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Occasional Paper 28

Edge Management In Woodlands

Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989

Edited by R. Ferris-Kaan

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Wildlife and Conservation Research Branch,
Forestry Commission

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Contents

Foreword

Within woodland, many plant and animal species are dependent on the existence of open areas with few trees for their survival. Such habitats may exist along roads and ridesides, or can be specially created. These edge habitats are boundaries, which can contain species from both adjoining areas. Roads and rides are valuable in that they may provide both grassland and woodland edge conditions for a wide range of different taxonomic groups. Other edges may represent the interface between woodland and heathland, bogs, adjacent arable land, or water bodies. Woodland edge habitats tend to develop a different flora and fauna from that of the woodland interior, both because they are open and better lit and as a result of different management.

Edge management, particularly of woodland rides, is now practised widely by a number of organisations. Precise objectives may vary, although management is commonly perceived to be of some conservation benefit. Maintenance of these habitats is required if their benefits are not to diminish. This may be a costly exercise, involving cutting and flailing of the vegetation. While some rationalisation of management is required, there is certainly a need for increased monitoring of edge management impact. To this end, it is important that the ecological needs of the plants and animals on edges are understood. In some cases this may demand an autecological approach to management, while in others the objective may be to increase variety. Woodland managers need to be equipped with this information so as to ensure, as far as possible, the adoption of appropriate management practices.

In bringing together interested parties and diverse researchers, this symposium recognised that there are still gaps in our knowledge, and that much management is carried-out according to best-guess recommendations. Its aims were to draw together current knowledge for a range of taxonomic groups, decide how best this information can be passed on to the manager, and identify research needs for the future. The contributions vary from summaries of work, reports of preliminary information, and more detailed review papers.

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Paper 1

Edge Habitats: An Introduction

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Ecotones and the edge effect

A useful definition of an ecotone is given by Odum (1971):

> An ecotone is a transition between two or more diverse communities. It is a function zone or tension belt which may have considerable linear extent, but it is narrower than the adjoining community areas themselves. The ecotonal community commonly contains many of the organisms which are characteristic of, and often restricted to the ecotone. Often, both the number of species and the population density of some of the species are greater in the ecotone than in the communities flanking it. The tendency for increased variety and density of community functions is known as the 'edge effect'.

It is this relative high quality, diversity or variety, which is often not fully realised, that often points us towards edges to achieve an improvement of nature conservation value in woodlands.

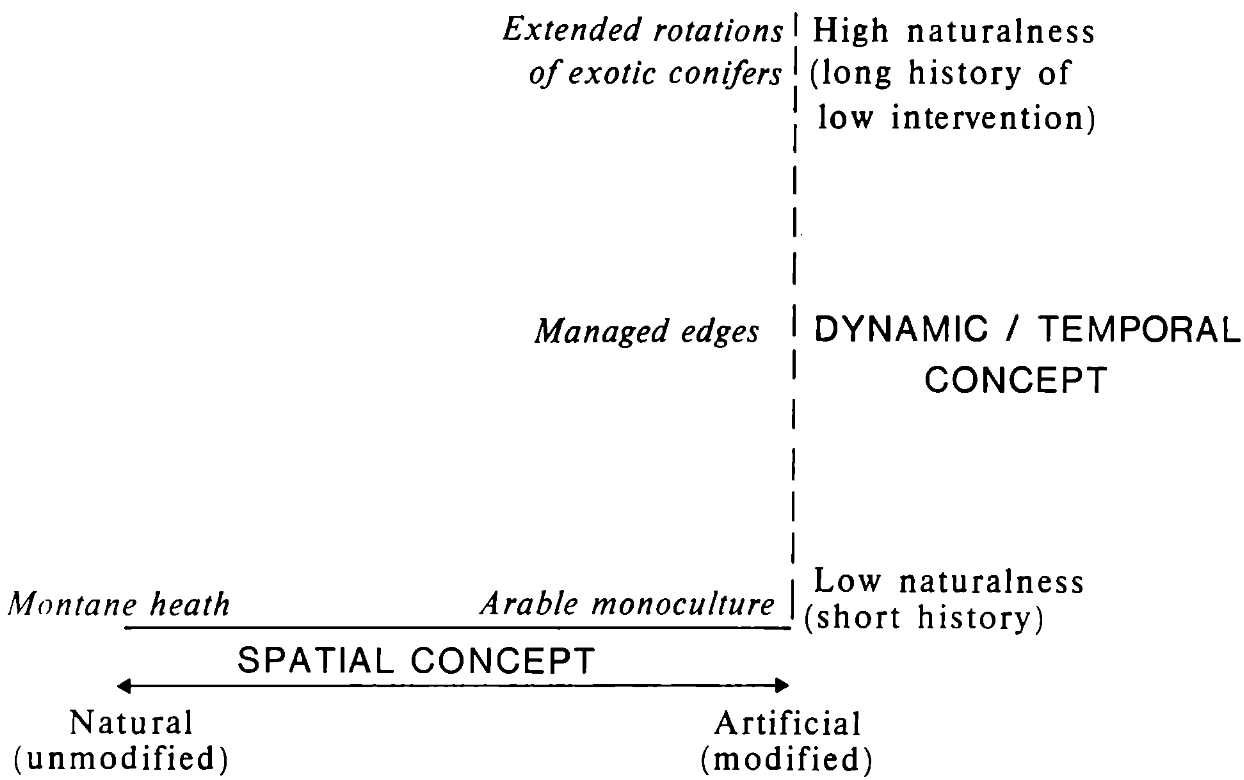
There are perhaps two important questions that need to be answered. The first is simply to ask why are we managing edges? An often quoted reason is to increase variety/diversity, but should this be aimed at species, communities or taxa? The second question is how do we advise the woodland manager? It is easy for researchers to confuse the issues by giving conflicting advice aimed at different species groups. The fundamental need is to manage ecosystems, communities or habitats to increase structural species diversity. The special needs of particular rare or sensitive species can be superimposed upon this where appropriate. Value judgements must be made when there are conflicts arising from this, and it is important that we understand the potential conflicts arising from an autecological approach. At the same time, researchers may need to help managers define priorities. For example, is there an overriding need for the management of a single species, such as the purple emperor butterfly, the barn owl, or the dormouse?

