targeted towards the less common habitats) show a much greater range of structural types, and, whilst still dominated by those types represented in the main plots, include far more unmanaged grassland, tall herb, marsh, flush and aquatic margin vegetation (Figure 4.3). This shows that these latter types are frequently present in the waterside landscape, but usually in fragments too small to be detected by the random plots.

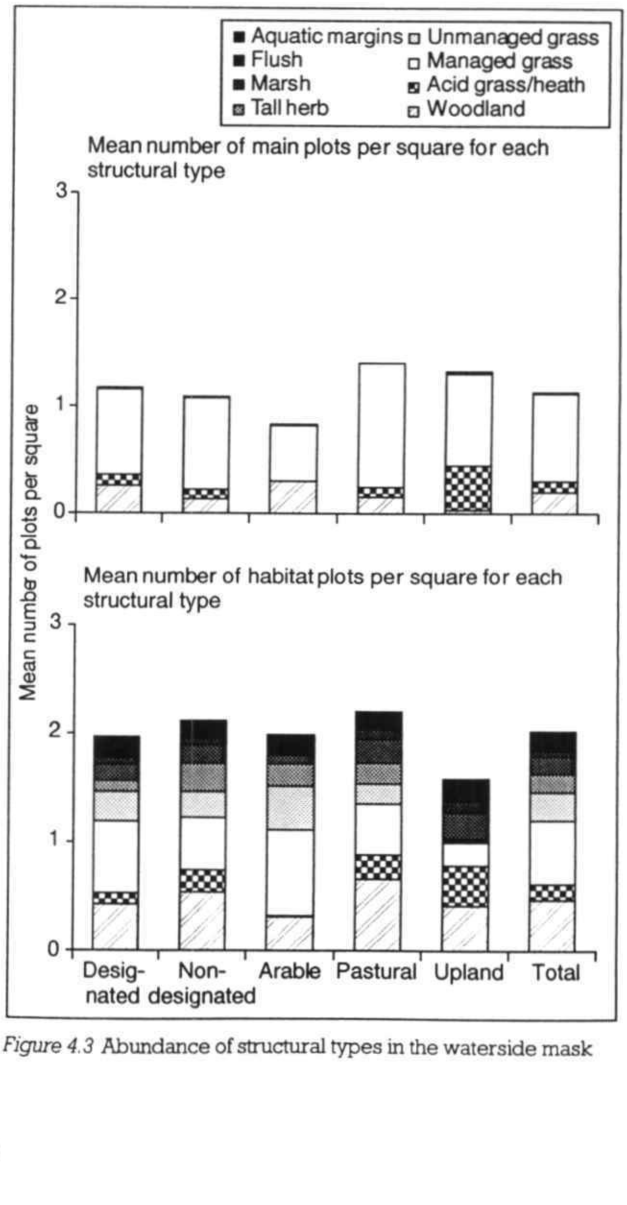

Figure 4.3 Abundance of structural types in the waterside mask

Table 4.6 Mean number of quadrats per square in each structural type, recorded in each stratum

	Arable				Pastural				Upland				Combined				Combined							
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Arable		Pastural		Upland		Total	
	Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean	
Structural type	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Main plots (200 m²)																								
Acid grass/heath					0.10	*7*	0.09	*6*	1.15	*71*	0.25	*20*	0.10	*8*	0.10	*9*			0.09	*7*	0.42	*32*	0.10	*9*
Flush									0.08	*5*			0.00	*0*							0.01	*1*	0.00	*0*
Managed grass	0.56	*60*	0.41	*66*	1.14	*83*	1.17	*82*	0.23	*14*	1.00	*80*	0.80	*69*	0.85	*78*	0.51	*61*	1.16	*83*	0.85	*65*	0.83	*73*
Unmanaged grass			0.03	*4*											0.01	*1*	0.01	*1*						
Woodland	0.38	*40*	0.18	*29*	0.14	*10*	0.17	*12*	0.15	*9*			0.26	*22*	0.13	*12*	0.31	*37*	0.16	*11*	0.03	*2*	0.21	*18*
Total	*0.94*	*100*	*0.62*	*100*	*1.38*	*100*	*1.43*	*100*	*1.62*	*100*	*1.25*	*100*	*1.17*	*100*	*1.09*	*100*	*0.83*	*100*	*1.40*	*100*	*1.32*	*100*	*1.13*	*100*
Habitat plots (4 m²)																								
Acid grass/heath			0.03	*1*	0.14	*6*	0.35	*17*	0.85	*44*	0.25	*17*	0.10	*5*	0.21	*10*	0.01	*0*	0.22	*10*	0.36	*23*	0.15	*7*
Aquatic margins	0.13	*7*	0.28	*11*	0.29	*12*					0.25	*17*	0.19	*10*	0.17	*8*	0.18	*9*	0.17	*8*	0.20	*13*	0.18	*9*
Flush			0.05	*2*	0.10	*4*	0.09	*4*	0.54	*28*			0.07	*3*	0.05	*2*	0.02	*1*	0.09	*4*	0.10	*7*	0.06	*3*
Managed grass	0.88	*52*	0.64	*25*	0.48	*21*	0.48	*23*	0.08	*4*	0.25	*17*	0.66	*34*	0.48	*23*	0.79	*40*	0.48	*22*	0.22	*14*	0.58	*29*
Marsh	0.06	*4*	0.10	*4*	0.24	*10*	0.17	*8*	0.23	*12*	0.25	*17*	0.15	*8*	0.17	*8*	0.08	*4*	0.21	*10*	0.25	*16*	0.16	*8*
Tall herb	0.06	*4*	0.46	*18*	0.14	*6*	0.26	*12*	0.08	*4*			0.10	*5*	0.27	*13*	0.20	*10*	0.19	*9*	0.01	*1*	0.17	*8*
Unmanaged grass	0.31	*18*	0.56	*22*	0.24	*10*	0.09	*4*	0.08	*4*			0.27	*14*	0.24	*11*	0.40	*20*	0.18	*8*	0.01	*1*	0.25	*13*
Woodland	0.25	*15*	0.44	*17*	0.67	*29*	0.65	*31*	0.08	*4*	0.60	*33*	0.43	*22*	0.54	*25*	0.31	*16*	0.66	*30*	0.42	*26*	0.47	*23*
Total	*1.69*	*100*	*2.56*	*100*	*2.29*	*100*	*2.09*	*100*	*1.92*	*100*	*1.50*	*100*	*1.96*	*100*	*2.11*	*100*	*1.99*	*100*	*2.21*	*100*	*1.58*	*100*	*2.03*	*100*
Waterside plots (1 m x 10 m)																								
Canal-side	0.38	*17*	0.10	*4*			0.09	*4*					0.19	*8*	0.07	*3*	0.28	*12*	0.03	*1*	0.00	*0*	0.14	*6*
Ditch-side	0.25	*11*	0.82	*31*			0.22	*9*			0.25	*14*	0.13	*5*	0.44	*19*	0.45	*19*	0.09	*3*	0.20	*11*	0.26	*11*
River-side	0.94	*42*	0.92	*35*	1.67	*62*	0.87	*35*	0.54	*27*	0.75	*43*	1.24	*51*	0.86	*37*	0.93	*39*	1.35	*52*	0.71	*39*	1.08	*45*
Stream-side	0.69	*31*	0.77	*29*	1.05	*39*	1.30	*53*	1.46	*73*	0.75	*43*	0.88	*36*	0.97	*41*	0.72	*30*	1.15	*44*	0.89	*49*	0.92	*38*
Total	*2.25*	*100*	*2.62*	*100*	*2.71*	*100*	*2.48*	*100*	*2.00*	*100*	*1.75*	*100*	*2.44*	*100*	*2.34*	*100*	*2.38*	*100*	*2.62*	*100*	*1.80*	*100*	*2.40*	*100*

The means for the combined strata are weighted by stratum area

Table 4.7 Mean number of different plot classes represented per square, by stratum

Strata	Main plots		Habitat plots		Waterside plots	
	All PC	*PCs F–H*	All PC	*PCs F–H*	All PC	*PCs F–H*
Designated arable	0.9	0.0	1.4	0.1	1.9	0.4
Non-designated arable	0.5	0.0	1.9	0.3	1.9	0.4
Designated pastural	1.0	0.0	1.9	0.3	1.6	0.3
Non-designated pastural	1.1	0.0	1.8	0.4	1.5	0.3
Designated uplands	1.2	0.0	1.2	0.0	1.5	0.0
Non-designated uplands	1.0	0.0	1.3	0.3	1.3	0.0
Combined designated	1.0	0.0	1.6	0.2	1.7	0.3
Combined non-designated	0.9	0.0	1.7	0.3	1.6	0.2
Combined arable	0.8	0.0	1.6	0.2	1.9	0.4
Combined pastural	1.0	0.0	1.8	0.3	1.6	0.3
Combined upland	1.0	0.0	1.2	0.2	1.3	0.0
Total	*0.9*	*0.0*	*1.6*	*0.2*	*1.7*	*0.3*

Plot classes (PC) F–H represent the wetland and moist grassland classes, ie core plot classes – see Table 4.2

4.8.7 The size of the waterside landscape in each stratum is similar, although slightly larger in the lowland strata; this is reflected by the number of waterside plots recorded. The differences in the proportions of structural types between designated and non-designated strata are minimal, for both main plots and habitat plots, suggesting that inherent differences between the strata are more important than designation in influencing the range of vegetation present.

Summary of size/abundance as a quality criterion

4.8.8 The mean length of water bodies per km square, and hence area of land within the buffer zone, is remarkably similar between strata, although slightly smaller in the uplands than the lowlands. There are differences in the relative abundance of different types of water bodies, with more big rivers and canals in the lowlands, and more lake and reservoirs in the uplands. The waterside and wetland vegetation was too scarce to be sampled by the randomly located main plots. However, aquatic margins, flush, marsh and tall herb vegetation were all recorded by habitat plots, showing that these habitats were present, but in small patches. Although scarce, these areas may provide a resource which could be enlarged.

4.9 Vegetation quality: diversity

4.9.1 Diversity can be expressed both as the variety of vegetation types and the number of plant species within a site, thus reflecting the range of variation in physical variables as well as the species richness associated with each vegetation type. The number of 'plot classes' present indicates the diversity of different vegetation types or habitats; the number of 'species groups' recorded is used to assess the species richness. The number of species recorded in quadrats is not reported as it cannot be directly related to quality, without taking account of the types of species present; for example, high species number may reflect either a 'high'-quality site or one which includes invasive grassland or woodland species. (See para 4.9.6 for discussion of species groups).

Number of different plot classes

4.9.2 The classification of quadrats into 'plot classes' has been used to consider the average range of vegetation present in each square, ie the higher the mean number of classes present in squares in a stratum, the greater the diversity of vegetation (Table 4.7). Overall, the waterside landscape is dominated by grasslands with significant areas of woodland, neglected and coarse grassland, together with tall herb vegetation. Only 1% of the main plots were in damp grasslands, and none in the water edge and wetland vegetation types. Because these main plots are randomly located, these proportions can be taken as being indicative of the relative areas of the more common vegetation types. The targeted habitat plots recorded more core wetland vegetation.

4.9.3 In the main plots, the number of different plot classes is quite consistent between strata, except for the non-designated arable stratum, where it is about half that of the rest, indicating that the latter is more uniform. Overall, just under one plot class is recorded, in main plots, in each square, indicating relative homogeneity. The diversity of vegetation types is slightly higher in the designated strata and is lowest in the arable strata.

4.9.4 The waterside plots which are randomly located alongside rivers, streams, ditches and canals show a much greater diversity of plot classes, especially in the arable strata, where they are more than twice as diverse, using this measure. These waterside plots include the greatest range of core waterside classes overall, although these plot classes are absent from the upland waterside plots. The targeted habitat plots also represent a greater diversity of plot classes than the main plots, and have nearly the same range of core waterside classes as the waterside plots. (See Section 4.11 for more detailed discussion of plot class composition).

Number of species groups

4.9.5 Species have been classified into 'species groups' to consider the range of different types of species present in each square (Table 4.8). Overall, the waterside landscape is dominated by managed grassland species, but moist grassland species are also important. Water edge and marsh species represent only 5% of records in the main plots, but 12% in the habitat plots and 34% in waterside plots.

4.9.6 The main plots, although much larger (200 m²) than the habitat (4 m²) and waterside plots (1 m x 10 m), include a smaller range of species groups per square. This is also true if just the waterside and wet grassland species groups are considered. For all plots, the designated squares include a slightly greater range of species groups than the non-designated squares. For the main plots, the pastural strata are more diverse than the arable and upland strata. For habitat and waterside plots, the pastural strata are most diverse. (See Section 4.11 for more detailed discussion of species group composition).

Summary of diversity as a quality criterion

4.9.7 The pastural strata showed the greatest diversity of species groups in all plot types, and of vegetation types in the main and habitat plots. The waterside plots, although only small in area, generally had twice as many species groups and vegetation types. They were also more diverse than the habitat plots in terms of core waterside species groups and vegetation types.

4.9.8 Although the waterside landscape has been defined as quite a narrow strip beside water bodies, the presence of core waterside plot classes in waterside plots but not in main plots shows that there is zonation within this buffer. Thus, most of the vegetation associated with wet or waterlogged land is concentrated immediately adjacent to the watercourses, rather than extending back the full 150 m. The same pattern is shown by the species groups, fewer of which are represented in the main plots compared to waterside plots, despite their larger size. The waterside plots include the greatest range of species groups, both overall and for the core species groups. This shows that there is a very narrow corridor containing wetland habitats, although it might be possible to expand this corridor, if conditions allowed these species to spread. In particular, those species which disperse via water may colonise areas which become suitable.

Table 4.8 Mean number of different species groups represented per square, by stratum

Strata	Main plots (200 m²) All SGs	Main plots *SG 3,7,8*	Habitat plots (4 m²) All SG	Habitat plots *SG 3,7,8*	Waterside plots (1 m x 10 m) All SG	Waterside plots *SG 3,7,8*
Designated arable	3.8	1.1	4.9	1.5	6.1	1.9
Non-designated arable	1.8	0.5	5.7	1.7	6.5	2.2
Designated pastural	3.9	1.0	6.3	2.2	7.3	2.6
Non-designated pastural	4.0	1.3	5.3	2.0	6.2	2.2
Designated upland	3.2	1.2	3.2	1.1	5.6	2.1
Non-designated upland	4.0	1.3	4.3	1.5	5.8	2.0
Combined designated	3.8	1.1	5.5	1.8	6.6	2.2
Combined non-designated	3.2	1.0	5.2	1.8	6.2	2.1
Combined arable	3.1	0.9	5.2	1.6	6.3	2.0
Combined pastural	3.9	1.1	5.9	2.1	6.9	2.4
Combined upland	3.9	1.2	4.1	1.4	5.7	2.0
Total	*3.6*	*1.0*	*5.3*	*1.8*	*6.5*	*2.2*

Species groups (SG) 3,7,8 represent the waterside and wet grassland groups, ie core species groups - see Table 4.3

4.10 Vegetation quality: naturalness

4.10.1 'Natural' is a term sometimes applied to vegetation which is considered to be unmodified by human influence – it probably cannot be strictly applied to any habitat in England. Waterside landscapes may include a number of semi-natural habitats of conservation interest, including wetlands, wet meadows and tall herb vegetation. In this context, naturalness is used as a measure of the extent of modification or disturbance away from the optimum required to maintain an area as semi-natural. Too little 'modification' may allow succession to scrub and woodland; too much may move the vegetation towards uniform grassland. Such modification or disturbance is indicated by the presence of species which are not normally associated with waterside habitats. The proportion of non-wetland species in each plot gives an indication as to the degree of disturbance or succession which is occurring.

Numbers of habitat indicator species

4.10.2 The classification into 'habitat indicator groups' has been used to examine the relative importance of species associated with different types of habitat (Table 4.9). The main plots (representative of the more common habitats) are dominated by neutral/calcareous grassland species and ruderal species, with a significant component of woodland species. Very few records were for core waterside species. This implies that wetland and wet grassland species have largely disappeared from the majority of the waterside landscape.

4.10.3 The habitat plots were also dominated by neutral/calcareous grassland, ruderal and woodland species, but there were more records of core waterside species. The waterside species were most common in the pastural strata. There was little difference between the designated and non-designated strata.

4.10.4 The waterside plots were also dominated by neutral/calcareous grassland, ruderal and woodland species, but there were more records of the core waterside species. The waterside species were most common in the lowland strata, whilst wet and moist grassland species were more common in the uplands. Again, there was little difference between the designated and non-designated strata.

Summary of naturalness as a quality criterion

4.10.5 Waterside and wet grassland species were uncommon in the main plots, implying that these species are scarce and so are not recorded by randomly located plots. Moist grassland species were recorded in main plots, particularly in the arable strata. Wetland and wet grassland species were recorded in habitat and waterside plots, indicating that the less-disturbed semi-natural wetland vegetation occurs immediately adjacent to water bodies, and in small fragments within the landscape. The dominance of even the waterside plots by grassland, ruderal and woodland species indicates that many streamsides are experiencing too much or too little disturbance, allowing domination by weedy or woody species. The indications of disturbance imply a lack of 'naturalness', although the succession to scrub and woodland is a 'natural' process. The lack of difference in the proportion of waterside and wetland species between the designated and non-designated strata suggests that wider countryside policy and management are required to maintain and enhance waterside vegetation.

4.11 Vegetation quality: representativeness

4.11.1 Representativeness involves using a classification of the range of vegetation being considered to allow comparison of examples of the same type. It is used to ensure that examples of the full range of types present within a region are protected, as well as giving emphasis to those which are 'typical'. The range of vegetation present is described here using the classification of quadrats into 'plot classes', and of species into 'species groups'.

Relative abundance of plot classes

4.11.2 None of the main plots were classified into the three core waterside plot classes (PCF–PCH), ie these vegetation types were not present in sufficient quantity to be sampled by the random plots. There are, however, a few examples of damp acid grassland (PCM), mostly from the designated upland stratum, which also includes plots in the wet heath (PCO) class. Overall, the main plots are dominated by semi-improved (PCI) and improved (PCJ) grassland (plots from

Table 4.9 Mean number of species per plot for each habitat indicator groups

	Arable				Pastural				Upland				Combined				Combined							
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Arable		Pastural		Upland		Total	
Habitat indicator groups	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Main plots (200 m²)																								
Waterside species	0.3	*1*	0.0	*0*			0.1	*0*	0.1	*1*		*0*	0.1	*1*	0.0	*0*	0.2	*1*	0.0	*0*	0.0	*0*	0.1	*1*
Wet grassland species	0.5	*2*	0.2	*1*	0.1	*0*	0.4	*2*	0.3	*2*		*0*	0.3	*1*	0.2	*1*	0.4	*2*	0.2	*1*	0.1	*0*	0.2	*1*
Moist grassland species	1.7	*8*	1.3	*8*	1.1	*6*	1.3	*8*	1.3	*7*	0.8	*3*	1.4	*7*	1.2	*6*	1.6	*8*	1.2	*7*	0.9	*4*	1.3	*7*
Wet heath/bog species	0.1	*1*					0.1	*0*	2.5	*13*	0.2	*1*	0.2	*1*	0.1	*0*	0.1	*0*	0.0	*0*	0.6	*3*	0.1	*1*
Acid grass/dry heath species	0.2	*1*	0.1	*1*	0.7	*4*	0.5	*3*	5.9	*32*	0.8	*3*	0.7	*3*	0.4	*2*	0.2	*1*	0.6	*3*	1.8	*7*	0.6	*3*
Neutral/calcareous grassland species	7.9	*36*	7.1	*42*	10.6	*61*	9.0	*52*	5.1	*28*	19.6	*78*	9.0	*45*	11.0	*57*	7.6	*38*	10.0	*57*	16.8	*71*	9.9	*50*
Wood edge/scrub species	1.2	*5*	1.5	*9*	0.3	*2*	0.4	*2*	0.1	*1*			0.8	*4*	0.7	*4*	1.3	*6*	0.3	*2*	0.0	*0*	0.7	*4*
Woodland species	5.0	*23*	2.7	*16*	1.8	*10*	2.3	*13*	2.3	*12*	1.4	*6*	3.5	*17*	2.2	*12*	4.2	*21*	2.0	*11*	1.6	*7*	2.9	*15*
Ruderal species	4.6	*21*	3.6	*21*	2.7	*16*	3.2	*18*	0.7	*4*	2.2	*9*	3.6	*18*	3.1	*16*	4.3	*21*	2.9	*17*	1.9	*8*	3.4	*17*
Alien species	0.4	*2*	0.4	*2*	0.1	*1*	0.2	*1*	0.1	*1*			0.3	*1*	0.2	*1*	0.4	*2*	0.2	*1*	0.0	*0*	0.3	*1*
All	*21.9*	*100*	*17.0*	*100*	*17.4*	*100*	*17.4*	*100*	*18.5*	*100*	*25.0*	*100*	*19.7*	*100*	*19.2*	*100*	*20.2*	*100*	*17.4*	*100*	*23.7*	*100*	*19.5*	*100*
Habitat plots (4 m²)																								
Waterside species	0.2	*2*	0.7	*6*	1.1	*7*	1.2	*7*	0.6	*4*	0.7	*4*	0.6	*4*	0.9	*6*	0.4	*3*	1.2	*7*	0.7	*4*	0.7	*5*
Wet grassland species	0.3	*2*	0.2	*1*	0.8	*5*	0.8	*5*	1.1	*7*	1.0	*6*	0.5	*4*	0.6	*4*	0.3	*2*	0.8	*5*	1.0	*6*	0.6	*4*
Moist grassland species	1.0	*8*	0.9	*7*	1.4	*9*	1.9	*11*	1.5	*9*	1.2	*7*	1.2	*8*	1.3	*9*	0.9	*8*	1.6	*10*	1.2	*7*	1.3	*9*
Wet heath/bog species	0.1	*1*	0.1	*1*	0.3	*2*	0.2	*1*	3.8	*23*	1.0	*6*	0.4	*3*	0.4	*2*	0.1	*1*	0.3	*2*	1.5	*9*	0.4	*3*
Acid grass/dry heath species	0.1	*1*	0.0	*0*	0.6	*4*	0.5	*3*	2.9	*18*	3.0	*17*	0.5	*3*	1.0	*6*	0.1	*1*	0.5	*3*	3.0	*17*	0.7	*5*
Neutral/calcareous grassland species	6.0	*48*	5.1	*45*	5.9	*37*	5.8	*34*	3.2	*20*	5.0	*29*	5.9	*41*	5.3	*36*	5.7	*47*	5.9	*36*	4.7	*27*	5.6	*39*
Wood edge/scrub species	1.0	*8*	0.9	*8*	1.3	*8*	1.5	*9*	0.1	*1*	0.5	*3*	1.1	*7*	1.0	*7*	0.9	*8*	1.4	*8*	0.4	*2*	1.0	*7*
Woodland species	1.4	*11*	1.2	*10*	3.1	*19*	3.0	*18*	2.4	*14*	4.7	*27*	2.2	*15*	2.8	*19*	1.4	*11*	3.1	*19*	4.2	*25*	2.5	*17*
Ruderal species	2.3	*18*	2.2	*19*	1.3	*8*	1.9	*11*	0.8	*5*	0.3	*2*	1.8	*12*	1.6	*11*	2.2	*18*	1.5	*9*	0.4	*2*	1.7	*12*
Alien species	0.1	*1*	0.1	*1*	0.2	*1*	0.1	*1*	0.1	*0*		*0*	0.2	*1*	0.1	*1*	0.1	*1*	0.2	*1*	0.0	*0*	0.1	*1*
All	*12.6*	*100*	*11.4*	*100*	*16.0*	*100*	*16.9*	*100*	*16.4*	*100*	*17.3*	*100*	*14.3*	*100*	*15.0*	*100*	*12.2*	*100*	*16.3*	*100*	*17.2*	*100*	*14.6*	*100*
Waterside plots (1 m x 10 m)																								
Waterside species	1.50	*9*	1.88	*10*	1.40	*6*	2.02	*10*	1.12	*4*	0.43	*2*	1.44	*7*	1.56	*7*	1.63	*9*	1.64	*7*	0.56	*2*	1.49	*7*
Wet grassland species	0.53	*3*	0.54	*3*	1.11	*5*	0.79	*4*	1.77	*7*	2.14	*8*	0.84	*4*	1.05	*5*	0.53	*3*	0.98	*4*	2.07	*8*	0.93	*5*
Moist grassland species	1.58	*9*	1.78	*10*	1.96	*9*	1.84	*9*	2.19	*8*	2.86	*11*	1.78	*9*	2.08	*10*	1.65	*9*	1.91	*9*	2.73	*11*	1.91	*9*
Wet heath/bog species	0.03	*0*	0.15	*1*	0.26	*1*	0.14	*1*	3.92	*15*	0.57	*2*	0.31	*2*	0.25	*1*	0.07	*0*	0.21	*1*	1.22	*5*	0.29	*1*
Acid grass/dry heath species	0.08	*0*	0.07	*0*	0.49	*2*	0.26	*1*	4.08	*16*	1.71	*7*	0.45	*2*	0.56	*3*	0.08	*0*	0.40	*2*	2.17	*8*	0.50	*2*
Neutral/calcareous grassland species	4.94	*29*	5.25	*29*	5.30	*23*	4.21	*20*	5.58	*22*	7.14	*27*	5.13	*25*	5.34	*25*	5.05	*29*	4.87	*22*	6.84	*26*	5.22	*25*
Wood edge/scrub species	1.92	*11*	2.23	*12*	2.39	*10*	2.81	*13*	0.73	*3*	1.43	*5*	2.07	*10*	2.25	*11*	2.03	*12*	2.56	*11*	1.29	*5*	2.15	*10*
Woodland species	3.11	*18*	1.97	*11*	6.16	*27*	4.35	*21*	5.23	*20*	7.00	*27*	4.56	*22*	4.17	*20*	2.72	*15*	5.45	*25*	6.66	*26*	4.39	*21*
Ruderal species	3.44	*20*	4.06	*22*	3.44	*15*	4.07	*19*	1.15	*4*	2.29	*9*	3.33	*16*	3.61	*17*	3.65	*21*	3.69	*17*	2.07	*8*	3.45	*17*
Alien species	0.17	*1*	0.13	*1*	0.58	*3*	0.39	*2*	0.15	*1*	0.43	*2*	0.35	*2*	0.31	*1*	0.16	*1*	0.51	*2*	0.38	*1*	0.33	*2*
All	*17.3*	*100*	*18.1*	*100*	*23.1*	*100*	*20.9*	*100*	*25.9*	*100*	*26.0*	*100*	*20.3*	*100*	*21.2*	*100*	*17.6*	*100*	*22.2*	*100*	*26.0*	*100*	*20.7*	*100*

The figures for combined strata are weighted by stratum area

arable fields were excluded from the analysis).