Artificiality and the need to manage

Some conservation protagonists have advocated non- or minimal-intervention in woodlands, considering 'naturalness' to be of greatest conservation value. Tansley (1939) has pointed out that 'The longer vegetation is let alone and left to develop naturally, the more it tends to form well-defined communities and the more these develop relatively constant and well-defined 'structures' in relatively stable equilibrium with their conditions of life.' The most natural (unmodified) community remaining in Britain is montane heath, as found on the summit plateau of the Cairngorm Mountains. The corollary of this situation has been described by Tansley (1939) in the following manner: 'Much vegetation, particularly when subject to human activity, is difficult or impossible to separate into distinct communities. It often presents all grades of mixture of the elements of several communities, in which dominance and strata are confused or obliterated.' In nature conservation terms, such communities are often considered to be less interesting. At the extreme of artificiality are the arable communities, managed on an annual cycle, of monocultures such as wheat and barley (Figure 1.1).

There is an artificiality about most edge communities in woodlands, which has long been recognised. Peterken (1981) states that: 'Rides, glades and ponds are important subsidiary habitats, which increase the range of habitats within woods, add to structural variety and maintain a large number of species. Most are artificial in origin and survive only by active management.' This would tend to put these communities towards the same end of the scale as the 'cornfield' community (Figure 1.1).

Figure 1.1



However, it is important to realise that, in addition to this purely spatial concept (x axis: Figure 1.1) of the nature conservation value of communities, there is a dynamic/temporal concept. This temporal element can be seen as a y axis (Figure 1.1), originating from the highly modified community. Management with a short history may well mean that a community has low 'naturalness', but with an increasing history of low or minimum intervention, high 'naturalness' would be achieved. Extended rotations of exotic conifers could be viewed in this manner. Managed edges too could reach a stage of high 'naturalness'. Peterken (1981) has suggested that, 'in the interests of ecological stability, the ride pattern of a woodland must be maintained once it exists, because old rides are generally richer than new rides.'

Management prescriptions for woodland rides generally follow the same pattern. For example, Smart and Andrews (1985) suggest that:

> They [paths, rides, etc.] can provide important semi-natural habitat within woodland as well as rich 'edge' habitat. To be of maximum use they require some form of management. Rides should be kept open without overhanging trees ..... On the ride itself a grassy sward can be encouraged by ..... annual mowing at the end of the growing season, and along its borders a gradient of different-aged scrub above 30 m wide, grading into the forest edge, can be obtained. This growth can be controlled by machine cutting ..... An average might be to cut 10% each year.