4.11.3 A greater range of plot classes were recorded by habitat plots. More plots were recorded in the damp acid grasslands (PCM), especially in the uplands, and in the damp neutral grasslands (PCL), mostly in the pastural strata. There were also plots recorded in the water edge/marsh (PCH), tall herb (PCE) and waterside tall herb (PCF) classes, mostly in the lowlands, with the greatest proportion in the pastural strata.

4.11.4 The waterside plots (Table 4.11) were dominated by tall herb (PCE) and woodland plot classes (especially PCA). The disturbed/eutrophic water edge class (PCG) was only recorded in waterside plots, where it accounted for 7% of the plots. The waterside tall herb class (PCF) was more common in the waterside plots, but the water edge/marsh category was less common than in the habitat plots. Together, though, the core plot classes (PCF–PCH) occurred in higher proportions in the waterside plots in the lowlands, but were absent from the uplands, indicating that these habitats mostly occur in the lowlands and are replaced by wet heath, bog and acid grassland in the uplands. There was no significant difference between the designated and non-designated squares.

Relative abundance of species groups

4.11.5 The main plots are dominated by managed grassland species (SG9) and moist grassland species (SG7) (Table 4.12). In the uplands, the acid grassland species (SG10) are also common. Waterside species (SG3) were uncommon in the main plots and found mostly in the arable strata.

4.11.6 In the habitat plots, the waterside species (SG3) were recorded more frequently, especially in the pastural strata. The highest proportion of waterside and wet grassland species (SG3, SG7, SG8) was recorded in the pastural strata.

4.11.7 A higher proportion of waterside species (SG3) and impeded drainage/marsh species (SG8) were recorded in the waterside plots, but moist grassland species (SG7) occurred at similar frequencies to the main and habitat plots. The pastural strata again had the highest average number of waterside species (SG3) per plot. In all three plot types, there was little difference between the designated and non-designated strata.

Summary of representativeness as a quality criterion

4.11.8 The randomly located main plots did not include waterside or wetland habitats but a range of plot classes from these habitats was recorded in the waterside and habitat plots. Most plot classes were recorded in all strata, with the exception of the wet heath and acid grassland classes which were mostly restricted to the uplands. There was little difference between the designated and non-designated strata. Waterside and wet grassland species were recorded most often in main plots in the uplands. In the lowlands they were more frequently found in waterside and habitat plots, where they were more common in the pastural landscapes. Wetland and tall herb species were more frequent in waterside plots compared to main and habitat plots, showing that these species are largely restricted to within a few metres of the water edge.

4.11.9 These figures show that landscape type and plot type (ie the part of the waterside landscape sampled) have far more influence on the proportion of wetland and wet grassland vegetation types and species than the presence of a designation.

4.12 Vegetation quality: rarity

4.12.1 The survey strategy employed for this project is designed to record representative examples of waterside vegetation, not rare types or rare species; although such species may be recorded, it is not possible to make any general statements about their abundance or distribution.

4.12.2 The vascular species recorded have been checked against the *Red Data Book* (RDB) list of species, and against the 'Nationally scarce' species list defined *in Guidelines for selection of biological SSSIs* (NCC 1989). The only RDB species was box (*Buxus sempervirens*). Nationally scarce species included shady horsetail (*Equisetum pratense*), wavy St John's wort (*Hypericum undulatum*), chestnut rush (*Juncus castaneus*), and marsh dock (*Rumex palustris*).

Table 4.10 Mean number of main and habitat quadrats per square, in each plot class, by strata

Plot class	Arable Designated Mean	%	Arable Non-des Mean	%	Pastural Designated Mean	%	Pastural Non-des Mean	%	Upland Designated Mean	%	Upland Non-des Mean	%	Combined Designated Mean	%	Combined Non-des Mean	%	Combined Arable Mean	%	Combined Pastural Mean	%	Combined Upland Mean	%	Total Mean	%
Main plots (200 m²)																								
PCA Woodland on heavy soils	0.13	*13*	0.03	*4*	0.14	*10*	0.17	*12*	0.08	*5*			0.13	*11*	0.08	*7*	0.09	*11*	0.16	*11*	0.01	*1*	0.11	*9*
PCB Basic/eutrophic woodland	0.06	*7*	0.03	*4*									0.03	*3*	0.01	*1*	0.05	*6*					0.02	*2*
PCC Open/disturbed woodland	0.06	*7*	0.05	*8*									0.03	*3*	0.02	*2*	0.06	*7*					0.03	*2*
PCD Coarse grassland	0.06	*7*	0.03	*4*									0.03	*3*	0.01	*1*	0.05	*6*					0.02	*2*
PCE Tall herb	0.06	*7*	0.03	*4*									0.03	*3*	0.01	*1*	0.05	*6*					0.02	*2*
PCF Waterside tall herb																								
PCG Disturbed/eutrophic water edge																								
PCH Water edge/marsh																								
PCI Semi-improved grassland	0.06	*7*	0.08	*12*	0.38	*28*	0.35	*24*	0.23	*14*	1.00	*80*	0.21	*18*	0.42	*38*	0.07	*8*	0.37	*26*	0.85	*65*	0.30	*27*
PCJ Improved grassland	0.19	*20*	0.10	*17*	0.76	*55*	0.43	*30*			0.25	*20*	0.43	*37*	0.27	*25*	0.16	*19*	0.63	*45*	0.20	*15*	0.36	*32*
PCK Neglected grassland	0.19	*20*	0.18	*29*			0.17	*12*					0.10	*8*	0.13	*12*	0.18	*22*	0.07	*5*			0.11	*10*
PCL Damp neutral grassland																								
PCM Damp acid grassland							0.04	*3*	0.23	*14*			0.01	*1*	0.02	*2*	0.00	*0*	0.02	*1*	0.04	*3*	0.01	*1*
PCN Short-term grassland	0.13	*13*	0.10	*17*	0.10	*7*	0.26	*18*					0.11	*9*	0.14	*13*	0.12	*14*	0.16	*11*	0.00	*0*	0.12	*11*
PCO Wet heath									0.23	*14*			0.01	*1*							0.04	*3*	0.01	*1*
PCP Acid grassland									0.85	*52*			0.04	*3*							0.16	*12*	0.02	*2*
Plot classes F–H	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*	0.00	*0*
All	*0.94*	*100*	*0.62*	*100*	*1.38*	*100*	*1.43*	*100*	*1.62*	*100*	*1.25*	*100*	*1.17*	*100*	*1.09*	*100*	*0.83*	*100*	*1.40*	*100*	*1.32*	*100*	*1.13*	*100*
Habitat plots (4 m²)																								
PCA Woodland on heavy soils	0.06	*4*	0.10	*4*	0.48	*24*	0.35	*16*	0.15	*8*	0.25	*17*	0.25	*14*	0.23	*11*	0.08	*4*	0.43	*21*	0.23	*15*	0.24	*12*
PCB Basic/eutrophic woodland	0.13	*7*	0.13	*5*	0.10	*5*	0.09	*4*					0.11	*6*	0.08	*4*	0.13	*6*	0.09	*5*			0.09	*5*
PCC Open/disturbed woodland	0.06	*4*	0.15	*6*	0.14	*7*	0.17	*8*					0.10	*5*	0.12	*6*	0.09	*5*	0.16	*8*			0.11	*5*
PCD Coarse grassland	0.31	*19*	0.74	*29*	0.14	*7*	0.13	*6*					0.22	*12*	0.32	*15*	0.46	*23*	0.14	*7*			0.26	*13*
PCE Tall herb	0.13	*7*	0.13	*5*			0.09	*4*					0.06	*4*	0.08	*4*	0.13	*6*	0.03	*2*			0.07	*4*
PCF Waterside tall herb			0.15	*6*			0.09	*4*							0.09	*4*	0.05	*3*	0.03	*2*			0.04	*2*
PCG Disturbed/eutrophic water edge																								
PCH Water edge/marsh	0.13	*7*	0.31	*12*	0.43	*22*	0.30	*14*			0.25	*17*	0.25	*14*	0.29	*14*	0.19	*9*	0.38	*19*	0.20	*13*	0.27	*14*
PCI Semi-improved grassland	0.38	*22*	0.21	*8*	0.43	*22*	0.26	*12*					0.38	*21*	0.17	*8*	0.32	*16*	0.36	*18*	0.00	*0*	0.29	*15*
PCJ Improved grassland			0.10	*4*			0.13	*6*					0.00	*0*	0.09	*4*	0.04	*2*	0.05	*3*	0.00	*0*	0.04	*2*
PCK Neglected grassland	0.31	*19*	0.54	*21*	0.19	*10*	0.17	*8*					0.24	*13*	0.26	*12*	0.39	*20*	0.18	*9*	0.00	*0*	0.25	*13*
PCL Damp neutral grassland	0.06	*4*			0.05	*2*	0.13	*6*	0.08	*4*			0.06	*3*	0.05	*2*	0.04	*2*	0.08	*4*	0.01	*1*	0.05	*3*
PCM Damp acid grassland	0.06	*4*					0.17	*8*	0.38	*20*	0.75	*50*	0.05	*3*	0.26	*12*	0.04	*2*	0.07	*3*	0.68	*43*	0.14	*7*
PCN Short-term grassland	0.06	*4*							0.62	*32*			0.06	*3*			0.04	*2*			0.12	*8*	0.03	*2*
PCO Wet heath																								
PCP Acid grassland							0.09	*4*	0.69	*36*	0.25	*17*	0.03	*2*	0.10	*5*			0.03	*2*	0.34	*21*	0.06	*3*
Plot classes F–H	0.13	*7*	0.46	*18*	0.43	*22*	0.39	*18*	0.00	*0*	0.25	*17*	0.25	*14*	0.38	*18*	0.24	*12*	0.41	*20*	0.20	*13*	0.31	*16*
All	*1.69*	*100*	*2.56*	*100*	*1.95*	*100*	*2.17*	*100*	*1.92*	*100*	*1.50*	*100*	*1.82*	*100*	*2.14*	*100*	*1.99*	*100*	*2.04*	*100*	*1.58*	*100*	*1.96*	*100*

The figures for combined strata are weighted by stratum area

Table 4.11 Mean number of waterside quadrats per square, in each plot class, by strata

Plot	Arable				Pastural				Upland				Combined				Combined							
	Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-des		Arable		Pastural		Upland		Total	
class	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
Waterside plots (1 m x 10 m)																								
PCA Woodland on heavy soils	0.19	8	0.03	1	0.95	35	0.48	19	0.15	8	0.50	29	0.53	22	0.32	14	0.13	6	0.77	29	0.43	24	0.44	18
PCB Basic/eutrophic woodland	0.19	8	0.26	10	0.14	5	0.13	5	0.08	4			0.16	7	0.14	6	0.21	9	0.14	5	0.01	1	0.15	6
PCC Open/disturbed woodland	0.06	3	0.13	5			0.09	4					0.03	1	0.08	3	0.09	4	0.03	1			0.05	2
PCD Coarse grassland	0.13	6	0.44	17	0.06	2	0.30	12			0.25	14	0.08	3	0.34	14	0.23	10	0.15	6	0.20	11	0.19	8
PCE Tall herb	0.75	33	0.95	36	0.14	5	0.57	23					0.45	18	0.56	24	0.82	34	0.31	12			0.49	21
PCF Waterside tall herb	0.19	8	0.23	9			0.22	9					0.10	4	0.17	7	0.20	9	0.09	3			0.13	5
PCG Disturbed/eutrophic water edge	0.06	3	0.15	6	0.29	11	0.30	12					0.16	7	0.17	7	0.09	4	0.29	11			0.16	7
PCH Water edge/marsh	0.19	8	0.10	4	0.24	9	0.09	4					0.20	8	0.07	3	0.16	7	0.18	7			0.15	6
PCI Semi-improved grassland			0.06	2											0.02	1	0.02	1					0.01	0
PCJ Improved grassland	0.06	3			0.33	12					0.25	14	0.18	7	0.06	3	0.04	2	0.20	8	0.20	11	0.13	5
PCK Neglected grassland	0.31	14	0.28	11	0.14	5							0.22	9	0.10	4	0.30	13	0.09	3			0.17	7
PCL Damp neutral grassland	0.13	6			0.24	9	0.17	7					0.17	7	0.07	3	0.08	3	0.21	8			0.13	5
PCM Damp acid grassland					0.19	7	0.13	5	0.46	23	0.75	43	0.11	4	0.24	10			0.17	6	0.69	39	0.16	7
PCN Short-term grassland																								
PCO Wet heath									0.69	35			0.03	1							0.13	7	0.02	1
PCP Acid grassland									0.62	31			0.03	1							0.12	7	0.02	1
Plot classes F–G	0.44	19	0.49	19	0.52	19	0.61	25	0.00	0	0.00	0	0.46	19	0.41	17	0.45	19	0.56	21	0.00	0	0.44	18
All	*2.25*	*100*	*2.62*	*100*	*2.71*	*100*	*2.48*	*100*	*2.00*	*100*	*1.75*	*100*	*2.44*	*100*	*2.34*	*100*	*2.38*	*100*	*2.62*	*100*	*1.80*	*100*	*2.40*	*100*

The figures for combined strata are weighted by stratum area

Table 4.12 Mean number of species records per quadrat, for each species group, by strata

Species group	Description	Arable				Pastural				Upland				Combined				Combined							
		Designated		Non-des		Designated		Non-des		Designated		Non-des		Designated		Non-designate		Arable		Pastural		Upland		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Main plots (200 m²)																									
1	Eutrophic woodland species	1.0	*7*	0.9	*7*	0.3	*2*	0.5	*3*	0.1	*1*			0.7	*4*	0.5	*3*	1.0	*7*	0.4	*2*	0.0	*0*	0.6	*4*
2	Bramble/tall herb species	1.2	*8*	1.1	*8*	0.3	*2*	0.2	*1*					0.8	*5*	0.5	*3*	1.2	*8*	0.2	*2*			0.6	*4*
3	Waterside species	0.3	*2*	0.3	*2*	0.0	*0*	0.1	*0*					0.2	*1*	0.1	*1*	0.3	*2*	0.0	*0*			0.1	*1*
4	Coarse grassland species	0.6	*4*	0.7	*5*	0.1	*1*	0.1	*0*					0.4	*2*	0.3	*2*	0.6	*4*	0.1	*1*			0.3	*2*
5	Woodland species on heavy soils	2.1	*14*	1.3	*9*	0.8	*5*	1.2	*8*	0.8	*7*	0.8	*4*	1.5	*10*	1.1	*7*	1.8	*12*	1.0	*6*	0.8	*4*	1.3	*8*
6	Ruderal species	1.0	*7*	1.1	*8*	1.1	*7*	1.4	*9*	0.3	*3*	0.6	*3*	1.0	*7*	1.1	*7*	1.0	*7*	1.2	*8*	0.5	*3*	1.0	*7*
7	Moist grassland species	3.6	*24*	3.0	*23*	3.4	*22*	3.2	*22*	1.5	*14*	5.2	*24*	3.4	*23*	3.6	*23*	3.4	*23*	3.3	*22*	4.5	*23*	3.5	*23*
8	Impeded drainage/marsh species	0.8	*5*	0.3	*2*	0.4	*3*	0.9	*6*	1.3	*12*	0.4	*2*	0.7	*4*	0.6	*4*	0.6	*4*	0.6	*4*	0.6	*3*	0.6	*4*
9	Managed grassland species	4.3	*28*	4.1	*31*	7.2	*48*	6.1	*42*	2.0	*18*	10.8	*50*	5.5	*37*	6.6	*41*	4.2	*29*	6.8	*45*	9.1	*47*	6.0	*39*
10	Acid grassland species	0.4	*3*	0.6	*4*	1.4	*10*	1.2	*8*	4.9	*45*	3.6	*17*	1.1	*7*	1.6	*10*	0.5	*3*	1.3	*9*	3.9	*20*	1.3	*8*
Waterside/moist grass species (3,7,8)		4.7	*31*	3.6	*27*	3.8	*25*	4.2	*29*	2.8	*25*	5.6	*26*	4.2	*28*	4.3	*27*	4.3	*30*	4.0	*26*	5.1	*26*	4.3	*28*
All		*15.2*	*100*	*13.4*	*100*	*15.2*	*100*	*14.6*	*100*	*10.9*	*100*	*21.4*	*100*	*15.0*	*100*	*15.9*	*100*	*14.6*	*100*	*15.0*	*100*	*19.4*	*100*	*15.4*	*100*
Habitat plots (4 m²)																									
1	Eutrophic woodland species	0.3	*3*	0.3	*4*	0.9	*8*	0.7	*5*	0.2	*3*	0.3	*3*	0.6	*5*	0.5	*4*	0.3	*3*	0.8	*7*	0.3	*3*	0.5	*5*
2	Bramble/tall herb species	0.9	*10*	1.1	*12*	0.9	*7*	1.0	*8*	0.1	*1*	0.3	*3*	0.9	*8*	0.9	*8*	1.0	*11*	0.9	*8*	0.3	*3*	0.9	*8*
3	Waterside species	0.3	*3*	0.5	*6*	0.7	*6*	0.9	*7*	0.2	*2*	0.5	*5*	0.5	*4*	0.6	*6*	0.4	*4*	0.8	*6*	0.4	*4*	0.5	*5*
4	Coarse grassland species	0.5	*5*	1.0	*11*	0.4	*3*	0.3	*3*	0.1	*1*			0.4	*4*	0.5	*4*	0.7	*7*	0.4	*3*	0.0	*0*	0.5	*4*
5	Woodland species on heavy soils	0.8	*8*	0.5	*6*	1.0	*9*	1.3	*11*	0.8	*10*	1.8	*17*	0.9	*9*	1.2	*11*	0.7	*7*	1.1	*10*	1.6	*16*	1.0	*10*
6	Ruderal species	0.3	*3*	0.5	*6*	0.3	*3*	0.4	*3*	0.1	*1*	0.2	*2*	0.3	*3*	0.4	*4*	0.4	*4*	0.3	*3*	0.2	*2*	0.3	*3*
7	Moist grassland species	1.9	*20*	2.1	*24*	2.3	*19*	3.3	*26*	0.6	*7*	1.7	*16*	2.0	*19*	2.4	*23*	1.9	*21*	2.7	*22*	1.5	*14*	2.2	*21*
8	Impeded drainage/marsh species	0.5	*5*	0.2	*2*	1.1	*9*	1.1	*9*	1.6	*20*	1.0	*9*	0.8	*8*	0.7	*7*	0.4	*4*	1.1	*9*	1.1	*11*	0.8	*7*
9	Managed grassland species	3.5	*37*	2.4	*27*	3.1	*27*	2.8	*23*	1.2	*14*	1.7	*16*	3.2	*31*	2.3	*22*	3.1	*34*	3.0	*25*	1.6	*15*	2.8	*27*
10	Acid grassland species	0.5	*5*	0.2	*2*	1.0	*9*	0.7	*6*	3.5	*42*	3.2	*30*	0.9	*8*	1.1	*11*	0.4	*4*	0.9	*7*	3.2	*32*	1.0	*9*
Waterside/moist grass species (3,7,8)		2.7	*28*	2.8	*32*	4.1	*35*	5.2	*42*	2.4	*28*	3.2	*30*	3.3	*31*	3.8	*36*	2.7	*29*	4.5	*38*	3.0	*29*	3.5	*33*
All		*9.6*	*100*	*8.7*	*100*	*11.7*	*100*	*12.3*	*100*	*8.4*	*100*	*10.7*	*100*	*10.5*	*100*	*10.6*	*100*	*9.3*	*100*	*11.9*	*100*	*10.2*	*100*	*10.5*	*100*
Waterside plots (1 m x 10 m)																									
1	Eutrophic woodland species	1.1	*8*	0.9	*7*	2.9	*16*	2.2	*14*	1.0	*6*	1.6	*9*	1.9	*12*	1.6	*10*	1.1	*8*	2.6	*15*	1.5	*8*	1.8	*11*
2	Bramble/tall herb species	1.6	*11*	1.9	*13*	1.5	*9*	1.5	*10*	0.2	*1*	0.9	*5*	1.5	*10*	1.5	*9*	1.7	*12*	1.5	*9*	0.7	*4*	1.5	*9*
3	Waterside species	1.9	*13*	2.4	*17*	1.3	*8*	2.8	*17*	0.2	*1*	0.4	*2*	1.6	*10*	2.0	*13*	2.1	*15*	1.9	*11*	0.4	*2*	1.8	*11*
4	Coarse grassland species	1.3	*9*	1.2	*9*	0.2	*1*	0.8	*5*			0.4	*2*	0.8	*5*	0.9	*5*	1.3	*9*	0.5	*3*	0.3	*2*	0.8	*5*
5	Woodland species on heavy soils	1.1	*8*	0.6	*4*	2.0	*12*	1.4	*9*	1.8	*11*	2.9	*16*	1.5	*10*	1.5	*9*	0.9	*6*	1.8	*10*	2.6	*15*	1.5	*10*
6	Ruderal species	0.6	*4*	0.9	*6*	1.3	*8*	1.1	*7*	0.3	*2*	0.3	*2*	0.9	*6*	0.8	*5*	0.7	*5*	1.3	*7*	0.3	*2*	0.9	*6*
7	Moist grassland species	3.5	*25*	3.6	*25*	3.8	*22*	3.9	*24*	1.7	*10*	3.7	*20*	3.5	*22*	3.7	*23*	3.5	*25*	3.8	*22*	3.3	*19*	3.6	*23*
8	Impeded drainage/marsh species	0.7	*5*	0.4	*3*	1.4	*8*	0.8	*5*	3.4	*20*	3.0	*16*	1.1	*7*	1.2	*8*	0.6	*4*	1.2	*7*	3.1	*17*	1.2	*7*
9	Managed grassland species	2.0	*14*	2.2	*15*	2.4	*14*	1.4	*8*	2.2	*13*	3.0	*16*	2.2	*14*	2.1	*13*	2.1	*15*	2.0	*12*	2.8	*16*	2.1	*13*
10	Acid grassland species	0.3	*2*	0.1	*1*	0.6	*4*	0.2	*2*	5.9	*35*	2.1	*12*	0.7	*5*	0.7	*4*	0.2	*2*	0.5	*3*	2.9	*16*	0.7	*4*
Waterside/moist grass species (3,7,8)		6.0	*43*	6.5	*45*	6.5	*37*	7.4	*46*	5.3	*32*	7.1	*39*	6.2	*40*	7.0	*44*	6.2	*44*	6.9	*41*	6.8	*38*	6.5	*41*
All		*14.1*	*100*	*14.3*	*100*	*17.5*	*100*	*16.2*	*100*	*16.7*	*100*	*18.3*	*100*	*15.7*	*100*	*16.0*	*100*	*14.1*	*100*	*17.0*	*100*	*18.0*	*100*	*15.8*	*100*

Table 4.13 Mean number of species per plot, for each fragility type, by strata

Threat	Plot type	Arable Desig-nated	Arable Non-des	Pastural Desig-nated	Pastural Non-des	Upland Desig-nated	Upland Non-des	Combined Desig-nated	Combined Non-des	Combined Arable	Combined Pastural	Combined Upland	Total
Canalisation/ dredging	Habitat plots ($4\ m^2$)	0.15	0.48	0.65	0.69	0.20	0.17	0.37	0.48	0.26	0.67	0.18	0.42
	Waterside plots (1 m x 10 m)	1.14	1.22	0.93	1.21	0.46	0.14	1.01	0.94	1.17	1.04	0.20	0.98
Drainage/ drying out	Habitat plots ($4\ m^2$)	0.81	1.15	2.19	2.54	1.88	2.00	1.47	1.90	0.93	2.33	1.98	1.66
	Waterside plots (1 m x 10 m)	2.64	3.25	3.09	3.51	2.92	2.86	2.85	3.25	2.85	3.26	2.87	3.02
Eutro-phication	Habitat plots ($4\ m^2$)	1.37	1.23	2.56	3.02	2.72	2.50	1.96	2.24	1.32	2.74	2.54	2.08
	Waterside plots (1 m x 10 m)	2.61	2.91	3.35	3.14	3.96	4.86	3.00	3.50	2.71	3.27	4.69	3.21
Aquatic herbicides	Habitat plots ($4\ m^2$)	0.00	0.20	0.15	0.38	0.08	0.17	0.07	0.26	0.07	0.24	0.15	0.15
	Waterside plots (1 m x 10 m)	0.36	0.37	0.28	0.26	0.31	0.14	0.32	0.27	0.36	0.27	0.17	0.30

4.13 Vegetation quality: fragility

4.13.1 Fragility reflects the degree of sensitivity of vegetation types and species to environmental change. Four types of change have been considered which may adversely affect waterside vegetation:

- canalisation/dredging;
- drainage/drying out;
- eutrophication;
- aquatic herbicides.