But, what should our objectives be? Will such management prescriptions achieve benefits to all things? I suspect not.

I see it as our task today to develop ideas for advising managers on the options available in edge management. Is the achievement of high structural species diversity an end in itself? Secondly, we must help the manager reconcile the demands of different species groups. Thirdly, we should address research requirements so that our advice becomes more sound through time.

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Paper 2

Managing Edge Vegetation

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Abstract

The aim of vegetation management on woodland edges has been to create a structurally graded edge. Management has not only to consider the actual vegetation present, but also the potential vegetation represented by the seed and bud bank in the soil. A series of edge management trials in the southern counties of England has been monitored for up to 3 years. There appears to be some zonation in the vegetation, with grasses aligned along the cut edge. Rapid responses from the buried seed bank have been matched by an influx of windblown species. However, increases in ruderal species threaten the survival of the more typical woodland species on some sites. Alternative forms of management may need to be considered.

Introduction

To begin with, the aims of wildlife edge management were thought of as being concerned with individual species. The aims could be divided into three broad groups — import, export, and maintenance of species. A census of known edge management trials for the intended benefit of particular species, carried out in 1987, showed that by far the majority were concerned with animal species. In only one case was the intention to build-up populations for subsequent invasion beyond the management area, the export aim.

One of the problems with single-species management is that the aims often interfere with one another. One particular example from Bedgebury Forest involved cutting back the edge of a stand of Corsican pine, *Pinus nigra* var. *maritima,* and assessing vegetational change after 8 years. The study was done with a view to benefitting shrub species. Prior to cutting, flowering plants and ferns were distributed close to the crop edge, with patches of shrubs extending up to 10-15 m into the stand. Eight years after the edge had been cut back by 4 m, there was a great deal of shrub growth at the edge, but little difference within the stand. Disappointingly, although the flowering plants were abundant at the edge, they had declined within the stand, and disappeared altogether at 6 m from the edge. That is not to say that the seed/bud bank was not still present. In management for shrubs, flowering plants had been affected detrimentally.

Partly as a consequence of this sort of experience, decisions were made to attempt management for particular communities, habitats or assemblages of species. Management was thought of as being for a particular stage in the succession. This approach can be examined in three parts:

1. Maintenance of the small shrub stage, the middle band between the road or rideside ditch and the crop edge, in perpetuity. This requires management on a short cycle, and can be very expensive.

2. Maintenance of a maximum number of stages, in parallel bands. This may prove prohibitively expensive unless markets can be found for the removed cut material. There may be a market for the shrub cuttings, but the grass cuttings pose a problem.

3. Managing a particular stage in the succession, but not in the same place at all times, creating a series of patches. This has proved to be cheaper, by and large, and a number of local County Naturalists' Trusts have adopted this approach to management.

It was also recognised that management was not solely to benefit the actual ground vegetation, but also needed to consider the seed and bud bank, the potential vegetation. Management of this potential vegetation may be at least as important as the actual vegetation.

Experimental work

A series of experiments was set up, half in old coppice and half in high-forest plantation, some conifer and some broadleaved. This was a joint project between the Forestry Commission and the Game Conservancy, with Wye College designing and undertaking the monitoring. Treatments varied from site to site, but included the creation of scallops, uniform widening, and the creation of rides where none had existed previously.

Experimental sites were mostly in Hampshire, with a concentration around Micheldever Forest (Forestry Commission), but also took in West Sussex and Dorset. They were predominantly ancient woodland sites and therefore started with a reasonable species complement, enhanced by the calcareous substrata present in most cases. In the plantation sites, internal edges were under consideration while at Crow's Hall, W. Sussex, the interest was in external edges along perimeter strips of coppiced woodland managed for pheasants. Additional treatments were comparisons of aspect, and studies of the impact of grazing by way of a series of exclosures.

Initial results

In the newly-created rides, vegetation is largely derived from species present in the seed bank or those brought in from elsewhere (i.e. wind-dispersed). An abundant species seen at Black Wood, Micheldever (Table 2.1), was hairy St John's wort, *Hypericum hirsutum,* which was consistently aligned along the cut edge. Willowherb species, *Epilobium* spp., and especially rosebay willowherb, *Chamaenerion angustifolium,* have also become abundant. However, the impact of deer has resulted in the virtual eradication of these species outside of the exclosure plots. The same is true of the scrub development, with little or no natural regeneration except for that within the exclosures. Throughout the new rides, numerous thistle species, *Cirsium* spp., have become established, and provide useful nectar sources for the many butterflies occurring on the site.