4.13.2 Species recorded in the waterside mask, which are sensitive to each of these four processes, have been identified. Their presence implies that an area remains relatively unaffected by these processes; therefore, the relative abundance of these species can be used as a measure of quality. Table 4.13 shows how the frequency of these species varies between strata for habitat and waterside plots (main plots have been omitted as they contain only small proportions of waterside and wetland species).

4.13.3 Canalisation, dredging and bank maintenance have most effect on the waterside plots and are largely restricted to lowland rivers and streams. Species sensitive to these processes are present in similar numbers in the arable and pastural strata. The smaller numbers in the uplands probably reflect their natural distribution, rather than implying that bank maintenance is having a detrimental effect.

4.13.4 Drainage and drying out affects both the waterside plots and the habitat plots placed on marsh, fen or wet pasture. In the lowlands, the species identified as being sensitive to these processes were most common in the pastural strata, suggesting that, in areas dominated by arable farming, the introduction of drainage systems and/or excessive water abstraction has affected them.

4.13.5 Eutrophication also affects both waterside and habitat plots. Again, species identified as sensitive to eutrophication were least common in the arable strata, suggesting that wetlands and watercourses in these areas have been particularly affected by fertilizer runoff.

4.13.6 Aquatic herbicides are likely to have most effect on the waterside plots. Plant species thought to be particularly sensitive to such treatment seem to be less common in the pastural strata than in the arable strata. They are also uncommon in the uplands, but this may be because they mainly have a lowland distribution.

4.13.7 Interpretation of these sensitive species is made difficult by the differences in natural distribution, many of them being naturally uncommon in the uplands, and by the possibly confounding effects of different processes, for instance eutrophication and the use of herbicides.

4.14 Vegetation quality: potential value

4.14.1 The value of wetland habitats, and of areas which have potential for wetland vegetation, depends on the current vegetation type, and on the potential for enhancement and restoration, the latter being affected by all the criteria discussed above.

4.14.2 Non-wetland elements of the waterside landscape can be divided into two types.

i. Land cover types which have received high management inputs and whose vegetation no longer contains any wetland species (eg arable fields, intensive grassland); although wetland creation may be possible in these situations, the current vegetation and seed bank will not influence the resulting vegetation. The areas of these land cover types available for such habitat creation schemes are shown in Appendix 1.

ii. Habitats which are derived from wetland or include wetland species; if these are on appropriate soils and hydrology, then restoration may be feasible, and the process will incorporate any wetland species present both above-ground and in the seed bank. The effort required to achieve this restoration will depend on the current vegetation, as well as on soil type, past management, and the length of time since wetland vegetation was dominant.

4.14.3 The relationships between the vegetation types recorded is shown in the ordination diagram in Figure 4.4, on which each quadrat is plotted according to its score on the first and second gradient. The first gradient separates the acid vegetation from the more neutral or calcareous vegetation. The second gradient separates the woodland, wetlands, and grassland. It is clear from this graph that there is a strong separation between the acid vegetation recorded in the uplands (on the right of the graph) and the waterside vegetation, with overlap restricted to damp mixed grassland (PCM). The water edge plot classes (PCF–PCH) are closely associated and overlap with each other. They also merge into the tall herb (PCE), coarse grassland (PCD) and neglected grassland (PCK) classes, all associated with unmanaged areas adjacent to rivers. There is also some overlap with the woodlands, particularly the open woodland (PCC). Of the grassland types, the greatest overlap is with the damp mixed grasslands (PCM) and meadows (PCK), indicating that these have more species in common with the waterside vegetation than the other grassland classes.

4.14.4 It is not possible to use this information to calculate directly the area of potential wetland vegetation. It is likely that some of the areas of vegetation from plot classes

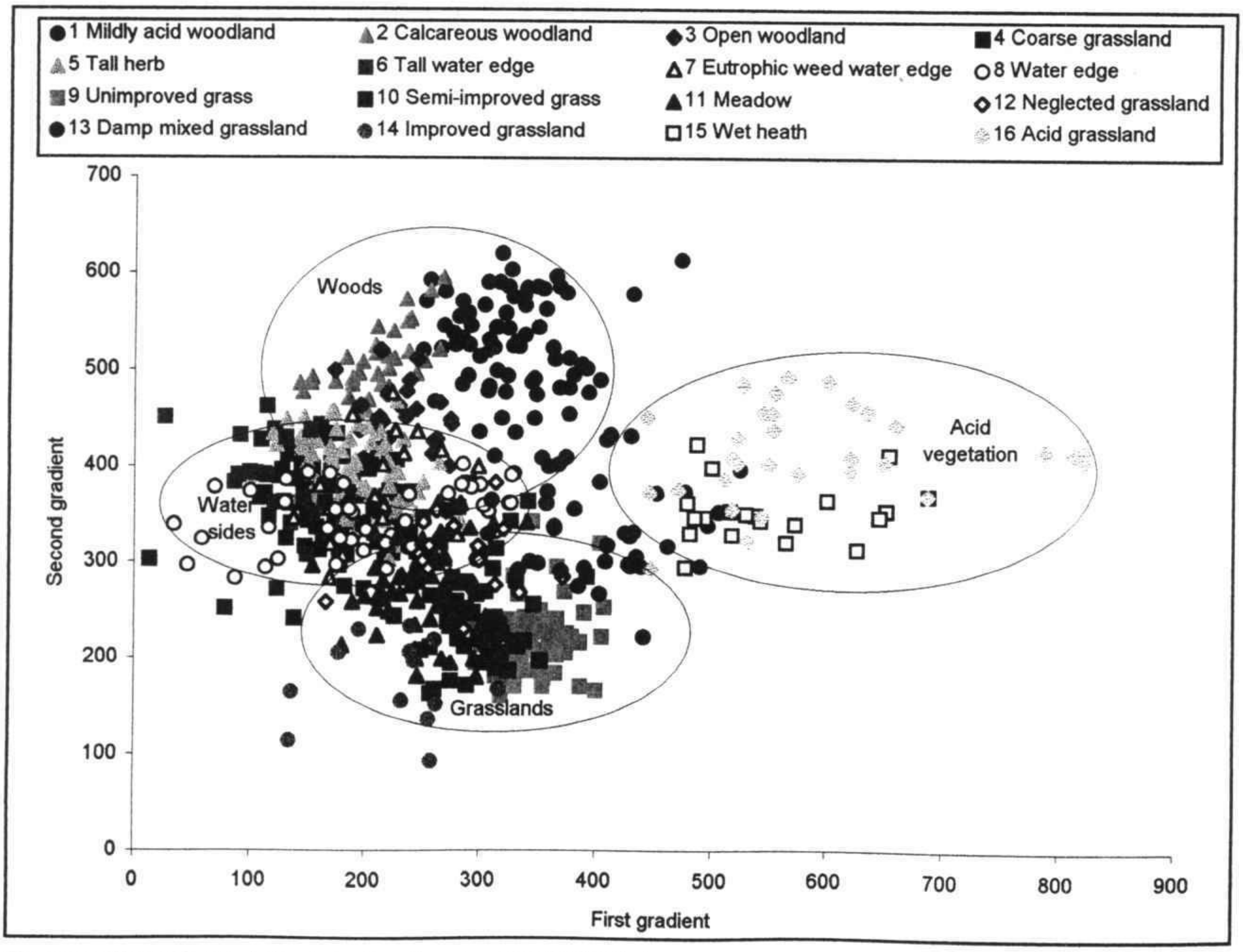

Figure 4.4 Waterside quadrats - ordination diagram using DECORANA scores

Table 4.14 Summary of waterside strata ranked by quality criteria

Quality measure	Arable Des	Arable Non-des	Pastural Des	Pastural Non-des	Upland Des	Upland Non-des
Size						
Estimated area of waterside landscape	4	3	1	2	5	6
Estimated area of wetland vegetation.	3	5	2	6	4	1
Diversity						
No. of core plot classes per square – habitat plots	5	2	3	1	6	4
No. of core plot classes per square – waterside plots	1	1	2	3	5	5
No. of core species groups per square – main plots	4	6	5	1	3	2
No. of core species groups per square – habitat plots	4	3	1	2	5	4
No. of core species groups per square – waterside plots	6	2	1	3	4	5
Naturalness						
No. of core habitat indicator species – main plots	1	4	5	2	3	6
No. of core habitat indicator species – habitat plots	6	5	2	1	3	4
No. of core habitat indicator species – waterside plots	6	5	4	3	2	1
Representativeness						
No. of plots in core plot classes – habitat plots	4	1	2	3	6	5
No. of plots in core plot classes – waterside plots	4	3	2	1	5	5
No. of species in core species groups – main plots	2	5	4	3	6	1
No. of species in core species groups – habitat plots	5	4	2	1	6	3
No. of species in core species groups – waterside plots	5	3	3	1	6	2
Fragility (all in waterside plots only)						
No. of species sensitive to canalisation/dredging	3	1	4	2	5	6
No. of species sensitive to drainage/drying out	6	2	3	1	4	5
No. of species sensitive to eutrophication	6	5	3	4	2	1
No. of species sensitive to aquatic herbicides	2	1	4	5	3	6
No. of criteria ranked first	2	4	3	7	0	4
No. of criteria ranked second	2	3	6	4	2	2
No. of criteria ranked third	2	4	4	5	4	1
No. of criteria ranked fourth	5	2	4	1	3	3
No. of criteria ranked fifth	3	5	2	1	5	5
No. of criteria ranked sixth	5	1	0	1	5	4

which overlap with waterside plot classes could be converted to wetland vegetation by altering the hydrology, eg by blocking drains, to encourage species more typical of wetter situations. The fragments of wetland vegetation that do remain would be an important seed source. Further examination of the spatial distribution of the plots could provide guidelines for choosing areas which are most likely to benefit from such recreation projects.

4.15 Quality criteria – ranking of waterside landscape strata

4.15.1 The six strata have been ranked in terms of the quality measures discussed above (Table 4.14).

4.15.2 No one strata scores highest on most measures of quality – the strata are ranked differently for different criteria. Thus, although the pastural strata have the largest area of waterside landscape, the uplands

Table 4.15 Number of squares with designations within waterside landscapes

Designation	Arable No.	Arable *% of stratum*	Pastural No.	Pastural *% of stratum*	Upland No.	Upland *% of stratum*	Waterside mask No.	Waterside mask *% of mask*
SSSI	2957	*40*	2686	*37*	1714	*23*	7357	10
NNR	208	*40*	196	*38*	112	*22*	516	<1
ESA	1418	*54*	335	*13*	882	*33*	2635	3
NP	457	*6*	1557	*22*	5216	*72*	7230	10
AONB	4835	*42*	1977	*34*	2848	*24*	11660	15
HC	144	*20*	561	*80*	1	*0*	706	<1
G Belt	4304	*42*	5260	*52*	579	*6*	10143	53
Any design	12400	100	13006	100	8789	100	34195	45

Squares may contain more than one designation, so the last row is not the sum of the above

Table 4.16 Number of survey squares with designations within the waterside landscapes

	Arable		Pastural		Upland		Waterside mask	
Designation	No.	*% of of stratum*	No.	*% of of stratum*	No.	*% of of stratum*	No.	*% of mask*
SSSI	1	*10*	5	*50*	4	*40*	10	*9*
NNR	0	*0*	0	*0*	0	*0*	0	*0*
ESA	3	*60*	0	*0*	2	*40*	5	*4*
NP	1	*7*	5	*33*	9	*60*	15	*13*
AONB	5	*38*	5	*38*	3	*23*	13	*11*
HC	0	*0*	1	*100*	0	*0*	1	*<1*
G Belt	6	*35*	10	*59*	1	*6*	17	*53*
Any designation	16	*100*	21	*100*	13	*100*	50	*43*

are estimated to have the greatest amount of wetland land cover. Also, the main plots are often ranked differently from the habitat and waterside plots, reflecting that different pressures are affecting the main habitats and the fragments.

4.15.3 In terms of the three landscape types, the pastural strata have the highest scores, followed by the arable and then upland landscapes. The pastural strata were ranked highest on quality, especially with respect to diversity and representativeness.

4.15.4 Although there are inconsistencies within the strata, the non-designated strata consistently have more high-ranking criteria than their designated equivalents. This suggests that there might be scope for improved targeting of designations with respect to waterside vegetation.

4.16 Designations

4.16.1 The above discussion has considered designations as a whole, but clearly different types of designation may have different effects. Within the waterside landscape as a whole, AONBs and Heritage Coasts are the most common designation, with SSSIs and National Parks also important. There is some regional variation, with SSSIs and Green Belt more common in the lowlands, AONBs and ESAs in the arable strata, and National Parks in the uplands (Table 4.15).

4.16.2 Analysis of individual designations was not an objective of the project, and was not incorporated into the sampling strategy. The number of sample squares available for each designation is insufficient to allow comparison (Table 4.16).

4.16.3 The situation is further complicated by the overlap between designations, with 20% of the designated survey squares having more than one designation (Table 4.17).

4.17 Conclusions

4.17.1 The waterside mask is dominated by grassland types, with only 3% being core wetland habitat (including fens, marshes and flushes). The core waterside types were most common in the uplands (9%) and pastural strata (3%), being much less common in the arable strata (<1%).

4.17.2 Few of the randomly located main plots sampled wetland or wet grassland vegetation, although some included species associated with moist grasslands. Wetland vegetation was mostly sampled by habitat plots and was most diverse in the pastural strata. Species associated with watersides were also more common in the lowlands. The more frequent sampling by the habitat plots indicates the fragmented nature of the remaining wetland habitats. The greater diversity of the wetland vegetation in the pastural strata could indicate a wider range of environmental conditions or less disturbance of the habitats.

4.17.3 When all the different quality criteria are considered, there is no overall pattern; the strata are ranked differently for different criteria. There is little difference between the quality of wetland and waterside

Table 4.17 Overlap between designations for waterside survey squares

Designation						% of designated squares
SSSI	AONB			HC		2
SSSI		NP				10
SSSI					GB	4
SSSI						4
		NP	ESA			4
			ESA			6
	AONB					24
		NP				16
					GB	30

vegetation in the designated and non-designated strata (with non-designated strata scoring slightly higher), suggesting that these habitats have not been targeted for designation. However, there is a trend towards an increase in the area of core vegetation from the arable to the upland strata but a decrease in the number of wetland species in this same direction. The overall quality of the vegetation is highest in the pastural stratum.

Chapter 5 PREDICTING CHANGES IN WATERSIDE VEGETATION

5.1 Introduction

5.1.1 This Chapter describes the development and use of conceptual models to predict the effect of environmental changes, and changes in agricultural management, on the quality of waterside landscapes.

5.1.2 TRISTAR (TRIangular STrAtegic Rules for British herbaceous vegetation) (Hunt *et al.* 1991) is an expert-system model which deals with the fundamental environmental and management processes controlling the composition of British herbaceous vegetation. The TRISTAR2 model, developed for this project, is a program which extends this approach specifically into the areas involving climate change scenarios.

5.1.3 TRISTAR2 takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and then predicts the composition of the new steady-state vegetation in terms of its component functional types.

5.1.4 Vegetational survey data collected during this study (see Chapter 4) were processed in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted.

5.2 Phase I – allocation of functional types

Brief description of methods

5.2.1 The initial steady-state vegetation was specified as a list of abundance of species in each of the survey plots. Each vegetation record has been classified according to both of two sets of criteria:

- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for the second of these classifications is a TWINSPAN analysis which divides the plots into 20 plot classes, as described in Chapter 4 (Section 4.4).

5.2.2 For each plot, one of 19 functional types (see Appendix 2) is then allocated to each of the component species using information from the databases of the Unit of Comparative Plant Ecology (UCPE) at the University of Sheffield. Briefly, two external groups of factors, called 'stress' and 'disturbance', both of which are antagonistic to plant growth, are recognised.

5.2.3 When the four permutations of high and low stress against high and low disturbance are examined, a different primary strategy type emerges in association with each of the three viable contingencies: **competitors** (C) in the case of minimum stress and minimum disturbance, **stress-tolerators** (S) in the case of maximum stress and minimum disturbance, and **ruderals** (R) in the case of minimum stress and maximum disturbance. Intermediate types of C-S-R strategy can be identified, each exploiting a different combination of intensity of external stress and disturbance.

5.2.4 TRISTAR2 conflated the weighted abundance of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundance for each of seven broader groups of functional types. These seven groups represent the three extreme corners of the C-S-R triangle ordination (see Figure 5.1), its centre, and its principal intermediate positions. These seven groups were each converted into a two-part numerical code which provided a computational mechanism for representing both 'pure' and intermediate functional types.

5.2.5 Once converted, the classifications according to functional type provided the

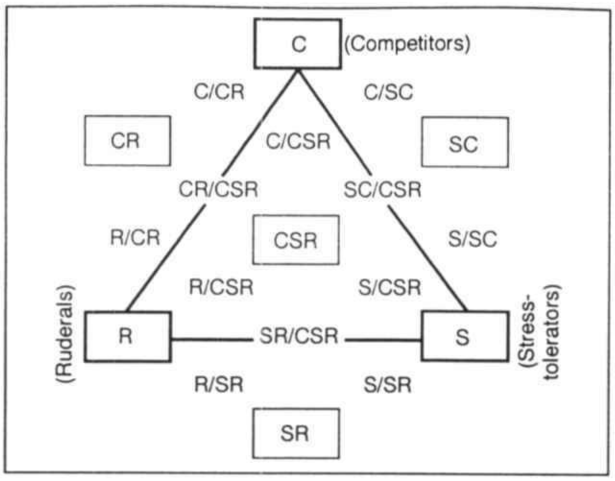

Figure 5.1 The C-S-R triangle ordination, showing the three principal functional types and intermediate positions

basis for all further work on the vegetation sample by TRISTAR2. Appendix 2 provides details of the TRISTAR model and how it has been used. The presentation for each scenario consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation, with an ecological interpretation.

Results

5.2.6 As stated in Chapter 2, the English waterside areas contain a wide range of distinctively waterside habitats, including wetland, woodland, grassland and tall herb vegetation, as well as a wide range of more general habitats. Each of these habitats contains a variety of vegetation types, making the waterside landscape particularly heterogeneous and complex.

5.2.7 Because the survey was of a broad waterside mask, it contains a variety of habitat types. For the purposes of the analysis of functional types, these have been divided into three groupings that relate to habitat type:

- **woodland** (plot classes A–C),
- **grassland and tall herb vegetation** (plot classes D, E, I–P)
- **wetland** (plot classes F–H).

For examination of vegetation change, grassland and tall herb vegetation is further subdivided by functional type into **base-rich** (plot classes D, E, I–L, N; relatively productive and most frequent in the lowlands) and **acidic** (plot classes M, O and P; unproductive, with high representation of type stress-tolerator, and predominantly upland).

5.2.8 The wetland habitats (plot classes F–H) are largely eutrophic with a predominance of types competitor and competitor/ruderal. The competitor/ruderal type will include a number of species from near the water's edge, such as watercress (*Rorippa nasturtium-aquaticum*), which are able to regenerate from shoot fragments following damage associated with flooding

5.2.9 The grassland and tall herb vegetation (plot classes D, E, I–P) can be subdivided into groups relating to their management on the basis of plant types. Acidic vegetation is almost by definition 'unimproved'. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. Type competitor/stress-tolerator/ruderal is the most characteristic of grazed conditions. However, in acidic vegetation (plot classes M, O and P), stocking rates are relatively low and, as well as type competitor/stress-tolerator/ruderal, stress-tolerator is represented. In base-rich vegetation (plot classes D, E, I–L, N), type competitor/stress-tolerator/ruderal has highest occurrence in PCI (semi-improved pasture) and PCL (damp neutral grassland) and, on this basis, these classes are most typical of relatively productive grassland. Many species of type competitor, competitor/ruderal and stress-tolerator/competitor indicate low or no management inputs, ie dereliction. Plot classes D (coarse grassland), E (tall herbs) and K (neglected grassland) are extreme examples of abandoned grassland with very high values of competitor, while PCN (short-term grassland) and PCJ (improved grassland), with additional high values of competitor/ruderal, have perhaps an additional history of disturbance.

5.2.10 The woodland type (plot classes A–C) is a relatively natural grouping. It has its own range of management procedures with understorey shading by its woody dominants. Analysis of data from the various scenarios is, however, difficult because separate analyses have not been carried out on the tree, shrub and herb layers. For example, herbs will be considerably more susceptible to most forms of disturbance than mature trees of a similar strategic type. Open/disturbed woodland (PCC) predictably has fewest species of type stress-tolerator and most of type ruderal and type competitor/ruderal.

5.2.11 In summary, the 'core' waterside vegetation was composed of competitor and competitor/ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types.

5.3 Phase II – effects of change scenarios on the abundance of functional types

Brief description of methods

5.3.1 The TRISTAR2 model was populated with six scenarios comprising selected combinations of two environmental factors – disturbance and eutrophication. Each scenario can have more than one possible management or climate change interpretation, and examples of the possible causes of each scenario are given in the results. The scenarios were:

i. decreased disturbance and no change in eutrophication;
ii. decreased disturbance and increased eutrophication;
iii. no change in disturbance and decreased eutrophication;
iv. no change in disturbance and increased eutrophication;
v. increased disturbance and decreased eutrophication;
vi. increased disturbance and increased eutrophication.

It is important to note that each scenario can have more than one possible management or climate change interpretation. For example, increased eutrophication could be caused by increased fertilizer application or increased deposition of atmospheric nitrogen.

5.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applied an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

Example results

5.3.3 Full outputs from the model are given in Appendix 2. Within this Chapter, summary results for only the wetland habitats (plot classes F–H) are described.

Scenario 1. Decreased disturbance and no change in eutrophication

5.3.4 Possible causes of this scenario, as it affects the core waterside vegetation, include cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting.

5.3.5 With respect to functional types, an increase in type competitor is predicted. Reduced disturbance may result from either a relaxation in land management (eg grazing) or an abatement of natural processes (erosion and sedimentation), or a combination of the two.

Scenario 2. Decreased disturbance and increased eutrophication

5.3.6 Possible causes of this scenario, as it affects the core waterside vegetation, include cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting, together with increased fertilizer runoff or atmospheric deposition, and more flooding.

5.3.7 Increased eutrophication in combination with decreased disturbance will have a greater and more rapid impact on the distribution of functional types than that exhibited in the previous scenario (disturbance decreased; eutrophication same). For the eutrophic wetland habitats, again an increase in type competitor is predicted, mainly at the expense of type competitor/ruderal. Even if natural processes (erosion and sedimentation) restrict the impact of type competitor, sites should be more strongly vegetated. Eutrophication should encourage rapid recovery following disturbance.

Scenario 3. No change in disturbance and decreased eutrophication

5.3.8 Possible causes of this scenario, as it affects the core waterside vegetation, include decreased usage of or pollution from fertilizers, and decreased deposition of nutrient-laden mud and silt.

5.3.9 Increases in types stress-tolerator and stress-tolerator/competitor and decreasing competitor, competitor/stress-tolerator/ruderal and ruderals (eg competitor/ruderal) are predicted. However, in wetland habitats (plot classes F–H), an increase in one of the main beneficiaries, type stress-tolerator, which grows very slowly, will take considerably longer and results may be less marked than predicted. Many species of type stress-tolerator do not form a persistent bank of seeds in the soil or exhibit long-distance dispersal. Thus, sites in plot classes where type stress-tolerator is poorly represented (especially PCF and PCH) may fail to be colonised by type stress-tolerator. In practice, the decreased eutrophication in wetland habitats is likely to occur rather rarely.

Scenario 4. No change in disturbance and increased eutrophication

5.3.10 Possible causes of this scenario, as it affects the core waterside vegetation, include increased flooding (in the absence of appreciable disturbance), and fertilizer runoff or atmospheric deposition.

5.3.11 Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Within eutrophic wetland habitats (plot classes F–H), where many species are fast-growing, rapid changes are predicted, with a decrease in competitor/stress-tolerator/ruderal and stress-tolerator/competitor types and an increase in competitor and competitor/ruderal.

Scenario 5. Increased disturbance and decreased eutrophication

5.3.12 Possible causes of this scenario, as it affects the core waterside vegetation, include increased grazing or cutting and increased recreational pressure, together with less fertilizer runoff or atmospheric deposition.

5.3.13 Increased disturbance coupled with decreased eutrophication will have a major impact on the composition with respect to functional types. Impacts of increased disturbance will be rapid in eutrophic wetland (plot classes F–H). Damage to perennial species should allow the spread of types ruderal and competitor/ruderal species. However, if disturbance is of regular occurrence (eg grazing) rather than intermittent (eg ploughing), these types will be less favoured because seed production will be impaired. Under these circumstances, perennial species of type competitor/ruderal and type competitor/stress-tolerator/ruderal will be favoured.

Scenario 6. Increased disturbance and increased eutrophication

5.3.14 Possible causes of this scenario, as it affects the core waterside vegetation, include increased flooding, increased grazing or cutting, and increased recreational pressure, together with increased flooding and fertilizer runoff or atmospheric deposition.

5.3.15 The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on the composition with respect to functional types. For eutrophic wetland habitats (plot classes F–H), these impacts will particularly involve losses of competitor, stress-tolerator/competitor and competitor/stress-tolerator/ruderal type species and an increase in types ruderal and competitor/ruderal.

5.4 Phase III – computation of an 'index of vulnerability'

5.4.1 For each of six scenarios, predictions for each functional type in each plot class present in the habitat (PCA, PCB, etc) are computed. An index of vulnerability is computed for each plot class. The index of vulnerability is displayed as a bar diagram for each plot class in Appendix 2 and is derived in three substages:

i. examine the original data to find the number of quadrats deviating appreciably from the typical;
ii. examine the TRISTAR2 predictions to find the new number of quadrats deviating appreciably from the original composition;
iii. find the 'index of vulnerability' for each plot class.

Table 5.1 'Indices of vulnerability' for six change scenarios

Scenario	Characteristics	Mean index of vulnerability	Impact
1	Decrease disturbance; no change in eutrophication	–0.04	Low
2	Decreased disturbance; increased eutrophication	0.07	Low
3	No change in disturbance; decreased eutrophication	0.07	Low
4	No change in disturbance; increased eutrophication	0.04	Low
5	Increased disturbance; decreased eutrophication	0.20	Medium
6	Increased disturbance; increased eutrophication	0.11	Low

Summary of results

5.4.2 Full outputs from the model are given in Appendix 2 and a summary is given in Table 5.1.

5.4.3 Scenarios 1–4 and 6 all have low total indices of vulnerability, even where eutrophication increases. Within each scenario, some individual plot classes show moderate levels of vulnerability (Appendix 2), but, in all cases, the waterside classes are not vulnerable.

5.4.4 Similarly, although the overall index of vulnerability is high for scenario 5 (increased disturbance and decreased eutrophication), the core waterside classes remain at low/medium risk, except for PCG (disturbed/eutrophic water edge).

5.5 Summary of modelling results

5.5.1 'Waterside' habitats form a heterogeneous grouping of wetland, woodland, grassland and tall herb vegetation. The individual classes differ in their representation of functional types. There are no plot classes with a predominance of ruderal types. Representation of type competitor is particularly high in some wetland (plot classes F–G) and some grassland and tall herb vegetation (plot classes D–E). Predictably, another grassland type (PCP) has most competitor/stress-tolerator/ruderal; grazing is a disturbance event (the removal of biomass) and induces stress (removal of nutrients). This plot class is also in the acidic grassland grouping (plot classes M, O and P), which, illustrating its low productivity, has high values for type stress-tolerator. Plot class P and woodland (plot classes A–C) have a high representation of type stress-tolerator/competitor .

5.5.2 TRISTAR predicts that all the plot classes will be relatively unresponsive, at least in the short term, to changes in land use which result in modifications to the level of disturbance or nutrient availability/eutrophication.

5.5.3 The impact to the various scenarios can be ranked as follows.

Low impacts

- Disturbance decreased; eutrophication increased (lowest impact)
- Disturbance decreased; eutrophication same
- Disturbance same; eutrophication increased
- Disturbance same; eutrophication decreased
- Disturbance increased; eutrophication increased

Moderate impact

- Disturbance increased; eutrophication decreased (highest impact)

5.5.4 The results of the modelling study indicate that the main threats to the waterside habitats are not associated with disturbance or eutrophication. However, they remain under threat from land drainage, the use of herbicides, and channel management.

Chapter 6 SUMMARY OF THREATS AND POLICY RESPONSES

6.1 Introduction

6.1.1 This Chapter summarises what is known about the existing extent and quality of watersides, reviews existing policy instruments, and assesses threats to this landscape type.

6.1.2 Waterside landscapes occur in many different settings and are highly valued for their geographical, historical, visual and wildlife diversity. Watersides range from steep river valleys in the uplands to meandering rivers surrounded by urban, pasture, arable and wooded land uses in lowland river plains, which provide habitats of international, national and regional importance. Particularly valued habitats include old meadows, wetland grasses and reed banks, marshes and mires (see Chapter 2),as well as other unimproved grasslands. However, because of the past canalisation of water channels, extensive drainage and intensification of agricultural land uses in the surrounding areas, many waterside areas have lost much of their diversity and subsequent conservation and landscape interest.

6.2 Key findings of the survey

Field survey

6.2.1 The mask occupies an estimated area of 17 730 km² and includes any vegetation cover/ land use which falls within this corridor (Table 6.1). For the purposes of this study, the Table has been presented in three landscape categories, as follows.

- Arable landscapes, where crops and intensively managed grasslands predominate, are concentrated in East Anglia and the eastern Midlands.

- Pastural landscapes, where grassland for livestock farming is the dominant use, are mainly found in the west and south-west.

- Upland landscapes are characterised by steep-sided river valleys, with adjoining land uses dominated by extensive livestock grazing.

6.2.2 In policy terms, it is also important to recognise that habitats – and the appropriate policies and systems for managing them – vary considerably between:
- the wider waterside corridor (150 m);
- waterside margins; and
- the water body itself.

6.2.3 The most important waterside habitats (as shown in Table 6.1) are described briefly below.

Table 6.1 The structure (km²) of the waterside mask, by landscape and habitat type (source: ITE)

	Arable		Pastoral		Upland		Total
	Desig'd	Non-des	Desig'd	Non-des	Desig'd	Non-des	mask
Unmanaged grass/tall herb[1]	230	76	103	50	2	58	519
Bracken (acid grassland)	16	0	13	12	59	0	100
Moorland grass (acid grassland)	0	0	1	0	67	0	68
Heath	66	0	1	0	95	1056	1218
Bogs/wet heath (mire)	0	0	0	0	18	159	177
Wetland (swamps/ marsh/wet)	16	9	208	3	11	219	466
Woodland/scrub	885	183	667	431	41	0	2207
Other (crops, impr. grassland, buildings, etc)	3956	2471	3500	2413	174	461	12975
Total	*5169*	*2739*	*4493*	*2909*	*467*	*1953*	*17730*

[1]Based on other definitions, some unmanaged grass may also be included in wetland

Bogs and wet heaths

6.2.4 Bogs and wet heaths (mires) are characterised by the presence of bryophytes, herbs and sub-shrubs, and cover an estimated 17 700 ha in the waterside mask. They are found almost exclusively in the uplands, of which the majority are non-designated.

Wetlands

6.2.5 Wetlands, which incorporate swamp, marsh and wet grasses, are relatively limited (some 46 600 ha of the mask) and found in uplands and designated pastoral lowlands. Wetlands are particularly susceptible to drying out and invasion by alder (*Alnus glutinosa*) and willow (*Salix* spp.) in drier fens.

Woodlands

6.2.6 Woodlands, including wet woodlands, are more extensive (over 220 700 ha) and found mainly in arable and pastoral lands, although waterside woodlands were more extensive in the past and are known to have been cleared as part of agricultural intensification in many agricultural areas.

Unmanaged grasslands

6.2.7 Unmanaged grass/tall herb which may include some seasonally wet grasses, such as traditionally managed summer pastures, is mainly found around the washlands of Cambridgeshire and Norfolk and covers some 51 900 ha, of which about two-thirds is designated.

Fens, carrs and reed banks

6.2.8 Because of the sampling technique used, the field survey did not identify other highly valued waterside features such as fens, carrs and reed banks. The fact that these have not been identified separately demonstrates their extreme rarity and fragmentation.

6.2.9 Other semi-natural vegetation types found in the waterside landscapes include:

- acid grasslands (bracken and moorland) of which there are some 17 000 ha, mainly in the uplands;
- extensive areas of heath (over 120 000 ha), mainly in non-designated upland areas, but to a limited extent along watersides in arable areas.

6.2.10 The survey indicates that only about 27% of the total waterside mask contains semi-natural habitats of some conservation interest; the remainder is developed land, arable or improved grasslands.

6.2.11 The survey results compare with previous estimates by the Countryside Commission, made on a very different basis, for a more broadly defined waterside landscape (which includes areas of 'waterside' habitats falling outside the 150 m corridor) of 300 000 ha, of which 100 000 ha is currently considered of high conservation and landscape value. English Nature has estimated that the lowland wet grass resource (which would include large areas such as the Broads, Romney Marshes and parts of the Somerset Levels not covered by the current survey) covers some 190 000 ha, of which some 100 000 ha is of botanical interest including up to 10 000 ha of fens and mires. Of this total resource, the Royal Society for the Protection of Birds (RSPB) estimates that some 100 000 ha of wetland is used by breeding waders.

Threats

6.2.12 The key threats to waterside habitats were identified by a meeting of experts (convened as part of this project). These threats relate to the management of watercourses themselves, land uses on river banks and, most importantly, the management of the wider catchment area. In descending order of importance, it was agreed that the key threats in the past have resulted from the following.

- Land use management in the water catchment, dominated by:
  agriculture: this is the predominant surrounding land use in all three waterside categories, but it has had particular impacts in lowlands where the conversion of wetlands and seasonal flood meadows to intensive pasture and arable land through extensive drainage works has allowed mechanisation and required the removal of hedgerows and waterside vegetation, including wet woodlands. The improvement of grass swards and higher stocking rates during sensitive spring periods have led to a loss of fauna and flora and of breeding grounds for birds. Fertilizer application has led to the eutrophication of watercourses and a loss of diversity of water margin species, which have also been impacted by pesticide and herbicide drift.
  forestry: runoff from conifer afforestation has led to the acidification of rivers in the

uplands and, as a result, the latest Forestry Commission guidelines restrict planting near watercourses. Clearfelling may lead to soil erosion and sedimentation. In the lowlands, afforestation with broadleaved and willow coppice are likely to have beneficial effects in limiting flood events, stabilising banks and reducing sedimentation.

- Management of watercourses for flood control, water abstraction, navigation and energy production (hydro-schemes and watermills), which have in the past led to canalisation of watercourses using hard engineering solutions (concrete banks, beds, weirs, etc), dredging, weed control and verge management. All have affected water margin and aquatic flora and fauna. The impacts of water resource management (water abstraction and reservoirs) associated with a high demand for water for industrial, agricultural and domestic uses have had a major impact in lowering water tables in some areas, leading to low flow with negative impacts on flora, fauna and the landscape along many rivers. The National Rivers Authority (NRA) has identified some 40 low flow rivers. Domestic and agricultural demand for water, and subsequent abstraction, is expected to continue to rise in most areas, unless other means of meeting limited demand are implemented.

- Land use on river banks: industrial and residential uses of river banks have a direct impact on water quality and quantity, and thus on habitats, because of the large demands for water abstraction and discharges of effluent and sewage. Redevelopment of urban watersides for residential, industrial and recreational purposes may improve the waterside landscape, but pressures for infill development in urban fringes and rural areas lead to increased demands for flood control, while limiting available space for flood protection. Pollution caused by industry (contaminants, heavy metals) and domestic sewage may have serious impacts on aquatic flora and fauna. However, impacts will differ on river appearance (with industrial pollution sometimes making rivers look clear and attractive, despite very low biodiversity), while sewage discharge will both reduce visual amenity and lower conservation interest.

It was also recognised that the magnitude of these threats differs between the arable, pastural and upland areas of England. Thus, intensive agriculture management is a greater threat in the arable and pastural areas, while afforestation is a greater threat in the uplands. Similarly, the threat from urban and industrial development and industrial pollution is greatest in the arable areas.

6.2.13 Other factors will also affect waterside habitats, but their impact will vary according to setting.

- Climate change leading to temperature and water level rise and changes in rainfall and drought will affect water flow, tree lines and may affect salmon reproduction rates.

- Hydro-schemes – few large schemes are expected, but some mini hydro development is anticipated in the uplands.

- Gravel extraction has serious but extremely localised impacts but offers opportunities for the creation of new habitats.

- New road building is expected to have greatest impact in the south-east.

6.2.14 Two other land uses have mixed, but mainly positive, impacts in conservation terms.

- Recreation may cause localised bank damage, disturbance or path erosion, but conservation management (eg for angling) may have beneficial impacts on water quality and waterside margins.

- Military use of watersides in areas owned by the Ministry of Defence (mainly heaths, moorlands or calcareous grasslands) generally has positive impacts.

6.2.15 Airborne pollution is not considered to have a wide impact on waterside habitats.

6.2.16 A number of different farming scenarios have been modelled by UCPE (see Chapter 5 and Table 6.2). The implications suggest that the most beneficial agricultural management practices for waterside areas would differ considerably between habitat types.

Conservation objectives

6.2.17 The expert group meeting agreed the following broad hierarchy of objectives for waterside areas, which are very similar to those of the Countryside Stewardship Scheme:

- to protect existing waterside landscapes of high value by maintaining traditional water levels and meadow management practices (eg ditch and dyke systems);
- to restore or enhance diversity across a wider area by re-instating landscape infrastructure (planting willows, creating ponds and meanders, etc);
- to re-create lost fens, carrs and reedbeds on selected areas of arable land and restore a few selected rivers by removing hard engineering features and drainage systems.

6.2.18 These priorities are also similar to those of the National Rivers Authority based on the Water Resources Act 1991 and the Code of Practice issued under the 1989 Water Act (see Box 6.1).

6.2.19 In designing policies to meet these key objectives for waterside habitats, a number of key issues have to be addressed.

- The diversity and fragmentation of habitats. Waterside habitats are very diverse. The most valued are highly fragmented and unlikely to have been subject to protective designations.

- The linear nature of the habitat offers opportunities to create a corridor for wildlife. Because of the mobility of species, the opportunities for some communities to re-establish themselves with minimum intervention is high but varies according to land use and habitat type.

- The management of the wider catchment is crucial but involves a large number of players, including local authorities, NRA, water companies, Forestry Commission and private landowners.

- Landownership and motivation of owners and users is crucial; alternative waterside management techniques may reduce flood protection, result in some land only being used seasonally (for recreation or grazing), and therefore reduce farmers' incomes or the amenity values of local communities.

6.3 The impact of current policies

6.3.1 Available policy instruments fall into a number of categories which may be summarised as follows:

- regulations to provide protection against deleterious activities in the areas of influence for the waterside landscape;
- land use planning related measures;
- economic instruments such as the European Union's Common Agricultural Policy (CAP), MAFF's Countryside Stewardship Scheme, Environmentally Sensitive Area scheme, English Nature's Wildlife Enhancement Scheme, and other schemes specifically aimed at waterside habitats;
- pilot and demonstration projects.

Box 6.1 *Responsibilities of the National Rivers Authority*

Under Section 16 of the Water Resources Act 1991 and Section 12 of the Land Drainage Act 1991 the NRA is obliged, in so far as it is consistent with its statutory functions or proposals (such as granting of land drainage consents), to:

- further the conservation and enhancement of natural beauty and the conservation of flora, fauna, geological and physiographic (landform) features of special interest;
- have regard to the desirability of protecting and conserving buildings, sites and objects of archaeological, architectural or historic interest;
- take into account the effect which proposals would have on the beauty or amenity of any rural or urban area or any such flora, fauna, features, buildings, sites or objects.

The NRA is guided by a Code of Practice on Conservation, Access and Recreation issued under the provisions of the 1989 Water Act which includes general policies and procedures for river basin management, including conservation; detailed recommendations for conserving and enhancing the environment in terms of landscape, wildlife and man-made heritage; and recommendations for the management of special sites and areas, including SSSIs, National Parks, ESAs, SAMs and listed buildings.

Policies to protect waterside habitats

6.3.2 International and UK legislation provides a complex framework of designations for the protection of waterside habitats. A hierarchy of designations exists.

- Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) are European designations under the Birds and Habitats Directives respectively, and are intended to strengthen national nature protection designations such as SSSI.

- NNR, SSSI and Scheduled Monument status are protective designations which also prevent deleterious actions.

- National Park, AONB and Green Belt

Table 6.2 Summary of UCPE scenario findings

Potential threat	Likely causes	Interpretation of results
Scenarios which might reduce nature conservation interest of wetland habitats		
Decreased disturbance and no change in eutrophication	Reduced fire, reduced grazing or cutting in woodlands and grasslands, reduced tidal movement because of sedimentation, man-made barriers or colonisation by a species tolerant of disturbance on saltmarshes	Woodland: little change in the tree species present but a possible increase in shade which will result in a reduction in the herb layer and an increase in stress-tolerant species. Both grasslands and wetlands will experience an increase in competitive species at the expense of species which are competitive ruderals. A possible reduction in the level of the water table and colonisation by trees. Overall, there will be a reduction in nature conservation interest
Decreased disturbance and increased eutrophication	Decreased disturbance from reduced burning, grazing, recreational pressure in all areas, increased fertilizer runoff and/or atmospheric deposition (nitrogen or sulphur)	Possible slight decrease in the tree species present but it is more likely that vernal and stress-tolerant species will increase with shade cover, resulting in increased nature conservation interest. Increase in competitive species in grasslands and wetlands leading to a decrease in ruderals and stress-tolerant species with a consequent loss of nature conservation interest. Changes will be greatest in more eutrophic grassland classes, and slower in acidic grasslands and wetland habitats
No change in disturbance and increase in eutrophication	Increased fertilizer runoff or atmospheric deposition and increased deposition of nutrient-rich soils on wetlands from increased flooding (but which does not scour soil or disturb)	Possible increase in tree growth and shade resulting in a reduction in ground flora but maintaining stress-tolerant species in woodlands. Decreases in stress-tolerant species and increases in competitive species, resulting in a decrease in nature conservation interest in all types of grasslands and wetlands
Increased disturbance and increased eutrophication	Increased burning, grazing, cutting, visitor pressure and flooding (wetlands), increased runoff and atmospheric deposition for all habitat types, deposition of nutrient-bearing soils on wetlands	In woodlands disturbance might result in opening of the tree canopy; there will be an increase in fast-growing species (competitors, competitive ruderals and ruderals) which will result in a decrease in nature conservation interest. In nutrient-rich grasslands and wetlands, there will be an increase in ruderals and competitive ruderals; in acidic conditions, a loss of stress-tolerant species; both will result in a loss of nature conservation interest
Scenarios which might enhance nature conservation interest of wetland habitats		
No change in disturbance and reduced eutrophication	Reduced fertilizer runoff or atmospheric deposition (nitrogen or sulphur), reduced deposition from flooding of wetlands (but with scouring, etc, left unchanged)	Decrease in competitive species in woodlands and grasslands and increase in stress-tolerant species of potential nature conservation interest. This scenario is unlikely to occur in wetlands but would result in decreases of competitive species and increases in stress-tolerant species of potential nature conservation interest
Increased disturbance and decreased eutrophication	Increased use of burning, cutting or grazing for grasslands and woodlands, less fertilizer runoff and atmospheric deposition, increased storm or flooding (but with no additional nutrients) for wetlands	In woodlands a decrease in tree density will result in changes in the ground flora, probably of all types. Increased disturbance for grasslands will result in a spread of ruderals and competitive ruderal species. In more acidic vegetation there will be an increase in stress-tolerant species and probably an increase in the level of the water table, leading to an overall increase in nature conservation interest

designations provide protection against planning permission for the change of use of the site; Heritage Coasts are not statutory designations but provide a framework for land use planning decisions.

6.3.3 The area of waterside designated as SSSI identified by the survey is limited as this designation has seldom been applied to watersides *per se* in the past; the SSSIs identified in the study are predominantly other habitats which happen to have water features running through them. Wetland SSSIs (not necessarily identified in the linear mask of the survey) are more widespread.

6.3.4 Section 17 of the Water Resources Act 1991 requires that English Nature, National Parks Authorities and the Broads Authority inform NRA of any sites of special interest and that the NRA notifies them before carrying out any activities or approving any proposals which might damage these special areas. EN/Countryside Council for Wales have identified a network of some 27 waterside SSSIs (EN 1994), which would cover some 3% of the river network by length; 12 have already been notified and include both whole rivers (Wye, Eden, Avon) and long stretches on rivers such as the Kennet.

6.3.5 New SSSIs should strengthen presumptions against development in floodplains, so reducing demand for flood defences to protect property.

6.3.6 However, SSSI or other protected status will seldom be the only tool required to enhance the quality of small areas of key waterside habitats – activities in the wider catchment area will continue to have major impacts on the water table and river flow levels. English Nature proposes to carry out detailed survey work during the winter of 1996 to identify whether SSSIs are being affected by intensive agricultural management and water abstractions in their catchment areas.

Land use and management planning approaches

6.3.7 Statutory land use planning for watersides and water catchments is the responsibility of local authorities. There is no specific *Policy planning and guidance note* relating to watersides but a number of other forms of guidance apply to those managing waterside areas or planning developments which will affect them (see Table 6.3).

6.3.8 In addition, the NRA's eight regional offices have wide-ranging statutory responsibilities to provide the following services: flood defence, water resources and quality, navigation, recreation, fisheries and conservation, all of which are addressed within the framework of local authority development plans, DOE planning guidance, and existing land uses. Nature conservation is addressed through a series of plans as follows.

- *Catchment Management Plans* (CMPs). A programme to produce CMPs started in 1991–92 and a total of 189 plans are scheduled for consultation by 1997–98. CMPs cover all of the NRA's statutory responsibilities and involve three stages: internal consultation, public consultation, and production of an action plan. They are non-statutory and rely on incorporation in local authority development plans and countryside agency management plans to be binding. There has therefore been increasing recognition in recent years of the need for early consultation and close co-operation with other interested parties.

- *Water Level Management Plans* (WLMP). This is a MAFF/EN initiative, with both the NRA (300 WLMPs) and the Internal Drainage Boards (200 WLMPs) agreeing to prepare WLMPs for SSSIs. Very few have so far been completed.

- *River Corridor Surveys* are scientific surveys of 500 m x 50 m stretches of rivers to identify key features on maps. Information is held at regional level on conservation databases and surveys are carried out regionally. The ten-year programme has been running for 3–4 years and has so far focused on areas subject to greatest development and management pressure. Although a large number of rivers have already been surveyed, NRA reports that it would be difficult to convert mapped data to a quantification of the extent of key habitats along the river network.

- *Landscape Assessments*, based on a wider/holistic methodology covering areas up to 1 km from the waterside, have been undertaken since 1993 as a baseline for CMPs, planning and design of NRA projects (flood defences, navigation and water abstractions), and EIAs of major projects by third parties. The targets for completion of landscape assessments are less clear than for other surveys, and NRA reports that progress has lagged behind CMPs.