Where bays were cut on either side of an existing grassy ride, again in Black Wood, Micheldever, the vegetational development has been of rank species. Nettles, *Urtica dioica,* have invaded rapidly, to the detriment of any smaller herbs present. This is particularly true of the wild strawberry, *Fragaria vesca,* present in the ride ditch and bank, and an important butterfly foodplant for the grizzled skipper, *Pyrgus malvae.*

At Waltham Trinleys, a plantation block separate from the main body of Micheldever Forest, rides were widened to 20 m. A slightly less calcareous site, the response to widening included an increase in marsh thistle, *Cirsium palustre,* and tufted hair-grass, *Deschampsia cespitosa* (Table 2.2). Along the cut edge the response was fairly typical, although the brash piles exerted an influence, with *C. palustre, U. dioica,* and wood spurge, *Euphorbia amygdaloides,* abundant in the vicinity.

At Crow's Hall, the woodland occurs as a thin strip with an external edge. The ruderal flora reflects this, and includes spear thistle, *Cirsium vulgare;* several dock species, *Rumex* spp.; false oat-grass, *Arrhenatherum elatius;* and couch, *Elymus repens* (Table 2.3). This contrasts with the woodland interior, where the seed bank response included *E. amygdaloides;* hairy St John's wort, *Hypericum hirsutum;* and ragwort species, *Senecio* spp.

Managed edges occasionally benefit some of the more stable woodland vegetation. For example, dog's mercury, *Mercurialis perennis,* has been found to respond in vigorous patches on the cut edges of rides or bays. However, in cases where cutting-back has left it exposed, *M. perennis* begins to show extensive die-back. In time, this and other woodland species may be lost from such sites.

Vegetation cover and/or frequency can be examined within three zones: zone a, representing the rideside; zone b, representing the cut zone of the bay; and zone c, the forest interior, or control. At Black Wood, where new rides were cut, a number of species were found to be significantly zoned (Table 2.1). Many species, particularly the grasses, align themselves within zone b. Big increases have been noticed for rough meadow-grass, *Poa trivialis;* annual meadow-grass, *Poa annua;* and creeping bent, *Agrostis stolonifera.* The ingress of *D. cespitosa* may pose a management problem in the future. A number of willowherb species — square-stemmed willowherb, *Epilobium tetragonum;* broadleaved willowherb, *E. montanum;* great willowherb, *E. hirsutum;* and rosebay willowherb, *Chamaenerion angustifolium* — have come in, both as windblown propagules and recruited from the soil seed bank. Three species of St John's wort — hairy St John's wort, *Hypericum hirsutum;*

trailing St John's wort, *H. humifusum;* and perforate St John's wort, *H. perforatum* — have appeared by the second year after cutting, presumably emerging from persistent soil seed banks. In addition to these, a number of disturbed-ground species have been found, such as creeping thistle, *Cirsium arvense;* and prickly sow-thistle, *Sonchus asper.* A scrub component has also begun to develop, but this is mainly confined to the exclosure plots, free from browsing by roe deer and rabbits. The frequencies of these species are fairly high at the cut edge, but show a marked decline inside the woodland interior, suggesting a rapid response to cutting.

At Crow's Hall, the situation is rather more complicated, with a perimeter strip/edge, a woodland strip, and the cut zone in the middle (forming a large 'skylight' glade) (Table 2.3). Grasses are important, with species such as sterile brome, *Bromus sterilis;* couch, *Elymus repens;* and false oat-grass, *Arrhenatherum elatius,* all very prominent, while *P. trivialis* has begun to colonise the cut area. It seems that this zone is stimulated by disturbance, resulting in a high diversity of species. Some species also show increases in the opposite direction, within the woodland hinterland. For example, bluebell, *Hyacinthoides non-scripta,* at Crow's Hall, and yellow archangel, *Lamiastrum galeobdolon,* at Waltham Trinleys, both increase in the woodland perimeter, following cutting. In the cut zone itself, increases are beginning to be noticed for species such as *U. dioica.*

Seed banks have also been studied, and zonations noted. The grasses, as would be expected, show a clear edge bias, with *P. trivialis* an important component. Some species show a preference for the canopy edge, with *Hypericum* spp. consistently forming a major component of the seed bank in this zone on a number of sites.