- *River Habitats Surveys* are based on a methodology which combines features of river corridor surveys and landscape assessments. They provide a broader

Table 6.3 Guidance relating to developments affecting the waterside landscape

DOE/MAFF/WO	1991	Conservation guidelines for drainage authorities
MAFF/English Nature/NRA	1992	Environmental procedures for inland flood defence works
DOE	1992	Circular: Development and flood risk areas
MAFF/WO	1993	Strategy for flood and coastal defence
MAFF	1993	Flood and coastal defence, project appraisal guidance notes
MAFF	1994	Water level management plans, a procedural guide for operating authorities
MAFF	1985	Guidelines for the use of herbicides on weeds in or near watercourses

picture of both the geomorphology and the existing flora and fauna (but not historical or cultural features) along river sections. A three-year programme ending in 1996 is intended to provide a database for a network of reference sites as the basis of a national assessment of waterside habitat quality.

Integration of conservation within other statutory operations

6.3.9 NRA's policy in relation to its own activities is to ensure that, wherever possible, waterside features are protected from the impacts of new engineering or maintenance works. Where this is not possible, compensatory habitat creation is undertaken (such as reedbeds to replace those lost as a result of widening or dredging, etc). General operation and maintenance practices are widely felt to have improved over the last ten years, with a general policy towards reinstating at least one soft bank for canals and channels and using soft engineering solutions, such as flood storage sites, wherever practicable. However, such policies are not enshrined in regulations and are not always pursued where costs are considered too great or when public objections are raised by landowners or users of areas which might be seasonally inundated. In such cases, flood protection is considered of over-riding priority and traditional hard engineering solutions are often resorted to.

6.3.10 The Forestry Commission guidelines for planting and management of conifer plantations now require the removal of planting along the banks of watercourses and provide guidance on the use of more appropriate species for bankside planting.

Habitat enhancement

6.3.11 NRA is also involved in a number of specific initiatives to enhance existing habitats.

- *Inclusion in capital works.* Schemes such as low flow alleviation or habitat improvement can be built into engineering schemes for flood defence (estimated at £7–15M yr^{-1} for the Thames Region alone) or water resources management. However, stringent cost benefit analysis requirements mean that proposed enhancement schemes are seldom approved.
- *Allocations from operation and maintenance budgets.* Some NRA regions have been successful in allocating direct labour staff time from revenue budgets for small-scale, labour-intensive schemes such as tree planting, ponding and flooding of meadows, etc. Thames Region alone reports that £0.5M has been allocated to such projects.
- *Stand-alone enhancement schemes.* These require some capital works, which are funded from DOE grant-in-aid, but budgets for such schemes are small (*c* £100,000 yr^{-1} per region) and subject to cuts.

6.3.12 Forest Enterprise also carries out positive conservation schemes for watersides, such as the creation of ponds and wetland areas in its own forests, through allocations from its budget for recreation, access and conservation.

Economic instruments

6.3.13 There are a large number of schemes to encourage the positive management of agricultural land in river catchments and to provide financial incentives for protecting, enhancing and re-creating waterside habitats.

6.3.14 The 1992 CAP reform contained options under the accompanying agri-environment regulation which allows for financial aid to be provided to farmers in order to adopt environmentally friendly practices, including long-term set-aside, reductions in pesticide and fertilizer use, and reductions in livestock grazing densities. The regulation has been applied in the UK through ESAs, Countryside Stewardship, Tir Cymen, the Habitat Scheme, the Moorland Scheme, Nitrate Sensitive Areas, the Countryside Access Scheme and the Organic Aid Scheme. The schemes with greatest direct relevance to waterside habitats are described below.

Environmentally Sensitive Areas (ESA)

6.3.15 The most important of these schemes in terms of area is the MAFF Environmentally Sensitive Area scheme, which, although not targeted specifically at waterside landscapes, includes a number of areas covered by the waterside mask (eg the Upper Thames Tributaries, Test Valley, Avon Valley, Somerset Levels and Moors and Suffolk River Valleys).

6.3.16 A number of ESAs have tiers or options which relate to the management of water levels. For example, Somerset Levels and Moors and the Broads have raised water level tiers. Others ESAs incorporate water level management requirements, eg the Upper Thames Tributaries. The Broads also has a grassland margin option, designed to reduce pollution of the watercourse.

6.3.17 Payments in the scheme range from £115 ha^{-1} yr^{-1} for maintaining grass in livestock areas, to £165 ha^{-1} yr^{-1} for raising levels, and £260 ha^{-1} yr^{-1} for reversion from arable to grass to cover income foregone. MAFF reports that little capital expenditure is involved in increasing water levels as most of the eligible bankside already has sluices and drainage channels. The uptake has been weakest either in areas with a few large landowners (such as Test Valley) or in predominantly arable areas.

6.3.18 ESA schemes now cover an estimated 10% of the total farming area, with a total annual budget of £43.3M available in 1995–96. Although waterside management measures are weak, they are present in all ESA types.

Nitrate Sensitive Areas (NSAs)

6.3.19 NSAs have been designated to protect 32 selected groundwater sources used to supply drinking water where nitrate levels are predicted to exceed 50 mg l^{-1}. No figures are available for the proportion of this area which falls in the waterside landscape; however, given the impact that NSAs have on river catchment land uses, surface and groundwater quality and water levels, the impacts on waterside habitats of changing agricultural practices will be beneficial.

6.3.20 Initially, the scheme focused on ten pilot areas covering 10 724 ha of agricultural land in 1990–91; take-up of the pilot scheme was very high at 9362 ha (86% of the total area and 80% of all eligible farmers). Payments were offered at two main levels: the premium arable rate offers the highest payments to encourage conversion of arable to extensive pasture; and the basic rate allows for continuation of arable cropping but requires farmers to adopt nitrate-reduction strategies including autumn cover crops. In the pilot scheme, the majority of land area (83%) was entered under the basic scheme, implying changes in management practice not land use.

6.3.21 In 1994 the scheme was extended to include a further 22 sites, and some 593 farmers. The total area of land eligible for the NSA scheme is now 35089 ha. By April 1996, over half of this eligible area (19611 ha) had been entered into agreements, involving 359 farmers. Again, the basic scheme, requiring a restricted rotation system, has proved most popular (over three-quarters of land area). Land entered into the pilot scheme is also eligible for a further five years. In 1995 the scheme has been further modified to allow NSA payments on set-aside pasture; this is expected to increase uptake, but not substantially.

6.3.22 The total budget available in 1995–96 is £8.4M and this is expected to increase as more land is entered into NSA agreements. Payments will continue up to 2003, but the success of the scheme, impacts on habitats and drinking water quality, and payment levels will be reviewed in 1998.

The MAFF Habitat Scheme

6.3.23 MAFF introduced the Habitat Scheme as a pilot project in May 1994 to provide incentives to set aside and manage land or create/improve wetland habitats for at least 11–20 years. The Scheme provides two options for watersides: taking banksides (50 m wide) out of production and creating buffer strips (£240–485 ha^{-1} yr^{-1}); and managing watersides by extensive grazing (£125–435 ha^{-1} yr^{-1}).

6.3.24 The Scheme also applies to saltmarsh creation and land which has previously been entered into the voluntary, now closed, five-year set-aside scheme.

6.3.25 Six pilot waterside areas have been selected by EN and MAFF to represent a wide cross-section of waterside habitat types, including River Derwent in Yorkshire, the Ribble Tributaries in Lancashire, River Beult in Kent, Upper Avon, Wylye and Nader Rivers in Wiltshire, Slapton Ley in Devon, and the Shropshire Mires.

6.3.26 Some 113 waterside schemes have been agreed, covering 800 ha. The highest uptake has been for extensification of grazing on grazing land, despite the higher grants available for arable reversion. A much greater interest from arable farmers is expected under new rules, which will allow set-aside land to be eligible for the Scheme. Arable land payments have also recently been increased to stimulate uptake.

6.3.27 The Scheme will be monitored over a four-year period to determine whether it is effective and whether the form and level of incentives are appropriate.

The Countryside Stewardship Scheme (CSS)

6.3.28 The CS Scheme provides incentives for the positive management of existing waterside areas and the restoration of wetlands and water meadows. It provides for ten-year management agreements with payments varying from £70 to £225 ha^{-1} yr^{-1} depending on the nature of the agreement, eg

- conservation of existing waterside pasture and meadow, £70 ha^{-1} yr^{-1};
- creation/restoration of waterside landscapes on improved land, £250 ha^{-1} yr^{-1};
- capital payments are also made for coppicing (eg £12.50 per tree).

6.3.29 In addition, on suitable land a supplement for additional restoration or re-creation of waterside landscapes of £40 is payable in the first year. Total available financing for the Scheme is £11.4M in 1995–96, rising to £17M in 1996–97. Table 6.4 shows that a total of some 20 000 ha has been entered into various management tiers of the Scheme, equivalent to some 3–4 % of the total semi-natural waterside landscape identified in the field survey. Some 85% of the total area involves protection and restoration of existing habitats; the re-creation of very scarce features has been limited to less than 300 ha, but re-creation of corridors or linking areas in arable land covers nearly 3000 ha. In addition, a proportion of the land entered into the CS 'historic landscapes' option is likely to involve watersides; the historic target focuses on designed parkland, ancient management systems (often related to water management), and important features like old orchards, much of which falls into the waterside mask.

6.3.30 Nature conservation designation covers a large proportion of existing semi-natural habitats in the coastal landscape mask and is clearly offering some protection from damaging developments and consequent needs for hard engineering approaches to flood defence. A number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. Following the review of Environment Land Management Schemes, it has been decided that the Countryside Stewardship Scheme should be the core scheme for conservation and enhancement of these habitats outside ESAs, and that merging of other schemes, such as the Habitat Scheme, with CSS should be considered in due course.

Wildlife Enhancement Scheme (WES)

6.3.31 The WES operated by English Nature provides capital and annual payments in support of management agreements for selected wetland areas, including some wet grasslands in England. The Reserves Enhancement Scheme is available on a similar basis to enhance the management of nature reserves by Wildlife Trusts.

Woodland Grant Schemes

6.3.32 The WGS implemented by the Forestry Commission provides special management grants for small areas of neglected woodlands. Grants of £35 ha^{-1} yr^{-1} may be used to cover the costs of pollarding and management of waterside willows.

Information and demonstration projects

6.3.33 Because of the heterogeneity of waterside habitat types, it is difficult to be prescriptive about the best management practices for watersides themselves and the surrounding area.

6.3.34 NRA is currently co-funding two demonstration projects which are being carried out by the River Restoration Project. They are three-year projects which aim to demonstrate the technical feasibility and economic costs and benefits of restoring the River Cole (Swindon) and the Skerne (Darlington) to their original flood levels. The total budget of £800,000 is provided by the European Community LIFE programme, NRA, CoCo, EN and Darlington Borough Council. First-year pre-works studies have

Table 6.4 Uptake of Countryside Stewardship Scheme for waterside areas, 1991–95

Type of agreement	Existing area (ha)
Protection and restoration and management of waterside land	17300
Re-creation of waterside landscapes on cultivated land	2700
Restoration/re-creation of reedbeds, fens and carrs	300

been completed and engineering works are underway. The third year will involve monitoring the costs and benefits. The key features of the demonstration projects are as follows.

- Water levels in the River Cole have risen as a result of agricultural discharges (from improved drainage) and runoff from Swindon, which has required hard engineering to deepen, widen and canalise the river. The only means of restoring the river to its previous course is by reducing the level of water runoff by restoring traditional drainage systems and extensifying livestock production. The involvement of the National Trust as the major landowner has made it easier to introduce the project than might have been the case with tenant farmers who would have required compensation for revenue foregone.

- The aims of the Skerne project are to enhance the value of watersides for public enjoyment.

The outcomes of the projects will be the basis for determining costs and priorities for restoration of waterside habitats in the longer term.

6.3.35 NRA and DOE have also jointly funded studies to assess the costs and benefits of a number of enhancement projects, such as low flow alleviation in the River Darent (Kent). These studies have used contingent valuation techniques to assess the environmental and recreational benefits of schemes, and included them in cost/benefit analysis.

6.4 Policy development

6.4.1 The waterside mask is extensive and contains a highly valued patchwork of different landscapes and habitats. However, the survey results show that the remaining areas of semi-natural habitat are limited and fragmented as a result of past water resource and land use management practices. The opportunities for enhancement and restoration are good but, given the wide range of possible actions which could be taken, it is not possible to make estimates of the costs of achieving conservation priorities in the waterside habitat.

6.4.2 The Rivers Restoration Project will provide important data on the costs and benefits of undertaking large-scale restoration. The costs are large at almost £0.5M for each of the two pilot rivers, compared to what is currently being spent on smaller projects. The corresponding scale of benefits may also be large but has not yet been quantified. When the projects have been completed, DOE, NRA and the Countryside Agencies will be in a better position to determine the appropriate allocation of resources between large-scale projects on a few key rivers and a larger number of small projects.

6.4.3 In the short term, smaller projects which link existing semi-natural areas along the wildlife corridors previously provided by the river network may offer opportunities for significantly enhancing the visual and wildlife diversity and interest of watersides (although more research is required on the net ecological impacts of wildlife corridors in the waterside setting). The benefits of enhancing diversity through small-scale actions are demonstrated by the NRA's planting and ponding activities and the success of the CS Scheme, which focus on re-creating diversity with minimal intervention and cost.

6.4.4 Current schemes have been mainly targeted at agricultural land, and in particular pastoral land. While this is likely to retain more existing semi-natural communities, the importance of re-creating waterside infrastructure in badly degraded arable landscapes should not be overlooked; it is however likely to be more costly. In addition, it should be recognised that the urban fringes offer opportunities for recreation, access and conservation benefits and should therefore be specifically targeted in future actions.

6.4.5 The close co-operation and support of all key agencies (NRA, local authorities, water companies, Forestry Commission), voluntary organisations (Wildlife Trusts, National Trust) and private landowners and tenants are important in the effective implementation of Catchment Management Plans. Early involvement of all interested parties is required in identifying opportunities and potential solutions for reducing pressures on threatened habitats. For instance, the early participation of landowners, developers and users of sites will increase understanding of the impacts of their activities and the demand for flood defences which result; understanding and modifying designs and approaches could create new opportunities for soft engineering approaches.

6.5 Increasing the body of knowledge and potential for further work

6.5.1 In the longer term there are no guarantees that resources will be available to cover ongoing management costs. Thus, it is imperative that new approaches to sustainable (economically viable) long-term management of the watersides continue to be developed and publicised. More work is needed to evaluate and extend existing experience, to develop guidelines for landowners and managers on the most suitable and economically viable regime for their circumstances, and to assist in the establishment of arrangements/ partnerships which will encourage managers to implement these practices. Guidelines need to reflect the type of waterside habitat, the extent and fragmentation of the habitat, the ownership characteristics, the climatic conditions, and the size and location.

6.6 Conclusions

6.6.1 Watersides comprise a valuable landscape, but they are currently dominated by managed and developed land use types. The survey results indicate that the core waterside vegetation amounts to only about 466 km^2 (<3% of the mask) and most of the rest is unmanaged grassland.

6.6.2 An expert group meeting within this study agreed the following broad hierarchy of objectives for waterside areas:

- to protect existing waterside landscapes of high value by maintaining traditional water levels and meadow management practices (eg ditch and dyke systems);
- to restore or enhance the diversity across a wider area by reinstating landscape infrastructure (planting willows, creating ponds and meanders, etc);
- to re-create lost fens, carrs and reedbeds on selected areas of arable land and restore a few selected rivers by removing hard engineering features and drainage systems.

6.6.3 The present study has defined the waterside landscape type, in its broadest sense, and has described its characteristics. To capitalise on the baseline study that has been completed, monitoring needs to be carried out at agreed intervals (eg at the time of the next Countryside Survey). Results from this baseline study and subsequent monitoring need to be analysed in the context of the success of the Countryside Stewardship Scheme and related work (eg CAP reform).

6.6.4 Nature conservation designation and a number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. However, survey results suggest that the remaining areas of semi-natural habitat are limited and fragmented and that the designated areas have no higher quality than the non-designated parts of the mask. If further work indicates that the above objectives are justifiable, then opportunities do exist for improvement of habitat, especially through river corridor and catchment planning initiatives.

6.6.5 To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches continue to be identified and publicised.

Chapter 7 SUMMARY AND CONCLUSIONS

7.1 Introduction

7.1.1 This Chapter summarises the Report in terms of the original project objectives (as described in Chapter 1), briefly summarises the advantages and disadvantages of the approach, and discusses future research needs.

7.2 Summary in relation to the original project objectives

Objective 1: To determine the distribution of the landscape type in England

7.2.1 The objective was to identify and map 1 km squares in England which support, or have some potential to support, waterside vegetation types. This objective was achieved by identifying 1 km squares which included land within 150 m of all waterways (streams, rivers, canals and lakes) in England. This cartographic mask was classified into arable, pastural and upland landscape types, based on the ITE Land Classification.

7.2.2 Because of the use of a 1 km resolution, and the specific definition of 150 m zones within each square, there is a mismatch between the number of 1 km squares in the database (75 752) and the area within the waterside mask available for sampling (17 730 km^2). However, the mask does provide a good sampling framework for assessing the current status of the waterside resource.

Objective 2: To survey the habitats (including major land cover types and ecological features such as hedgerows) and historic features within each landscape type

7.2.3 Unlike other threatened habitats studied in this project, the Countryside Survey 1990 (CS1990) database included a reasonable representation of 1 km squares which included part of the waterside mask. Thus, a further field survey was unnecessary. To characterise the mask, field data were taken from 116 of the CS1990 survey squares recorded in England. The results were extrapolated from the sample squares to the waterside landscape as a whole.

7.2.4 Land cover and boundaries were mapped in 1990 for the whole of each square, using a standard coding system (Barr *et al.* 1993). To provide 'quality' information, vegetation data were taken from up to five 200 m^2 nested quadrats within the waterside mask, in each square. In addition, information was also used from any of up to five 4 m^2 'habitat plots', targeted at less common habitats which were not represented by the main plots, and up to four 10 m x 1 m waterside plots.

7.2.5 It was not possible to include an historical component to this study.

Objective 3: To determine, on a regional basis and in relation to current designations, the composition of the landscape type in terms of the quantity and quality of the surveyed features

7.2.6 Quantitative estimates of land cover and boundaries have been made for the waterside mask and for strata within it. The core wetland vegetation types (including fens, marshes and flushes) occupied only 3% of the mask, much of which was in the upland strata. Unmanaged grass and tall herb vegetation, which is often associated with river banks and lake margins, was most common in the arable strata. Wetland was slightly more frequent in non-designated strata.

7.2.7 The mask was dominated by improved grassland, crops and built features, with significant areas of heath and bog in the uplands.

7.2.8 Objective measures of vegetation have been related to quality criteria, to provide an empirical evaluation of the quality of heathland vegetation in different parts of the lowland heath landscape: size, diversity, naturalness, representativeness, rarity, fragility, potential value.

7.2.9 Using at least two separate measures of each of the quality criteria, the six strata were ranked. Based on quadrat information, no one stratum scored highest on most measures of quality – the strata are ranked differently for different criteria. The pastural strata have the highest scores, followed by the arable and then upland landscapes. Although there were inconsistencies within the strata, the non-designated strata consistently have more high-ranking criteria than their designated equivalents.

Designation

7.2.10 It was recognised that, without time-series data, it was difficult to assess the effect of designation. As indicated in para 7.2.9, there is a suggestion that vegetation quality is slightly higher in non-designated strata. However, it was not known whether correlations between any 'good' areas of waterside vegetation and some form of designation were because the designation had been effective, or whether the designation was made because of the quality of the heath. The approach adopted in this study was to stratify the field sample according to designation status.

7.2.11 Results related to designation are included in Section 7.3, but clearly different types of designation may have different purposes. Within the waterside mask, AONBs and Heritage Coasts are the most common designation, with SSSIs and National Parks also important. There is some regional variation; SSSIs and Green Belt are more common in the lowlands, AONBs and ESAs in the arable strata, and National Parks in the uplands.

Objective 4: To develop models to predict the effect of environmental and management changes on the distribution and quality of the landscape types and their constituent habitats

7.2.12 Unlike other landscapes studied in this project, it was found that selecting potential environmental impacts by modelling was inappropriate for the waterside landscape. This is because the specialist waterside vegetation types are known to be relatively insensitive to acidification and nitrogen loading (the two pollutants that were considered within the project).

7.2.13 The study has made use of the C-S-R classification of functional types and of the TRISTAR2 model which takes a given specification of an initial steady-state vegetation, adopts some altered environmental and/or management scenario, and predicts the composition of the new steady-state vegetation in terms of its component functional types. Most of the 'core' waterside vegetation was composed of competitor and competitor/ruderal species. The remaining vegetation plot types were representative of all other combinations of functional types.

7.2.14 The TRISTAR2 model calculated the predicted change in abundance of the functional types, under each of six specimen change scenarios, and an index of vulnerability was produced. The waterside mask includes a heterogeneous grouping of wetlands, grassland and tall herb vegetation, and woodlands. The vulnerability of all habitat groupings to the change scenarios was low, with only one plot class reaching even moderate vulnerability. Vulnerability of different habitat types differed only slightly according to scenario.

Objective 5: To make recommendations on ways in which policy instruments may be refined to further protect, enhance or re-establish habitats which characterise the landscape type

7.2.15 The results from the field survey and the outputs from the vegetation change models have been considered in the light of current policy measures.

7.2.16 Watersides comprise a potentially valuable landscape, but are currently dominated by managed and developed land use types. The survey results indicate that the core waterside vegetation amounts to only about 466 km^2 (<3% of the mask) and most of the rest is unmanaged grassland.

7.2.17 An expert group agreed the following broad hierarchy of objectives for waterside areas:
- to protect existing waterside landscapes of high value by maintaining traditional water levels and meadow management practices (eg ditch and dyke systems);
- to restore or enhance diversity across a wider area by re-instating landscape infrastructure (planting willows, creating ponds and meanders, etc);
- to re-create lost fens, carrs and reedbeds

on selected areas of arable land and restore a few selected rivers by removal of hard engineering features and drainage systems.

7.2.18 Nature conservation designation and a number of well-established schemes, such as Countryside Stewardship, now cover large proportions of the eligible land area. However, survey results suggest that the remaining areas of semi-natural habitat are limited and fragmented and that the designated areas have no higher quality than the non-designated parts of the mask. If further work indicates that the above objectives are justifiable, then opportunities do exist for improvement of habitat, especially through river corridor and catchment planning initiatives.

7.2.19 To ensure that the benefits of these measures are retained in the long term, and transferred to other areas, it is also essential that effective management approaches continue to be identified and publicised.

Objective 6: To develop a methodology for measuring change in these habitats which is sufficiently robust and precise to assess the effectiveness of policies at a national (England) scale

7.2.20 In designing the field survey, future measurement of change was a major consideration. Methods were developed from the Countryside Survey 1990 approach (which has as a major objective the establishment of a high-quality baseline against which future change can be measured). The potential and chosen approaches for measuring change are reported separately from these landscape reports (Bunce in prep.).

7.3 Advantages and disadvantages of the research approach

7.3.1 The basic approach used to address the objectives given above is shown in para 1.4.2. The advantages and disadvantages of the approach are considered under a range of headings.

Use of available, spatial data to define the lowland heath mask

7.3.2 At the start of the study there was no national map of waterside habitats. To study areas which included both existing waterside habitats and areas in which there was the potential to restore, re-create or improve them, a broad definition of the waterside zone was necessary (in which to study change).

Use of a 1 km square as a sampling unit

7.3.3 To be compatible with Countryside Survey 1990, the sampling unit was a 1 km square. This is said to represent a good balance between an area which contains enough information for it to be classified as a particular land type and one which is not too large to be field-surveyed. Use of the 150 m mask within each 1 km squares avoided wasted effort in analysing results from land which was not 'waterside' in character. The approach did allow the calculation of national estimates but, for reasons of matching sample number to scale, these estimates are not highly accurate (see calculation of statistical errors in Chapter 4).

The choice of strata

7.3.4 Part of the sampling strategy was to stratify the field sample so that differences in vegetation change between different land types, and between designated and non-designated areas, could be identified. The relatively small number of samples meant that only four strata were appropriate and, further, all designation types had to be aggregated to allow any comparisons to be made at all: no results are available in relation to any one designation type. The choice of 'arable', 'pastural' and 'upland' landscape types was logical and proved revealing, but more samples in a more disaggregated range of land types would have given clear indications as to where threats were greatest and most change was likely to occur.

Modelling vegetation change

7.3.5 Although not as conceptual in approach as had originally been specified, the UCPE approach to modelling was shown to be valuable in terms of identifying vulnerability to likely threats under a range of scenarios. However, the links between suggested scenarios and policy implementation were not spelled out and might form the focus of further work.