Clearly, diversity is increased as a result of the edge management process. A Crow's Hall, the number of species recorded has doubled within 2 years. However, these increases may only be temporary. Many of the species found in these early successional stages are monocarpic and may well give way to dominant perennials, especially grasses; sedges, *Carex* spp.; and bramble, *Rubus fruticosus.* In the future, edge management may be more concerned with the control of invasive species. It seems likely that losses of stable woodland species, and particularly the ancient woodland indicators, will occur. This may even affect those ancient woodland species which rely on seed banks for their regeneration. For example wood melick, *Melica uniflora;* and wood millet, *Milium effusum,* have shown signs of decline in these current studies.

Conclusion

In order to retain some of these species, edge-management practices as currently proposed may not always be appropriate. Methods of widening or deepening the canopy edge, such as retaining 'islands' of trees on rides, or carrying out extra-heavy thinning at compartment perimeters, are more likely to guarantee many ancient woodland species a better chance of survival. Such management, of course, runs counter to the exponents of open areas for butterflies and scrub: to achieve both objectives might well mean even wider, graded canopy edges, or a complete revision of the silvicultural systems within the compartments themselves.

Table 2.1 Percentage frequency of plant species showing significant zonation with respect to a newly-created ride (b), and the adjacent woodland (c), at Black Wood, Micheldever Forest, Hampshire

Species	1987		1988	
	b	c	b	c
Agrostis stolonifera	-	-	6	2
Deschampsia cespitosa	2	-	8	-
Milium effusum	19	-	-	-
Poa annua	-	-	7	-
Poa trivialis	-	-	14	-
Carex sylvatica	34	23	39	25
Ajuga reptans	3	-	7	-
Cerastium arvense	5	-	8	2
Cirsium arvense	10	-	44	3
Clematis vitalba	33	3	8	2
Epilobium montanum	7	-	2	-
Epilobium roseum	16	-	10	-
Epilobium tetragonum	-	-	21	-
Fragaria vesca	6	-	8	-
Glechoma hederacea	12	-	3	1
Hypericum hirsutum	50	5	41	5
Hypericum perforatum	-	-	24	1
Plantago major	7	-	2	-
Ranunculus repens	15	3	12	2
Rubus fruticosus	16	6	16	5
Sonchus oleraceus	23	3	14	2
Urtica dioica	16	3	22	3
Veronica chamaedrys	4	2	16	1
Veronica serpyllifolia	5	-	8	-
Vicia sativa	8	1	-	-
Salix caprea	5	-	11	-

Table 2.2 Plant species showing significant differences in percentage frequency between ride edge (a), cut areas (b), and woodland canopy (c) zones in an over-widened ride at Waltham Trinleys, Micheldever Forest, Hampshire

Species	1987			1988		
	a	b	c	a	b	c
Agrostis capillaris	-	-	-	22	10	-
Agrostis stolonifera	11	1	7	20	1	-
Deschampsia cespitosa	16	4	4	28	18	9
Holcus lanatus	24	6	-	17	1	-
Melica uniflora	28	8	-	2	-	-
Poa trivialis	22	8	-	37	30	22
Carex sylvatica	38	10	9	26	11	15
Juncus bufonis	15	3	-	-	-	-
Cirsium palustre	15	17	-	53	38	-
Epilobium tetragonum	-	-	-	22	10	-
Euphorbia amygdaloides	20	21	2	24	46	26
Fragaria vesca	7	4	2	20	10	2
Hypericum hirsutum	37	17	-	31	27	4
Hypericum humifusum	20	3	-	13	-	-
Hypericum perforatum	-	-	-	13	3	-
Hypericum pulchrum	-	-	-	31	8	-
Lamiastrum galeobdolon	5	29	33	9	37	52
Mercurialis perennis	17	27	31	26	45	31
Ranunculus repens	9	1	-	20	1	-
Rubus fruticosus	30	34	9	30	37	15
Scrophularia nodosa	11	7	-	-	-	-
Sonchus oleraceus	22	4	2	11	1	-
Veronica serpyllifolia	4	1	-	20	3	-
Betula pendula	57	21	4	44	28	4
Fraxinus excelsior	24	17	24	26	11	33
Salix caprea	13	5	-	22	8	-

Table 2.3 Percentage frequency of plant species at Crow's Hall, West Sussex, showing species significantly zoned with respect to the perimeter edge (a), the control/cut areas (b), and the woodland strip (c), following the cutting back of skylight-glades