7.4 Future research needs

7.4.1 Research of the type undertaken in this ambitious project cannot answer every question and inevitably leads to more questions. Some of the areas for future research are listed below.

Monitoring

7.4.2 As stated above, the present project has laid a baseline against which further survey results may be measured and compared. It will be important to monitor the land cover changes and the quadrats which have already been recorded and to link these monitoring results with information on take-up from Countryside Stewardship Scheme monitoring. Links should be made explicitly with other environmental monitoring schemes, including any future Countryside Surveys and the Environmentally Sensitive Area monitoring. Only in this way can change be objectively determined and links with policy instruments properly understood.

Interpretation of modelling results

7.4.3 There is scope for further analysis of the modelling results, especially in identifying both the spatial and vegetational characteristics of areas likely to undergo change.

Integration of data

7.4.4 As stated above, opportunities to link the results of this study with work elsewhere should be sought so that links between change, habitat management/creation and policy may be better understood.

Landscape ecology

7.4.5 The spatial characteristics of habitats in the waterside areas are interesting in terms of fragmentation and connectedness. If habitat creation (and management) is to lead to maximum wetland quality, for example, then the spatial characteristics of potential areas of heath need to be known. The landscape ecology of the watersides has not been well studied and needs further investigation, especially in relation to areas of potentially improved habitat as defined within this project.

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Appendix 1 Tables to accompany Chapter 4 – Ecological characteristics of the waterside mask

This Appendix includes Tables that add detail to Chapter 4 and information on the use of quality criteria for site evaluation (Box A1.1).

Box A2.1 The use of quality criteria for site evaluation

The development of the concept of evaluation for sites originated in the post-war years when the Nature Conservancy was set up with the objective of identifying a series of National Nature Reserves. The impetus originally came from the work of Tansley (1939) on British vegetation and was encapsulated in Cmnd 7122. Whilst it was implicit that the sites should form a representative series of the 'best' examples of habitats in Britain, explicit criteria were not defined and other factors such as diversity and variety of species often determined the status of individual sites. In some regions, series were set up explicitly, eg the woodland series of sites set up by R E Hughes (unpublished) on the basis of a combination of geological and climate criteria in north Wales. The necessity to rationalise the number of sites throughout Britain led to the *Nature conservation review*, carried out in the early 1970s but eventually described by Ratcliffe (1977). That document set out the quality criteria that had been used in the selection process but these were largely *post hoc* as the large number of contributors largely worked independently.

In the early 1980s there was much discussion of the necessity for objective criteria, eg the conference at University College London (Rose 1981). Bunce (1981) laid out the necessity of prerequisites of classification to ensure that differences of quality were not inherently due to basic differences between the ecological character of sites. For example, limestone vegetation is usually species-rich whereas acid vegetation is species-poor. More recently, Usher (1991) has also pointed out that the diversification of inherently simple ecological systems represents degradation.

Usher (1986) summarised the work up to that date on evaluation and drew heavily on the work by Margules and Usher (1981). He discussed in detail the criteria laid down by Ratcliffe and showed how they had been used by various studies in different ways. He also showed how the relative weighting attached to the importance of the criteria varied widely between individuals. In this respect, conservation evaluation had paralleled that in the analogous field of landscape evaluation. Liddle (1977) laid out comparable principles and Robinson *et al.* (1976) demonstrated how objective criteria could be used for landscape assessment. The next stage for both topics was that objective criteria were virtually ignored because of the over-riding necessity for speed in the evaluation process. In landscape evaluation a decision on objective criteria could take one or even two orders of magnitude longer than on-the-spot examination, yet the outcome would, to a policy advisor, be identical.

In the case of nature conservation evaluation, the criteria had been laid down but the pressure for site safeguard meant that the majority of sites were evaluated intuitively. Within the voluntary movement this is epitomised by the recent requirement to justify the status of many sites long after they had been identified as of conservation significance.

Although there is negligible recent literature on evaluation techniques in Britain, there has been a continuing programme abroad, especially in Australia. A major meeting on systematic and conservation evaluation was held in South Africa in 1992, where most of the British speakers emphasised the need for speed in the evaluation process because of threats rather than the development of objective criteria. Crowe (1993) summarised these criteria and identified particularly the work by Margules (1989), Pressey and Nicholls (1989), Rebolo and Siegfried (1990) and Williams, Vane-Wright and Humphries (1993) in that 'together their papers embodied principles, criteria and analytical methods necessary for scientific evaluation'. They agreed that the limit of analysis should be the site and that accurate species and abundance data for the sites under consideration should be obtained. Whilst this is never completely possible, surrogate measures could be used which allow the prediction of presence or absence of individual species.

This strategy had been followed in the threatened habitats project, with measures of vegetation being used as the taxon for evaluation, partly because of the ease of consistent recording and partly because of its ready correlation with other groups. Crowe (1993) concluded that ecologists did not appreciate the severity of the conservation crisis and that short cuts were essential to identify species in crisis. Whilst this conclusion may be true on a world scale, the necessity in the present project is to develop objective measures which can determine explicitly the effects of designation in statistical terms. In this respect the methodology employed in the current project represents a combination of the criteria laid down by Margules (1989) and Pressey and Nicholls (1989), together with the vegetation survey principles of Austin and Heyligers (1989). It has also been decided as a matter of principle to rank the various scores separately and not to add them together to achieve a final 'score' – statistical considerations preclude such additions as the scale of the various measures is not known. Further, as Pielou (1991) has emphasised, and Crowe (1993) has subsequently reinforced, simple measures are more readily understood.

Table A1.1 Estimates of land cover types in the waterside strata
based on descriptions of land cover for parcels within the waterside buffer zone for sample 1 km squares

	Arable				Pastural				Upland			
	Designated		Non-designated		Designated		Non-designated		Designated		Non-designated	
Land cover type	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%
Crops	1569	*30*	1461	*53*	308	*7*	573	*20*	0	*0*	61	*3*
Improved grassland	1912	*37*	798	*29*	2698	*60*	1616	*56*	78	*17*		
Unimproved grassland	40	*1*	12	*0*	77	*2*	15	*1*	89	*19*	54	*3*
Unmged grass/tall herb	230	*4*	76	*3*	103	*2*	50	*2*	2	*0*	58	*3*
Bracken	16	*0*			13	*0*	12	*0*	59	*13*		
Moorland grass					1	*0*			67	*14*		
Heath	66	*1*			1	*0*			95	*20*	1056	*54*
Bogs/wet heath					0	*0*			18	*4*	159	*8*
Wetland	16	*0*	9	*0*	208	*5*	3	*0*	11	*2*	219	*11*
Woodland/scrub	885	*17*	183	*7*	667	*15*	431	*15*	41	*9*		
Coast	17	*0*					2	*0*			79	*4*
Built/roads/rail	418	*8*	199	*7*	417	*9*	206	*7*	8	*2*	267	*14*
Total	*5169*	*100*	*2739*	*100*	*4493*	*100*	*2909*	*100*	*467*	*100*	*1953*	*100*

	Combined				Combined							
	Designated		Non-designated		Arable		Pastural		Upland		Total	
Land cover type	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%	Area km^{-2}	%
Crops	1877	*19*	2095	*28*	3031	*38*	881	*12*	61	*3*	3972	*22*
Improved grassland	4688	*46*	2415	*32*	2710	*34*	4315	*58*	78	*3*	7102	*40*
Unimproved grassland	206	*2*	81	*1*	52	*1*	92	*1*	143	*6*	287	*2*
Unmged grass/tall herb	335	*3*	184	*2*	307	*4*	154	*2*	59	*2*	520	*3*
Bracken	88	*1*	12	*0*	16	*0*	26	*0*	59	*2*	101	*1*
Moorland grass	68	*1*					1	*0*	67	*3*	68	*0*
Heath	162	*2*	1056	*14*	66	*1*	1	*0*	1151	*48*	1218	*7*
Bogs/wet heath	18	*0*	159	*2*			0	*0*	176	*7*	176	*1*
Wetland	234	*2*	231	*3*	24	*0*	211	*3*	229	*9*	465	*3*
Woodland/scrub	1592	*16*	614	*8*	1067	*14*	1098	*15*	41	*2*	2206	*12*
Coast	17	*0*	81	*1*	17	*0*	2	*0*	79	*3*	98	*1*
Built/roads/rail	844	*8*	673	*9*	617	*8*	624	*8*	276	*11*	1516	*9*
Total	*10129*	*100*	*7601*	*100*	*7907*	*100*	*7403*	*100*	*2419*	*100*	*17730*	*100*

Table A1.2 Proportion of boundary types, by strata, in waterside landscapes calculated from non-curtilage boundaries within the buffer zone of survey squares

	Arable		Pastural		Upland		Combined		Combined			
	Des	Non-des	Des	Non-des	Des	Non-des	Des	Non-des	Arable	Pastural	Upland	Total
Boundaries	%	%	%	%	%	%	%	%	%	%	%	%
Bank	*1*		*1*	*1*	*1*		*1*	*1*	*0*	*1*	*0*	*1*
Fence	*60*	*42*	*57*	*58*	*47*	*36*	*56*	*49*	*46*	*58*	*42*	*52*
Fence/bank	*1*	*0*	*1*	*1*	*3*		*1*	*1*	*0*	*1*	*2*	*1*
Hedge	*19*	*34*	*9*	*8*	*0*	*2*	*10*	*20*	*30*	*9*	*1*	*16*
Hedge/bank	*0*	*0*	*5*	*5*	*4*		*4*	*2*	*0*	*5*	*2*	*3*
Hedge/fence	*15*	*22*	*13*	*20*		*4*	*11*	*20*	*20*	*17*	*2*	*17*
Hedge/fence/bank	*1*	*1*	*8*	*5*	*3*		*6*	*3*	*1*	*7*	*2*	*4*
Hedge/wall			*0*				*0*			*0*		*0*
Hedge/wall/fence			*0*			*1*	*0*	*0*		*0*	*1*	*0*
Wall	*4*	*0*	*2*	*0*	*26*	*39*	*6*	*3*	*1*	*1*	*32*	*4*
Wall/bank	.				*1*		*0*				*1*	*0*
Wall/fence	*0*	*1*	*3*	*0*	*15*	*17*	*4*	*2*	*1*	*1*	*16*	*3*
Total	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*	*100*

Table A1.3 Classification of quadrats from the waterside landscape (using TWINSPAN). Numbers in plain type give the numbers of quadrats at each division. Bold letters in square brackets correspond to the plot class. Numbers in italics indicate maximum score for left hand-side of division

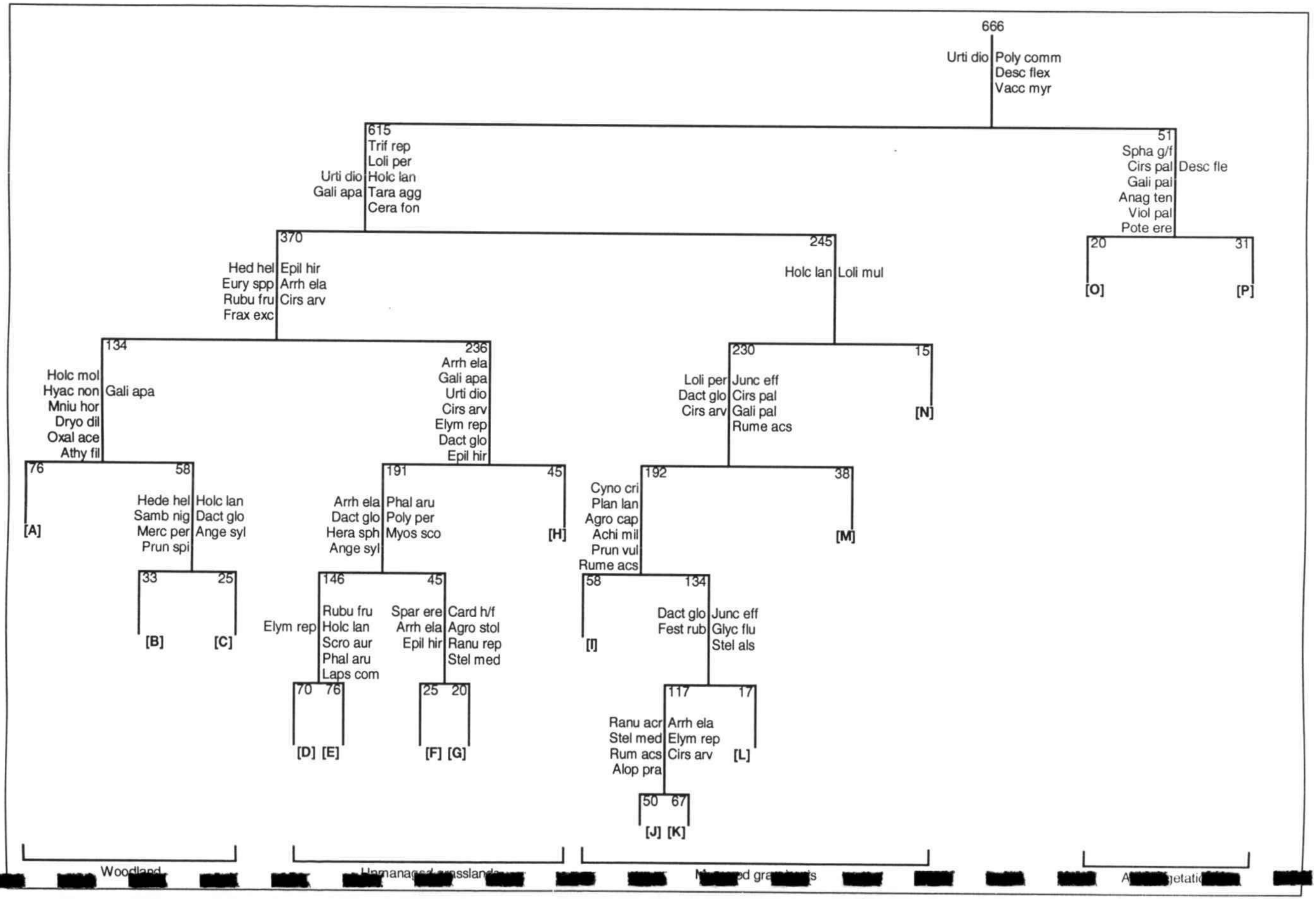


Table A1.4 Waterside landscapes – description of plot classes

Plot class	% of plots Waterside	Main	Habitat	Total no.	Description	Constants	Preferentials	Dominants
PCA	51	14	34	76	Woodland on heavy soils	*Rubu fru* *Eury spp* *Hede hel*	*Rubu fru* *Dryo dil*	*Alnu glu* *Acer pse* *Cory ave*
PCB	61	6	33	33	Basic/eutrophic woodland	*Urti dio* *Gali ap* *Hede hel*	*Hede hel* *Gali apa* *Urt dio*	*Hede hel* *Urti dio* *Cory ave*
PCC	32	12	56	25	Open/disturbed woodland	*Urti dio* *Eury spp* *Gali apa*	*Eury spp* *Crat mon* *Frax exc*	*Gali apa* *Urti dio* *Elym rep*
PCD	40	3	57	70	Coarse grassland	*Urti dio* *Elym rep* *Arrh ela*	*Elym rep* *Arrh ela* *Gali apa*	*Arrh ela* *Elym rep* *Urti dio*
PCE	86	3	12	76	Tall herb	*Urti dio* *Arrh ela* *Gali apa*	*Epil hir* *Arrh ela* *Gali apa*	*Urti dio* *Arrh ela* *Epil hir*
PCF	68 ·	32	0	25	Waterside tall herb	*Urti dio* *Epil hir* *Phal aru*	*Epil hir* *Phal aru* *Urti dio*	*Urti dio* *Phal aru* *Epil hir*
PCG	100	0	0	20	Disturbed/ eutrophic water edge	*Urti dio* *Agro sto* *Phal aru*	*Poly per* *Phal aru* *Rume obt*	*Agro sto* *Urti dio* *Phal aru*
PCH	31	69	0	45	Water edge/marsh	*Agro stol* *Phal aru* *Urti dio*	*Phal aru* *Myos sco*	*Phal aru* *Glyc max* *Agro stol*
PCI	3	47	50	58	Semi-improved grassland	*Holc lan* *Loli per* *Dact glo*	*Cyno cri* *Plan lan* *Agro cap*	*Loli per* *Agro cap* *Holc lan*
PCJ	18	68	14	50	Improved grassland	*Loli per* *Holc lan* *Ranu rep*	*Loli per* *Trif rep* *Tara agg*	*Loli per* *Holc lan* *Agro sto*
PCK	28	21	51	67	Neglected grassland	*Holc lan* *Cirs arv* *Loli per*	*Loli per* *Cirs arv* *Dact glo*	*Loli per* *Agro sto* *Holc lan*
PCL	65	0	35	17	Damp neutral grassland	*Agro stol* *Ranu rep* *Holc lan*	*Stel als* *Glyc flu* *Junc eff*	*Agro sto* *Holc lan* *Alnu glu*
PCM	42	11	47	38	Damp acid grassland	*Holc lan* *Rume ace* *Ranu rep*	*Rume ace* *Cirs pal* *Junc eff*	*Junc eff* *Holc lan* *Agro cap*
PCN	0	93	7	15	Short-term grassland	*Loli per* *Loli mul* *Trif rep*	*Loli mul* *Loli per* *Poa ann*	*Loli per* *Loli mul* *Trif rep*
PCO	45	15	40	20	Wet heath	*Poly comm* *Junc eff* *Spha g/f*	*Poly com* *Spha g/f* *Nard str*	*Spha spp* *Junc eff* *Agro cap*
PCP	26	35	39	31	Acid grassland	*Desc flex* *Agro cap* *Gali sax*	*Desc flex* *Gali sax* *Vacc myr*	*Moli cae* *Pter aqu* *Call vul*

Appendix 2 Technical appendix to Chapter 5 – Predicting changes in waterside vegetation

This Appendix includes:

- details of the TRISTAR model
- figures showing the effects of different change scenarios on vegetation within the waterside mask.

A2.1 Introduction

A2.1.1 The UCPE contribution to the threatened habitats project involves taking vegetational survey data, provided for the selected habitats by ITE, and processing these data in three distinct phases by means of the TRISTAR2 model. After the final phase, the outputs of the modelling are examined and interpreted by UCPE. Each phase in this process will now be described separately, with illustrations given at intervals to provide a worked example.

A2.2 Phase I – allocation of functional types

A2.2.1 The initial steady-state vegetation is specified by ITE in the form of a list of abundances of species in each of many survey samples or records. An example of such data appears in Figure A. The record labelled A1–A is the first in the series and contains 12 species, bristle bent (*Agrostis curtisii*) to gorse (*Ulex europaeus*) inclusive. Each vegetation record arrives at UCPE bearing a classification according to both of two sets of criteria:

- the designated status, if any, of the site from which the record was taken, and
- the plant community type into which the vegetation of the quadrat falls.

The basis for these two classifications is the ITE TWINSPAN analysis which is described elsewhere in this Report.

A2.2.2 For each vegetation record, one of 19 functional types is then allocated to each of the component species using information from UCPE databases. The system used, the C-S-R classification of functional types (Grime 1974, 1979; Grime Hodgson & Hunt 1988), has been explained in moderate detail by Hunt *et al.* (1991). Briefly, it recognises two external groups of factors, both of which are antagonistic to plant growth. The first group is called *stress* and consists of factors which place prior restrictions on plant production, such as shortages of light, water, carbon dioxide, mineral nutrients, or chronically non-optimal temperatures. The second group, called *disturbance*, causes the partial or total destruction of plant biomass after it has been formed, and includes management factors such as grazing, trampling, mowing and ploughing, and also phenomena such as wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A2.2.3 When the four permutations of high and low stress against high and low disturbance are examined (Figure B), a different primary strategy type emerges in association with each of the three viable contingencies: *competitors* in the case of minimum stress and minimum disturbance, *stress-tolerators* in the case of maximum stress and minimum disturbance, and *ruderals* in the case of minimum stress and maximum disturbance. The initials of these three 'primary' strategists give the C-S-R model its name. The fourth contingency, that of maximum stress and maximum disturbance, does not support plant life at all. The triangular diagram (Figure B) which emerges from this view of plant life gives the TRISTAR system its name.

A2.2.4 Intermediate types of C-S-R strategy can be identified, each exploiting a different combination of intensity of external stress and disturbance. The positions of any of a wide variety of species (or, by aggregating its component species, of any vegetation type) can thus be displayed on a hexagonal diagram (Figure C) which represents the central zone of the original triangle (Figure B) turned clockwise through 45°. The positions on this diagram can each be identified by means of a C, S, and R co-ordinate on a scale of 1–5 (Figure D), thus facilitating the quantitative treatment of any position within C-S-R space. This can be done for individual species, for individual samples, or for groups of samples. All play a part in the modelling conducted within the threatened habitats project. Plant strategy theory in this form is thus applicable to vegetation systems other than those from which it was derived, and does not rely upon the estimation of specific plant parameters.

A2.2.5 The TRISTAR2 conflates the weighted abundances of up to a maximum of 19 individual functional types which may be present within each sample. This process created weighted abundances for each of seven broader groups of functional types (those shown in bold type in Figure C). These seven groups represent the three extreme corners of the C-S-R triangle ordination, its centre, and its principal intermediate positions. The seven groups are each converted into a two-part numerical code (seen, for example, in the second and third columns of Figure E). The two-part code provides a computational mechanism for representing both 'pure' and intermediate functional types.

A2.2.6 Once converted, the classifications according to functional type provide the basis for all further work on the vegetation sample by TRISTAR2. The first page of the presentation for each habitat (or subhabitat, if appropriate) consists of a divided percentage bar diagram illustrating the functional composition of all the plot classes present in the initial vegetation. Ecological notes on the habitat as a whole appear at this point.

A2.3 Phase II – effects of change scenarios on the abundance of functional types

A2.3.1 The TRISTAR2 model is next provided with various climate change or management scenarios. These have various implications for vegetation because they represent possible changes in environmental stress and disturbance. Initially, eight specimen scenarios were suggested by the project team (Figure F). Although these were all of direct interest to the project, it was felt that sufficient information on habitat sensitivity and resilience could be obtained by applying a smaller number of scenarios (Figure G). These involve only certain of the possible combinations of the two variable factors, environmental disturbance and eutrophication (the latter being defined as a *relaxation* of stress).

A2.3.2 For each factor and functional type within the six specimen scenarios, TRISTAR2 applies an appropriate numerical multiplier according to our understanding of the effects of the factor. The essence of the approach is that seven functional types are each driven by this weighting in different directions and with different gradients, according to information from UCPE's extensive survey and screening databases.

A2.3.3 However, even the six simple scenarios adopted do not always have a simple environmental interpretation. Their value lies in there being a representative group of theoretical changes against which the robustness of different habitats, of different categories of designation, or of different functional types or plant community may be tested. The main difficulty here is that a single scenario condition, such as 'increased eutrophication', may have a multiplicity of meanings. For example, it may literally mean reduced stress, in the sense of a reduced presence of toxic compounds or of a movement away from chronically non-optimal temperatures, or it may mean an enrichment of the environment in the sense of an increased availability of mineral nutrients or an enhancement of CO_2 level. The term 'decreased eutrophication' may have the opposite meaning to these, and similar arguments apply to 'decreased' or 'increased' levels of disturbance factors such as grazing, trampling, mowing, ploughing, wind damage, frosting, droughting, soil erosion, acutely non-optimal temperatures and fire.

A2.3.4 For these reasons the scenarios listed in Figure G cannot be identified explicitly in terms of *all* the environmental or management changes which they may present. The total number of permutations of scenarios runs into tens of thousands, and even one of the scenario lines in the Table may have very many variants, according to which definitions of disturbance and eutrophication are adopted.

A2.3.5 Nonetheless, each scenario prompts TRISTAR2 to predict a new abundance for each functional type under the new stable state. New percentage abundances for each functional type and designation stratum are calculated for all scenarios.

A2.3.6 For each of six scenarios a Table is computed (but not presented) which groups the predictions for each functional type in each plot classes presenting the habitat (PCA, PCB, etc). TRISTAR2 calculates the predicted change in percentage abundance of each of the seven functional types C, C-R, CSR, R, S, SC and SR relative to the initial composition of each plot class in the habitat. When charted, this analysis form the top left-hand element in the display of predictions for each scenario (pages 72–78).

A2.4 Phase III – computation of an 'index of vulnerability'

A2.4.1 Next, an index of vulnerability is computed for each plot class. This is done in three substages.

i. Examine the original data to find the number of quadrats deviating appreciably from the typical

The mean and standard deviation (SD) of each functional type within each plot class is calculated (the type-mean and type-SD). The mean across all seven type-SDs within each plot class is also derived (the class-type-SD). Each individual quadrat is then examined and the percentage abundance of each of its functional types is compared with the type-mean from the appropriate plot class; the result is expressed as a deviation from the type-mean. The mean of all such deviations for the quadrat is then compared with the class-type-

SD to find which quadrats have mean deviations greater than one unit of SD. Such quadrats are classified as outliers and their number is noted; the remaining quadrats, those within one class-type-SD (the great majority), are classified as typical.

ii. **Examine the TRISTAR2 predictions to find the new number of quadrats deviating appreciably from the original composition**

In the model prediction the abundances of CSR types within each of the quadrats have often changed. The new abundances are compared with the original class- and type-means and SDs (as in substage (i)). The new counts of typical or outlying quadrats are obtained. Some plot classes may contain more outliers under the new scenario, but others may be more resistant to predicted change, or may even contain fewer outliers (ie be made more typical) in certain instances.

iii. **Find the 'index of vulnerability' for each plot class**

This is simply the proportional change (on a scale of −1.0 to +1.0) in the number of quadrats identified as 'outliers', in each plot class, found by comparing substages (i) and (ii).

A2.4.2 The index of vulnerability is displayed as a bar diagram for each plot class in the habitat (the top right-hand section of the presentation in pages 72–78). A value of 0.0 in this diagram indicates that no increase or decrease in number of outliers has taken place as a result of the imposition of the scenario in question. If some change has taken place, this is classified as 'decreased' (ie having fewer outlying quadrats, indicating a composition even more typically uniform than before), or 'increased' to a 'low', 'moderate' or 'high' degree (indicating an appropriate amount of departure from typicality) according to the thresholds shown on each diagram. These particular thresholds have no absolute validity in themselves and are provided only as comparative tools. The indices of vulnerability are summarised across all plot classes in a small Table below the diagram. Ecological notes on the effects of the particular scenario within the current habitat conclude the presentation of each scenario.

A2.4.3 Finally, page 79 summarises the mean index of vulnerability across all scenarios for each plot class within the current habitat. Further ecological notes are added at this point. Comparisons between different habitats (or subhabitats) will ultimately be made possible by means of such material.

Figure A. Sample of raw data as received from ITE

Quadrat identifier	Species	Cover (Inner nest)	Cover (Outer nest)
A1–A	*Agrostis curtisii*	5	0
A1–A	*Calluna vulgaris*	10	0
A1–A	*Campylopus* sp.	1	0
A1–A	*Carex pilulifera*	1	0
A1–A	*Erica cinerea*	15	0
A1–A	*Erica tetralix*	10	0
A1–A	*Hypogymnia physodes*	1	0
A1–A	*Leucobryum glaucum*	1	0
A1–A	*Molinia caerulea*	40	0
A1–A	*Potentilla erecta*	1	0
A1–A	*Pteridium aquilinum*	10	0
A1–A	*Ulex europaeus*	1	0
A1–B	*Calluna vulgaris*	95	0
A1–B	*Cladonia impexa*	1	0
A1–B	*Cladonia* sp.	1	0
A1–B	*Erica cinerea*	5	0
A1–B	*Molinia caerulea*	1	0
A1–C	*Agrostis canina canina*	1	0
A1–C	*Agrostis curtisii*	20	0
A1–C	*Molinia caerulea*	35	0
A1–C	*Polygala serpyllifolia*	1	0
A1–C	*Pteridium aquilinum*	90	0
A1–C	*Rubus fruticosus*	1	0
A1–C	*Teucrium scorodonia*	1	0
A1–C	*Ulex europaeus*	1	0
A1–D	*Calluna vulgaris*	95	0
A1–D	*Dicranum scoparium*	1	0
A1–D	*Erica cinerea*	1	0
A1–D	*Hypnum cupressiforme*	1	0
A1–E	*Agrostis curtisii*	1	0
A1–E	*Calluna vulgaris*	5	0
A1–E	*Cephalozia* sp.	1	0
A1–E	*Drosera intermedia*	1	0
A1–E	*Drosera rotundifolia*	5	0
A1–E	*Erica tetralix*	15	0
A1–E	*Eriophorum angustifolium*	1	0
A1–E	*Gymnocolea inflata*	1	0
A1–E	*Juncus bulbosus*	1	0

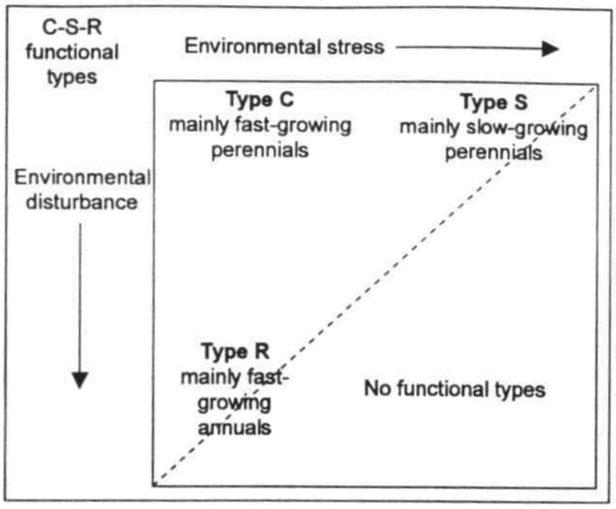


Figure B. The relationship between stress and disturbance factors and the C-S-R types

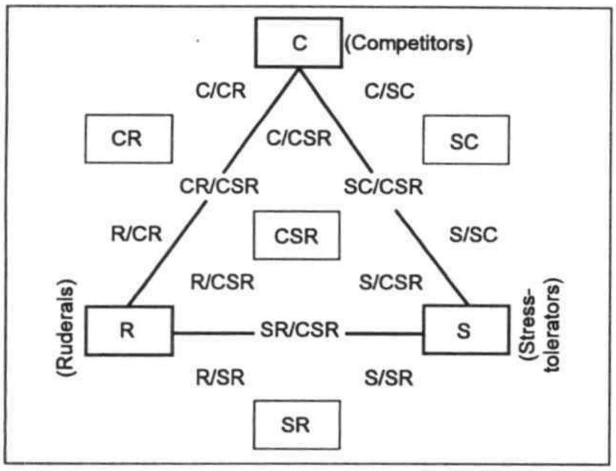


Figure C. The C-S-R triangle ordination showing the three principal functional types and intermediate positions

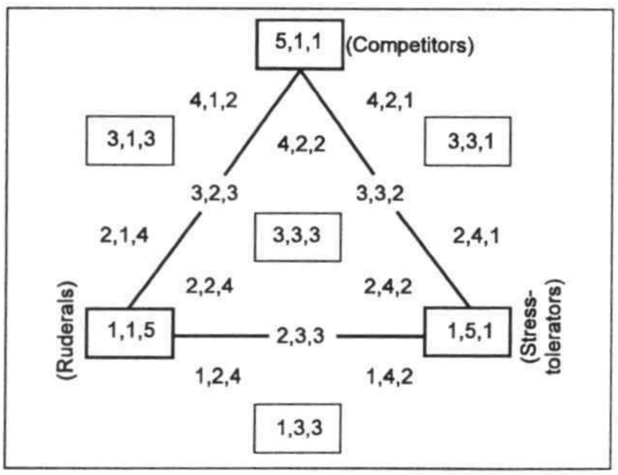


Figure D. C-S-R co-ordinates of functional types

Figure E. Reclassification of species according to functional types

Quadrat identifier	Species	C-S-R classification Part 1	Part 2	Cover
A1–A	*Agrostis curtisii*	5	5	5
A1–A	*Calluna vulgaris*	6	6	10
A1–A	*Campylopus* sp.	7	7	1
A1–A	*Carex pilulifera*	5	5	1
A1–A	*Erica cinerea*	5	6	15
A1–A	*Erica tetralix*	5	6	10
A1–A	*Hypogymnia physodes*	0	0	1
A1–A	*Leucobryum glaucum*	5	5	1
A1–A	*Molinia caerulea*	6	6	40
A1–A	*Potentilla erecta*	3	5	1
A1–A	*Pteridium aquilinum*	1	1	10
A1–A	*Ulex europaeus*	6	6	1
A1–B	*Calluna vulgaris*	6	6	95
A1–B	*Cladonia impexa*	5	5	1
A1–B	*Cladonia* sp.	5	5	1
A1–B	*Erica cinerea*	5	6	5
A1–B	*Molinia caerulea*	6	6	1
A1–C	*Agrostis canina canina*	3	3	1
A1–C	*Agrostis curtisii*	5	5	20
A1–C	*Molinia caerulea*	6	6	35
A1–C	*Polygala serpyllifolia*	5	5	1
A1–C	*Pteridium aquilinum*	1	1	90
A1–C	*Rubus fruticosus*	6	6	1
A1–C	*Teucrium scorodonia*	3	4	1
A1–C	*Ulex europaeus*	6	6	1
A1–D	*Calluna vulgaris*	6	6	95
A1–D	*Dicranum scoparium*	5	5	1
A1–D	*Erica cinerea*	5	6	1
A1–D	*Hypnum cupressiforme*	5	7	1
A1–E	*Agrostis curtisii*	5	5	1
A1–E	*Calluna vulgaris*	6	6	5
A1–E	*Cephalozia* sp.	7	7	1
A1–E	*Drosera intermedia*	5	7	1
A1–E	*Drosera rotundifolia*	3	6	5
A1–E	*Erica tetralix*	5	6	15
A1–E	*Eriophorum angustifolium*	5	6	1
A1–E	*Gymnocolea inflata*	7	7	1
A1–E	*Juncus bulbosus*	3	7	1

Figure F. Eight specimen scenarios

1. An 80% reduction in sulphur emissions
2. A 40% reduction in nitrogen emissions
3. A 10% increase in nitrogen emissions
4. A 3°C increase in temperature, together with
   - 10% extra precipitation
   - 10% less precipitation
5. Reduction of grazing to 50% (where relevant)
6. Removal of land from arable (where relevant)
7. Removal of land from forest (where relevant)

Figure G. Six simplified scenarios used by UCPE.

UCPE scenario	Disturbance factor	Eutrophication factor	Example
1	Decreased	The same	Less grazing, trampling, cutting or burning, etc, but resource levels unaltered
2	Decreased	Increased	Less grazing, trampling, cutting or burning, but more resources such as light, water or nutrients
3	The same	Decreased	No change in grazing, trampling, cutting or burning, etc, but fewer resources such as light, water or nutrients
4	The same	Increased	No change in grazing, trampling, cutting or burning, etc, but more resources such as light, water or nutrients
5	Increased	Decreased	More grazing, trampling, cutting or burning, etc, and fewer resources such as light, water or nutrients
6	Increased	Increased	More grazing, trampling, cutting or burning, etc, and more resources such as light, water or nutrients

Baseline [the intial state]

General notes on this habitat

For the purposes of this interpretation, the waterside plot classes will be divided into three groupings that relate to habitat type:

- **woodland** (plot classes A–C),
- **grassland and tall herb vegetation** (D–E, I–P) and
- **wetland** (F–H).

Grassland and tall herb vegetation is further subdivided by functional type into **base-rich** (plot classes D–E, I–L, N; relatively productive and most frequent in the lowlands) and **acidic** (M, O and P; unproductive, with high representation of type S, and predominantly upland).

1. **Woodland** (plot classes A–C) is a relatively natural grouping. It has its own range of management procedures with understorey shading by its woody dominants. Analysis of data from the various scenarios is, however, difficult because separate analyses have not been carried out on the tree, shrub and herb layers. The three layers will not necessarily respond in the same way to the same scenario. For example, herbs will be considerably more susceptible to most forms of disturbance than mature trees of similar strategic type. A further problem relates to another characteristic group of woodland species not adequately separated by type alone, namely vernal herbs. These spring flowers are classified as type SR. They have more or less completed their annual growth cycle before the tree canopy is fully expanded, and are particularly important to the public perception of woodland. Some of Britain's best-loved flowers are woodland vernals (eg bluebell (*Hyacinthoides non-scripta*) and wild daffodil (*Narcissus pseudonarcissus*)). Class 1 (woodland on heavy soils) has the smallest representation of S, a type which, in the context of woodland, is often associated with shade tolerance, and most species of SR, and presumably most vernal species. Open/disturbed woodland (class 3) predictably has fewest species of type S and most of type R and type CR.

2. **Grassland and tall herb vegetation** (plot classes D–E, I–P) can be subdivided into groups relating to their management on the basis of plant types. **Acidic vegetation** is almost by definition 'unimproved'. An early stage in reclaiming the land for intensive agriculture would have been the application of lime. Type CSR is the most characteristic of grazed conditions. However, in acidic vegetation (plot classes M, O and P) stocking rates are relatively low and, as well as type CSR, S is well represented. In **base-rich vegetation** (plot classes D–E, I–L, N), type CSR has highest occurrence in plot classes I and L and, on this basis, these classes are most typical of relatively productive grassland. Many species of type C, CR and SC indicate low or no management inputs, ie dereliction. Plot classes D, E and K are extreme examples of abandoned grassland with very high values of C, while classes J and N, with additional high values of CR, have perhaps an additional history of disturbance. However, the presence of

ruderal types is difficult to interpret for grassland habitats. Most ruderals are entirely dependent upon the production of seed for regeneration, and flowering shoots tend to be removed by grazing animals. Thus, the presence of ruderals in grassland may paradoxically be most characteristic of derelict conditions. For example, there are more annuals in meadows, which have an unmanaged phase before the hay cut, than in pasture, which is grazed throughout the growing season. However, there are exceptions. A few species, particularly thistles (*Carduus* and *Cirsium*), are protected against most herbivores and the low-growing annual meadow-grass (*Poa annua*) is characteristic of over-grazed conditions. Also, ruderals may originate as a consequence of previous land use practices. If land was formerly under arable cultivation, weeds will appear in short-term leys for many years, even if they are unable to set seed. Their stock will be replenished from the soil seed bank.

3. **Wetland habitats** (plot classes F–H) appear eutrophic with a predominance of types C and CR. The CR type will include a number of species from near the water's edge, such as watercress (*Rorippa nasturtium-aquaticum*), which are able to regenerate from shoot fragments following damage associated with flooding.

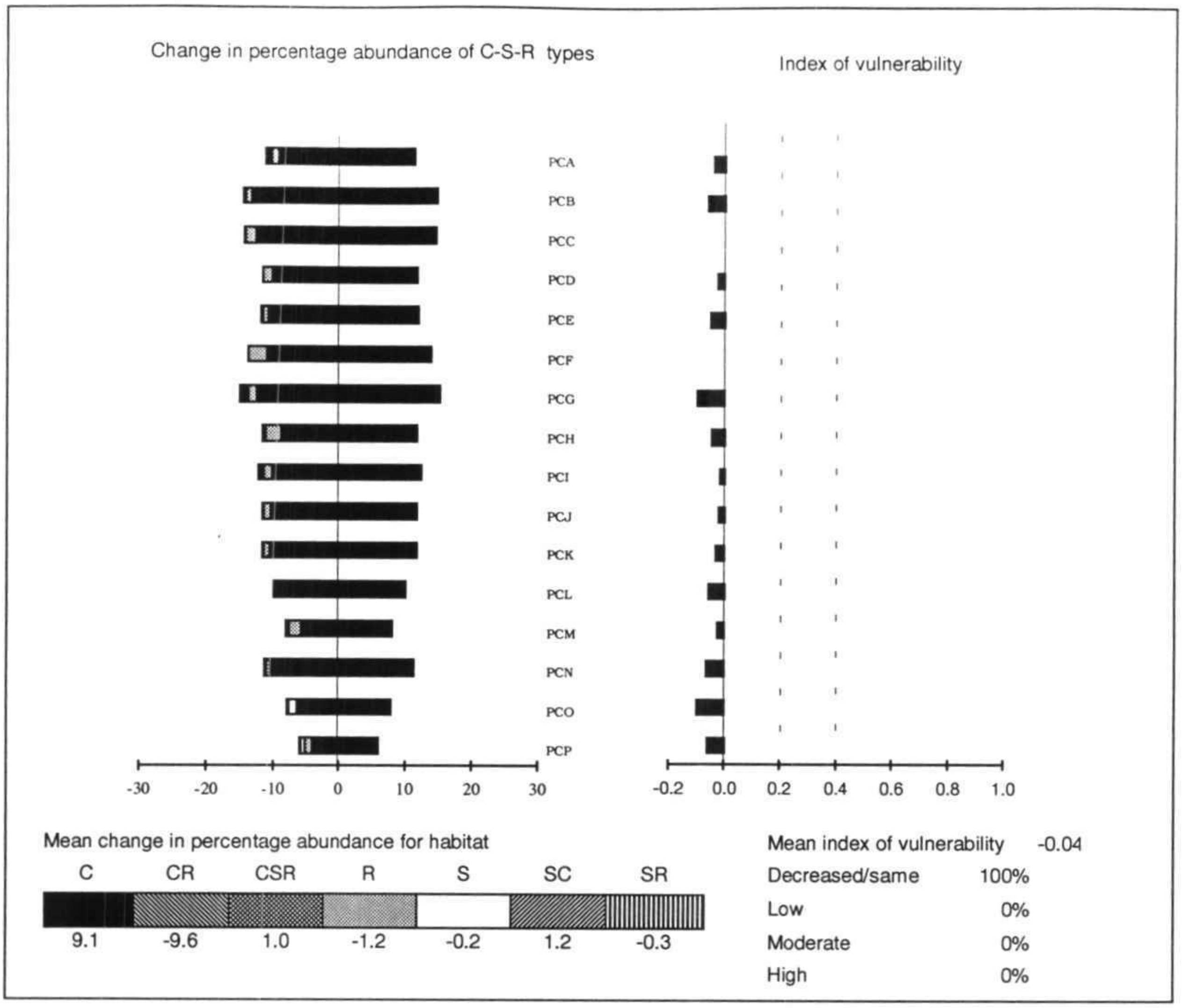
Key species

These include great willow-herb (*Epilobium hirsutum*), reed canary-grass (*Phalaris arundinacea*), creeping bent (*Agrostis stolonifera*) and common bent (*Agrostis capillaris*)

Important invaders

- **Derelict conditions**
  Birch (*Betula pendula*, *B. pubescens*) and other trees and shrubs
  Bracken (*Pteridium aquilinum*)
  Mat-grass (*Nardus stricta*), tor-grass (*Brachypodium pinnatum*) and other coarse grasses
- **Derelict eutrophicated conditions**
  Gorse (*Ulex europaeus*) – especially in areas which become burnt
  Bramble (*Rubus fruticosus*)
  Stinging nettle (*Urtica dioica*), creeping thistle (*Cirsium arvense*) and other tall herbs
  False oat (*Arrhenatherum elatius*), common couch (*Elytrigia repens*) and other coarse grasses
  In wet areas
    soft rush (*Juncus effusus*)
    tufted hair-grass (*Deschampsia cespitosa*)
    great willow-herb (*Epilobium hirsutum*)
    reed canary-grass (*Phalaris arundinacea*)

Scenario 1 – [Disturbance decreased; eutrophication the same]

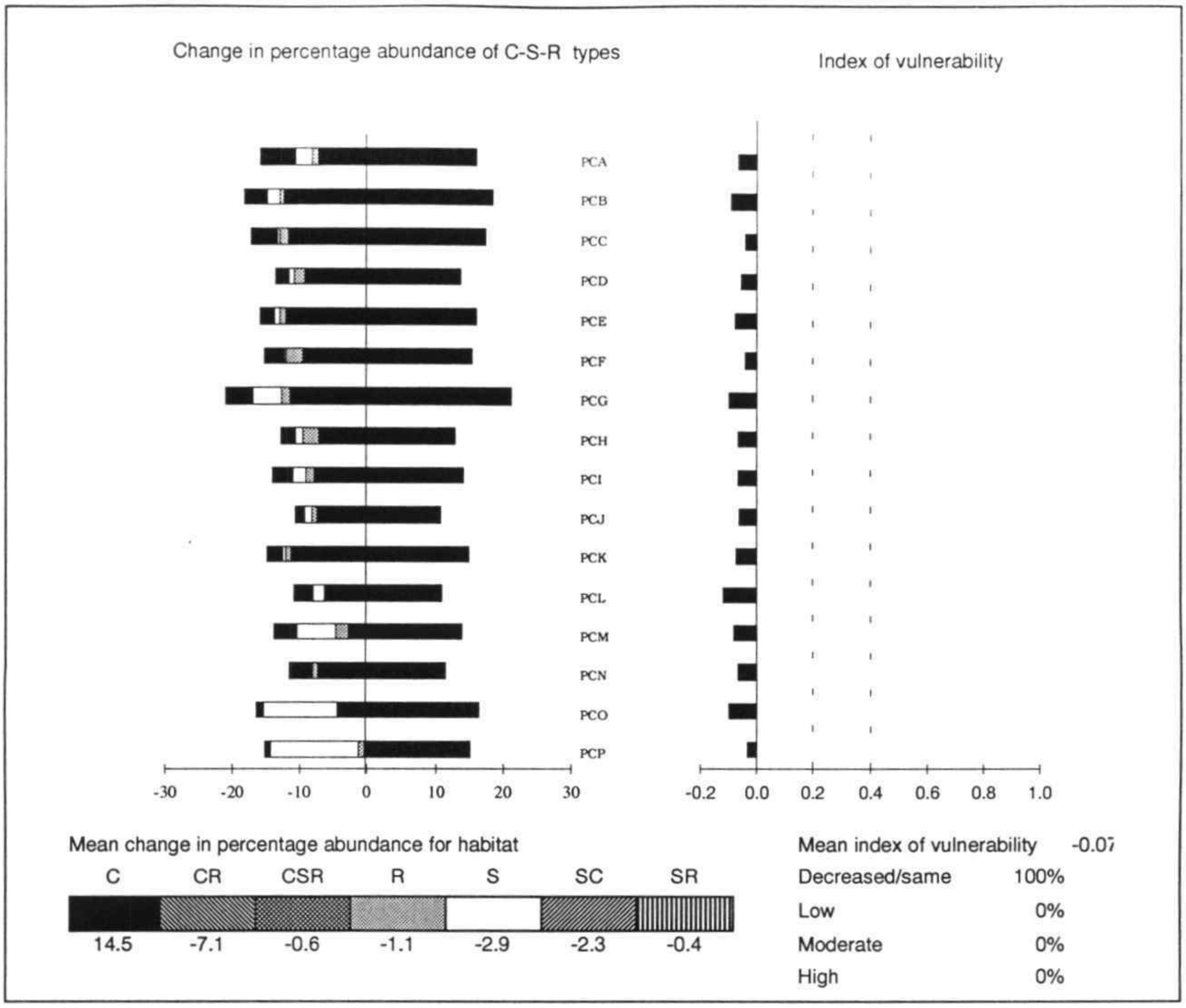


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires], less flooding
- **Grassland and tall herb vegetation** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires, less flooding
- **Wetland habitats** – *decreased disturbance* – cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting

In **woodland** (plot classes A–C) only a small change is predicted. To some extent this prediction accords with expectations from ecological theory. Floristic and strategic composition is strongly influenced by the dominants of the system, ie trees. Most trees are of type SC and will change little. However, slightly increased shade and greater litter production are likely, which would tend to suppress further the herb layer and could even encourage species of type S. It is, however, unlikely that type C will be a beneficiary as predicted by TRISTAR. In **grassland and tall herb vegetation** (plot classes D, E, I–P), similar shifts in functional type are predicted. In the more eutrophic classes (plot classes D–E, I–L and N), a denser taller sward would be expected and, consistent with this, there are increases in type C primarily at the expense of type CR. Even in less productive grassland (**acidic vegetation**, plot classes M, O and P), where growth rates are slower, similar but smaller changes are expected. Paradoxically, reduced disturbance from land use activities could in unproductive situations eventually result in episodes of increased disturbance. An increase in above-ground biomass is predicted and, in the event of fire, a greater quantity of combustible material would be present. However, because of their proximity to water, these classes will probably not be vulnerable to fire. Associated with the increased biomass will be increased water loss through transpiration. The colonisation of wetlands by trees can substantially reduce the water table. For **wetland habitats** (classes F–H), which are eutrophic, a similar change to that for productive grassland is predicted, namely an increase in type C. Reduced disturbance may result from either a relaxation in land management (eg grazing) or an abatement of natural processes (erosion and sedimentation), or a combination of the two. The values for index of vulnerability are negative and short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 2 – [Disturbance decreased; eutrophication increased]

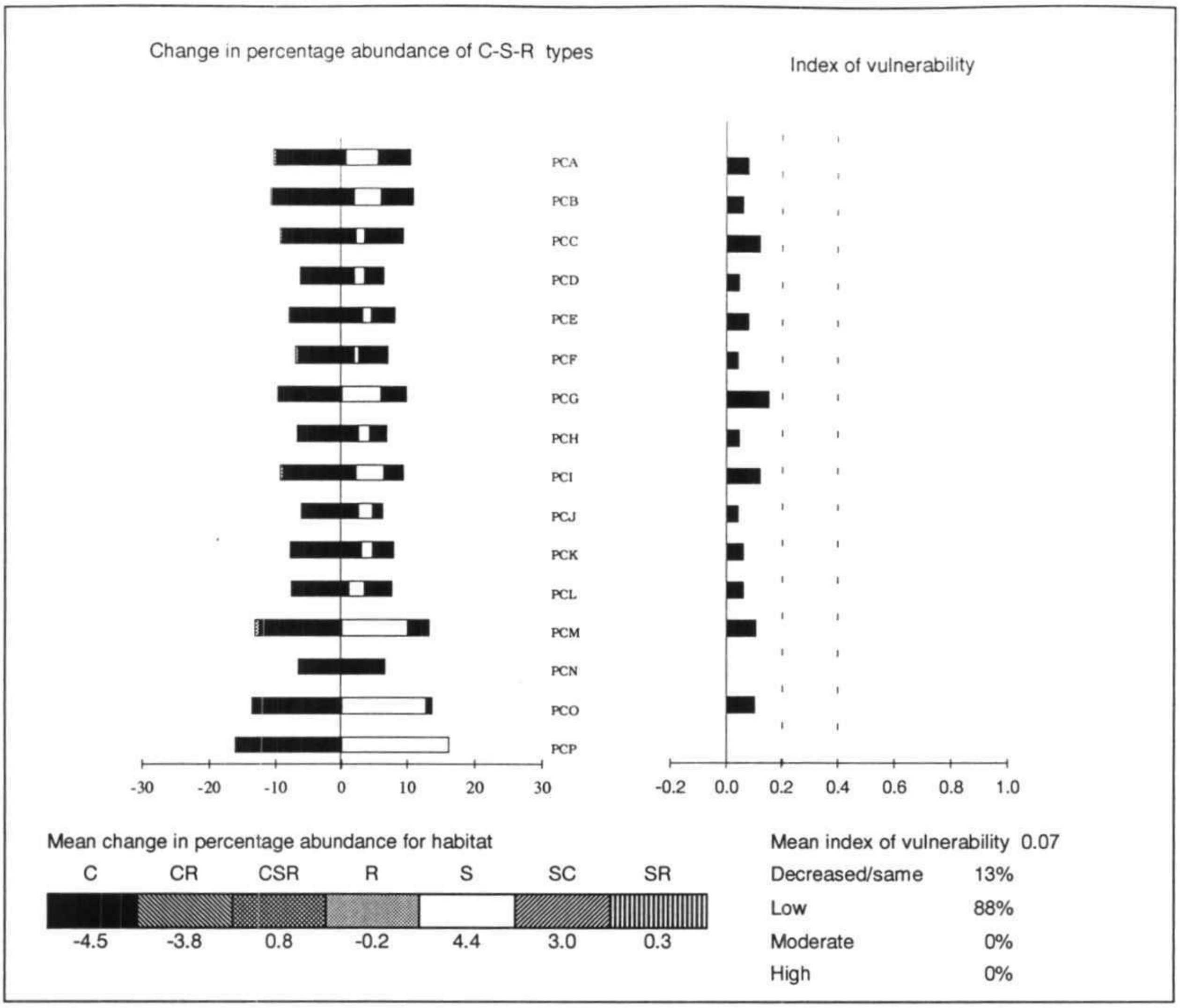


Possible causes of this scenario

- **Woodland** – *decreased disturbance* – no tree thinning [in heathy areas a reduced incidence of fires], less flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding
- **Grassland and tall herb vegetation** – *decreased disturbance* – cessation/reduction of grazing or cutting, less recreational pressure, reduced incidence of fires; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding
- **Wetland habitats** – *decreased disturbance* – cessation/reduction of flooding, particularly severe floods where there is silt deposition or scouring by fast-flowing water, less recreational pressure, grazing or cutting; *increased eutrophication* – fertilizer runoff or atmospheric deposition, more flooding

Increased eutrophication in combination with decreased disturbance will have a greater and more rapid impact on the distribution of functional types than that exhibited in the previous scenario (disturbance decreased; eutrophication same). Taller, faster-growing vegetation should be produced and overall losses of types S and ruderals and an increased representation by type C are predicted. The reality for woodland (plot classes A–C) is likely to be somewhat different to that predicted by TRISTAR. Floristic and strategic composition is strongly influenced by the dominants of the system, ie trees. Most trees are of type SC and therefore the predicted small losses within type SC are unlikely to happen. Instead, increased shade and litter production are likely, which would tend to suppress further the herb layer. In reality, types SR (vernals) and S seem most likely to increase in the longer term, provided that there are no barriers to their initial establishment. In **grassland and tall herb vegetation** (plot classes D–E, I–P), the prediction of losses of types S and ruderals and an increased representation by type C accords better with expectations. However, the more eutrophic classes (plot classes D–E, I–L and N) will lose type CR and exhibit rapid change, while in the less productive **acidic vegetation** change will be slower and major losses will be of type S. For eutrophic **wetland habitats** (plot classes F–H), again an increase in type C is predicted, mainly at the expense of type CR. Even if natural processes (erosion and sedimentation) restrict the impact of type C, sites should be more strongly vegetated. Eutrophication should encourage rapid recovery following disturbance. The values for index of vulnerability are again negative, indicating that short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 3 – [Disturbance same; eutrophication decreased]

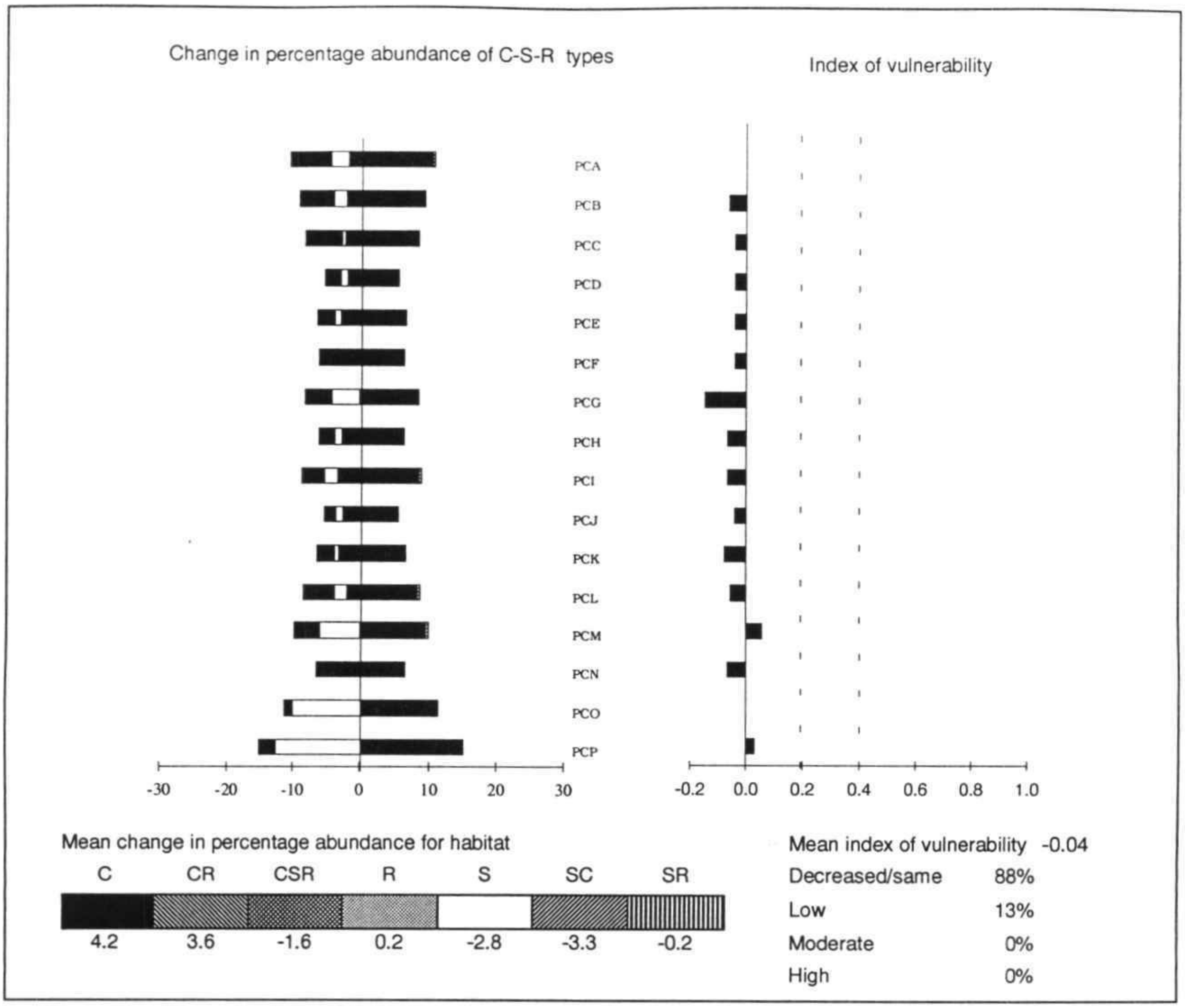


Possible causes of this scenario

- **Woodland** – *decreased eutrophication* – potentially a natural consequence of woodland ageing; the soil becomes progressively depleted of nutrients as the tree biomass increases. Also, reduced flooding, if this did not affect the level of disturbance, could reduce nutrient inputs into the system
- **Grassland and tall herb vegetation** – *decreased eutrophication* – decreased usage of or pollution from fertilizers; reduced flooding, if this did not affect the level of disturbance, could reduce nutrient inputs into the system
- **Wetland habitats** – *decreased eutrophication* – decreased usage of or pollution from fertilizers, decreased deposition of nutrient-laden mud and silt

Increases in types S and SC and decreasing C, CSR and ruderals (eg CR) are predicted. However, an increase in one of the main beneficiaries, type S, which grows very slowly, will take considerably longer, and results may be less marked than predicted. Many species of type S do not form a persistent bank of seeds in the soil or exhibit long-distance dispersal. Thus, sites in plot classes where type S is poorly represented (eg plot classes A–F, H–L and N) may fail to be colonised by type S. **Grassland and tall herb vegetation** (plot classes D–E, I–P) and **wetland habitats** (plot classes F–H) are expected to change in accordance with the general pattern predicted above. In less acidic vegetation (plot classes M, O and P), growth rates will already be slow and a major shift to class S is expected. However, the more eutrophic classes (D, E, I–L and N) start with a high nutrient status and will therefore not reach such low levels of productivity. For this reason, in many instances increases in types SC and CSR will be greater than in type S. In practice, the decreased eutrophication in **wetland habitats** is likely to occur rather rarely. Impacts on the **woodland** grouping (plot classes A–C) are difficult to predict. The predictions given are probably incorrect because the canopy and herb layer were not separated prior to the analysis. If growth of the tree canopy is reduced, an increase in the biomass of the ground flora is possible. Because the nutrient demands of small fast-growing herbs may well be less than those of large slow-growing trees, increasing types could even include type C. Values for index of vulnerability are low, indicating that short-term impacts on the strategic composition of the vegetation will be slight.

Scenario 4 – [Disturbance same; eutrophication increased]

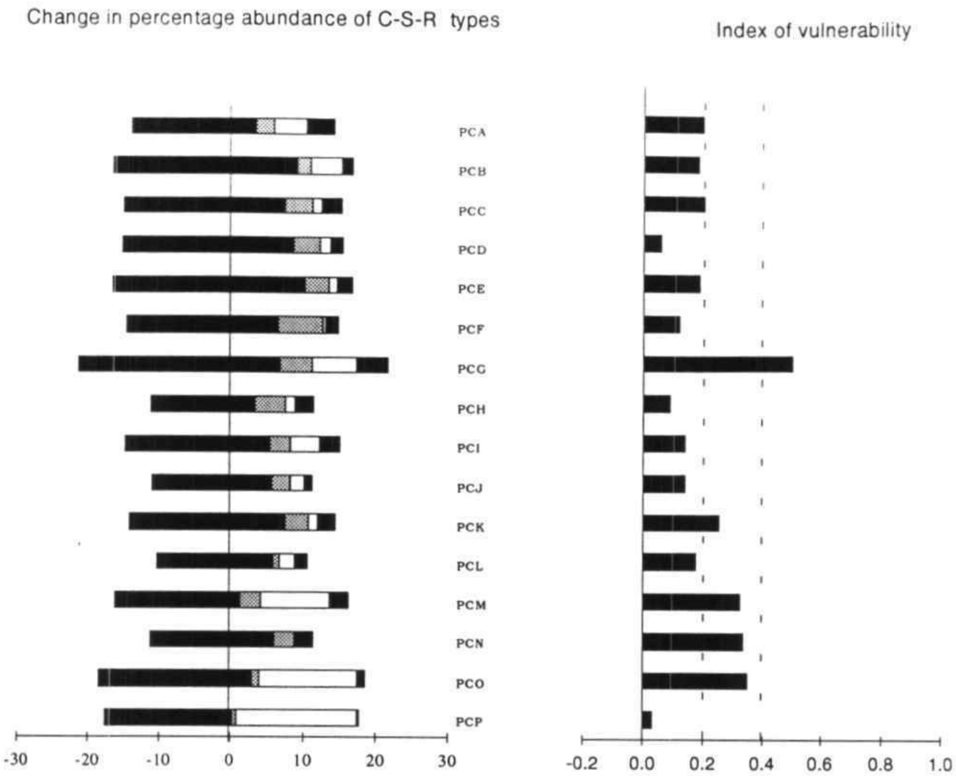


Possible causes of this scenario

- **Woodland** – *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice, increased flooding (in absence of appreciable disturbance)
- **Grassland and tall herb vegetation** – *increased eutrophication* – fertilizer runoff or atmospheric deposition, increased flooding (in absence of appreciable disturbance)
- **Wetland habitats** – *increased eutrophication* – increased flooding (in absence of appreciable disturbance), fertilizer runoff or atmospheric deposition

Increased eutrophication is one of the most important scenarios to consider with respect to changing land use. Within eutrophic **grassland** (plot classes D–E, I–L and N) and **wetland habitats** (plot classes F–H), where many species are fast-growing, rapid changes are predicted, with a decrease in CSR and SC types and an increase in C and CR. In less productive **acidic vegetation** (plot classes M, O and P), growth rates are slower and the predicted shift is more from class S and SC. In the **woodland** grouping (plot classes A–C), the initial predicted invasion by competitive herbs will perhaps only occur at the woodland margin. Increased eutrophication may increase tree growth and shade. This would reduce the cover of ground flora species of all functional types except perhaps types SR (vernals) and S. The largely negative values for index of vulnerability indicate that short-term impacts on the strategic composition of the vegetation will be small.

Scenario 5 – [Disturbance increased; eutrophication decreased]



Mean change in percentage abundance for habitat

C	CR	CSR	R	S	SC	SR
-12.9	5.4	-1.8	2.9	4.4	0.8	1.1

Mean index of vulnerability	0.20
Decreased/same	0%
Low	63%
Moderate	25%
High	6%

Possible causes of this scenario

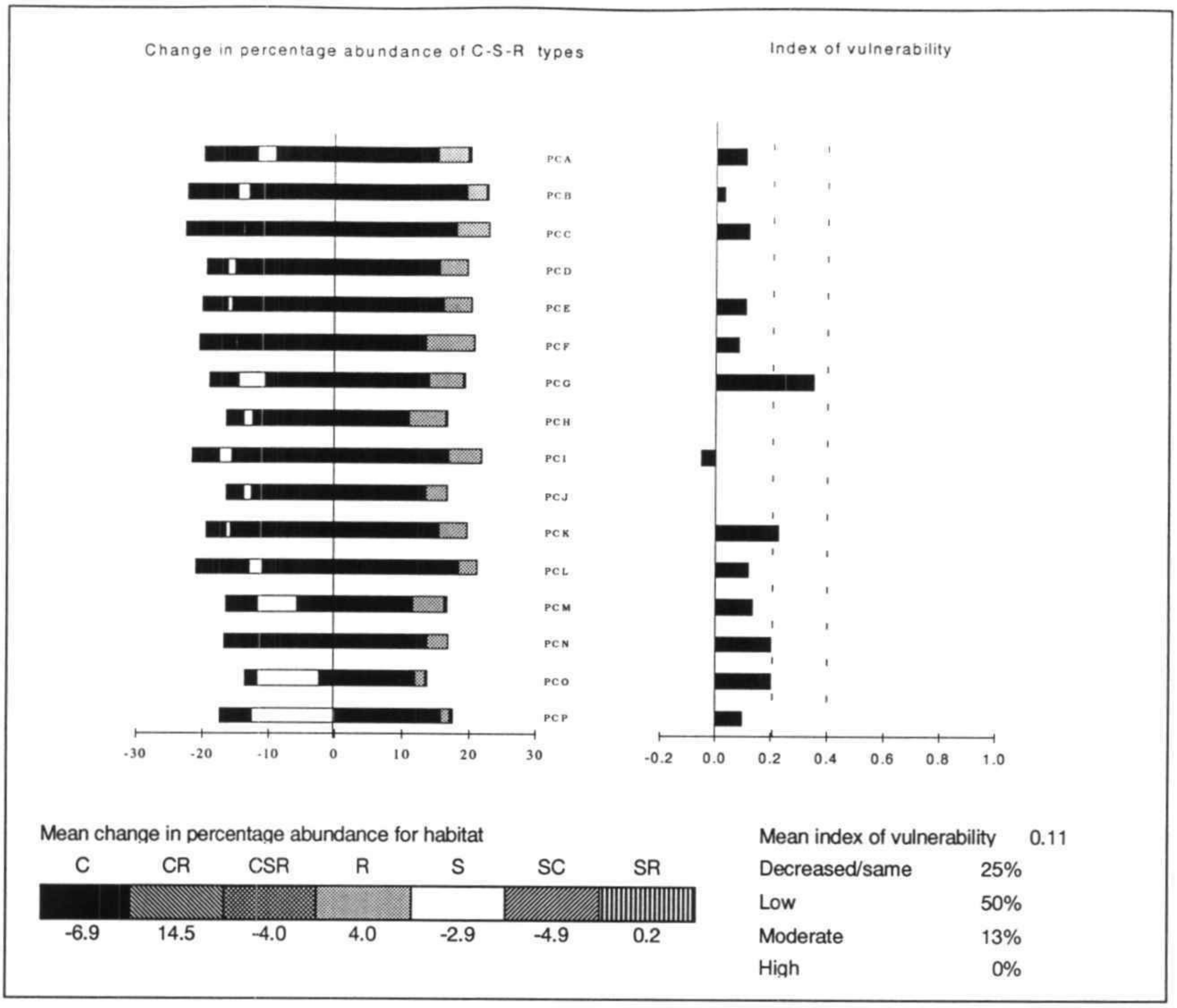
- **Woodland** – *increased disturbance* – tree thinning, incidence of fire (discouraged during forestry practice); *decreased eutrophication* – less fertilizer runoff or atmospheric deposition mainly from agricultural sources, less fertilizer added as a part of silvicultural practice or more leaching
- **Grassland and tall herb vegetation** – *increased disturbance* – increased grazing or cutting, reduced incidence of fires, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition
- **Wetland habitats** – *increased disturbance* – increased grazing or cutting, increased recreational pressure; *decreased eutrophication* – less fertilizer runoff or atmospheric deposition.

Flooding typically causes increased disturbance and increased eutrophication. It therefore cannot play a part in this scenario.

Increased disturbance coupled with decreased eutrophication will have a major impact on the composition with respect to functional types. Impacts of increased disturbance will be rapid in eutrophic **grassland and tall herb vegetation** (plot classes D–E, I–L and N) and wetland (plot classes F–H). Damage to perennial species should allow the spread of types R and CR species. However, if disturbance is of regular occurrence (eg grazing) rather than intermittent (eg ploughing), these types will be less favoured because seed production will be impaired. Under these circumstances, perennial species of type CR and type CSR will be favoured. TRISTAR does not distinguish these effects of low-level disturbance over long periods from more severe but punctuated episodes of disturbance. However, this does not appear to be a problem here. An increase in both type CR and CSR at the expense of type C is predicted in this particular example. In less productive **acidic vegetation** (plot classes M, O and P), opportunities for species with short life cycles are more restricted. Type SR, particularly low-growing bryophytes, would be expected to be the main beneficiary of disturbance but little change is predicted here. The main impact of decreased eutrophication should be an increase in type S. However, this type grows very slowly and many species of type S are poor colonists. Thus, changes will also be correspondingly slow and it is only in less productive **acidic vegetation** that major increases in type S are forecast. Because of reduced above-ground biomass there could in some classes be a reduction in transpirational water loss leading to a slightly increased water table. The changes affecting the woodland grouping (plot classes A–C) are difficult to predict. Increased disturbance coupled with decreased eutrophication will reduce the density of the tree canopy. The extent to which the lower strata can respond to the decreased shading will depend on the severity of the nutrient stress imposed and on whether the disturbance directly affects all strata. Less severe scenarios may encourage the expansion of all functional types in the ground layer. The values for index of vulnerability show a wide range of susceptibilities. High vulnerability is shown by plot class G and moderate vulnerability by classes K, M, N and O.

NB This scenario assumes only modest changes in disturbance and eutrophication. Under conditions both of high stress (which permits only slow growth) and of high disturbance (where recovery necessitates rapid growth), no plant species can survive. This combination of high stress and high disturbance is characteristic of many areas of 'open country' suffering problems of recreational damage (eg the Pennine Way).

Scenario 6 – [Disturbance increased; eutrophication increased]



Possible causes of this scenario

- **Woodland** – *increased disturbance* – tree thinning, reduced incidence of fires (a normal component of forestry practice), increased flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition mainly from agricultural sources, fertilizer applications as a part of silvicultural practice, increased flooding
- **Grassland and tall herb vegetation** – *increased disturbance* – increased incidence of fires, more grazing, more recreational pressure, increased flooding; *increased eutrophication* – fertilizer runoff or atmospheric deposition, increased flooding
- **Wetland habitats** – *increased disturbance* – increased flooding, increased grazing or cutting, increased recreational pressure; *increased eutrophication* – increased flooding, fertilizer runoff or atmospheric deposition

The combination of increased eutrophication and increased disturbance, which is a very common impact upon the British landscape, will have major impacts on the composition with respect to functional types. For eutrophic **grassland** (plot classes E–F, I–L and N) and **wetland habitats** (plot classes F–H), these impacts will particularly involve losses of C, SC and CSR type species and an increase in types R and CR. However, in less productive grassland, **acidic vegetation** (plot classes M, O and P), greatest losses of type S are predicted. In the woodland grouping (plot classes A–C), this combination of events may result in periods with a relatively open canopy immediately following disturbance but with rapid recovery because of eutrophication. Under these circumstances, fast-growing species of type C, CR and R might be encouraged, particularly if these species had good dispersal in space (numerous, wind-dispersed seeds or spores) and/or in time (a persistent seed bank in the soil). Over half of the classes have at least moderate values for index of vulnerability. Overall, there is comparatively low vulnerability associated with this scenario, with only plot classes G and K showing moderate vulnerability.

Index of vulnerability

'Waterside habitats' are a heterogeneous grouping of wetland, woodland, grassland and tall herb vegetation. The individual plot classes differ in their representation of functional types. There are no plot classes with a predominance of ruderal types. Representation of type C is particularly high in some wetland (plot classes F–G) and some grassland and tall herb vegetation (plot classes F–G). Predictably, another grassland plot class (P) has most CSR; grazing is both a disturbance event (the removal of biomass) and induces stress (removal of nutrients). This plot class is also in the acidic grassland grouping (M, O and P) which, illustrating its low productivity, has high values for type S. Plot class P and woodland (plot classes A–C) have a high representation of type SC.

TRISTAR predicts that all classes will be relatively unresponsive, at least in the shorter term, to changing land use. Only one class reaches 'high' vulnerability. The impact to the various scenarios can be summarised as follows.

Low – moderate impacts
('Disturbance – decreased; Eutrophication – increased'<'Disturbance – same; Eutrophication – increased'= 'Disturbance – decreased; Eutrophication – same< 'Disturbance – same; Eutrophication – decreased' <'Disturbance – increased; Eutrophication – increased'<'Disturbance – increased; Eutrophication – decreased')

High impacts (none)

The differences between habitat groupings are also relatively slight. However, average vulnerability is greatest in plot classes associated with unproductive vegetation (plot classes G, M and O) and which contain many species of type S.