Species	1987			1988			1989		
	a	b	c	a	b	c	a	b	c
Agrostis stolonifera	-	-	-	8	2	-	27	-	-
Arrhenatherum elatius	4	-	-	17	4	-	13	-	-
Bromus sterilis	16	-	-	37	18	3	29	6	3
Dactylis glomerata	7	-	-	16	-	-	15	-	-
Elymus repens	-	-	-	8	-	-	14	-	-
Holcus lanatus	-	-	-	8	2	2	20	6	3
Poa trivialis	22	8	8	35	39	50	23	23	48
Poa nemoralis	-	-	-	10	39	44	4	16	10
Bryonia cretica	4	-	-	14	6	-	4	2	-
Cirsium arvense	8	-	-	22	-	-	27	2	3
Galium aparine	18	2	-	63	33	19	20	-	3
Glechoma hederacea	70	35	25	51	29	28	64	35	41
Hedera helix	31	28	14	27	14	6	41	23	17
Heracleum sphondylium	6	-	-	20	8	3	27	8	17

Paper 3

Modelling Light Conditions in Woodland Rides

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Abstract

Modelling light in woodland rides involves combining a map of the forest with an ephemeris of the sun so that for each instant the relative positions of the sun, and the trees in the direction of the sun, are known for any location. These data are used to calculate the amount of solar energy and duration of sunlight for any spot on the forest floor. Forest clearings of different orientations, shapes and sizes may then be tested using this information so that the best type of clearing is chosen.

Computer modelling

A collaborative study was undertaken between the Royal Greenwich Observatory and the Forestry Commission Research Division to test different types of clearings. These are clearings of different shapes, sizes and orientation, and attempts were made to find which were the best. This is defined as the clearing which receives most sunlight and the most energy from the sun. These tests were undertaken using a computer, with a program that would model the sun and shape of the clearings in the forest, and calculate the duration of the sunlight and amount of radiation received. This would allow some judgement before actual management taking place.

By studying an altitude and azimuth diagram of the sun (Figure 3.1), it is possible to follow its movement in the sky for a particular latitude. The altitude is the angle from the horizon up to the sun, and the azimuth is the angle from True North round the horizon. There is a wide range of movement between 21 June and 21 December, and this again varies depending on the latitude. The modelling of the sun movement is a straightforward process.

In addition to being able to calculate the altitude and azimuth of the sun for any instant, it is necessary to know the altitude of the tree-tops (Figure 3.2). A particular point on the ground will be in sunlight when the altitude of the tree-tops in the direction of the sun is less than the altitude of sun. The formula for calculating the altitude of the trees is simply as follows:

$$\frac{\text{Height of tree crop}}{\text{Distance of ground}} = \tan\text{ (altitude)}$$

As this is always calculated in the direction of the sun, it is important to know where the sun is. The duration of sunlight can be calculated by taking repeated measurements of the distance from numerous points to the edge of the tree crop, and calculating the altitude of the trees in addition to the sun's altitude and azimuth.

The other important calculation is of the sun's energy, and this is also included in the computer model. The radiation flux is comprised of two parts, the direct radiation and scattered radiation. The latter is a fraction of the former, and is also related to that proportion of the sky which is visible. Therefore, it is important to know the profile of the trees through 360^{0}.

As would be expected, the duration of sunlight between March and September for a point, *P*, in the model, is greatest for a south-facing bay (Figures 3.3 and 3.4). At this north edge there is quite a rapid rise at first from 0 h to over 7 h. This however decreases slightly to just under 7 h by 21 June. This is due to the fact that *P* is only receiving sunlight for a small portion of the day when the sun is moving quickest in the sky. However, the sun is higher in the sky at this time and so the irradiation reaching the bay does not change, and may actually be slightly greater. The other orientations do not acutally give a lot of sunlight. However, it should be recognised that this is only for one particular point on the ground.

Modelling can produce contour maps to show the sunlight hours across entire bays at different orientations. For a bay facing south on an east/west ride, the maximum sunlight hours on 21 June may be 9-10 h in the centre of the ride, declining to 6 h towards the corners (Figure 3.5). For the less favourable orientation, on a ride running north/south, the maximum sunlight hours received in the centre of the bay will be about 6 h, with hardly any sunlight at all in the southern corner.

Figure 3.1 Solar location diagram. The diagram shows the altitude and azimuth of the sun for a range of local apparent solar times from sunrise to sunset at latitude N 51° 30′ (which is the latitude of London) for a series of dates throughout the year. The dark curves represent the apparent path of the sun on the dates shown.

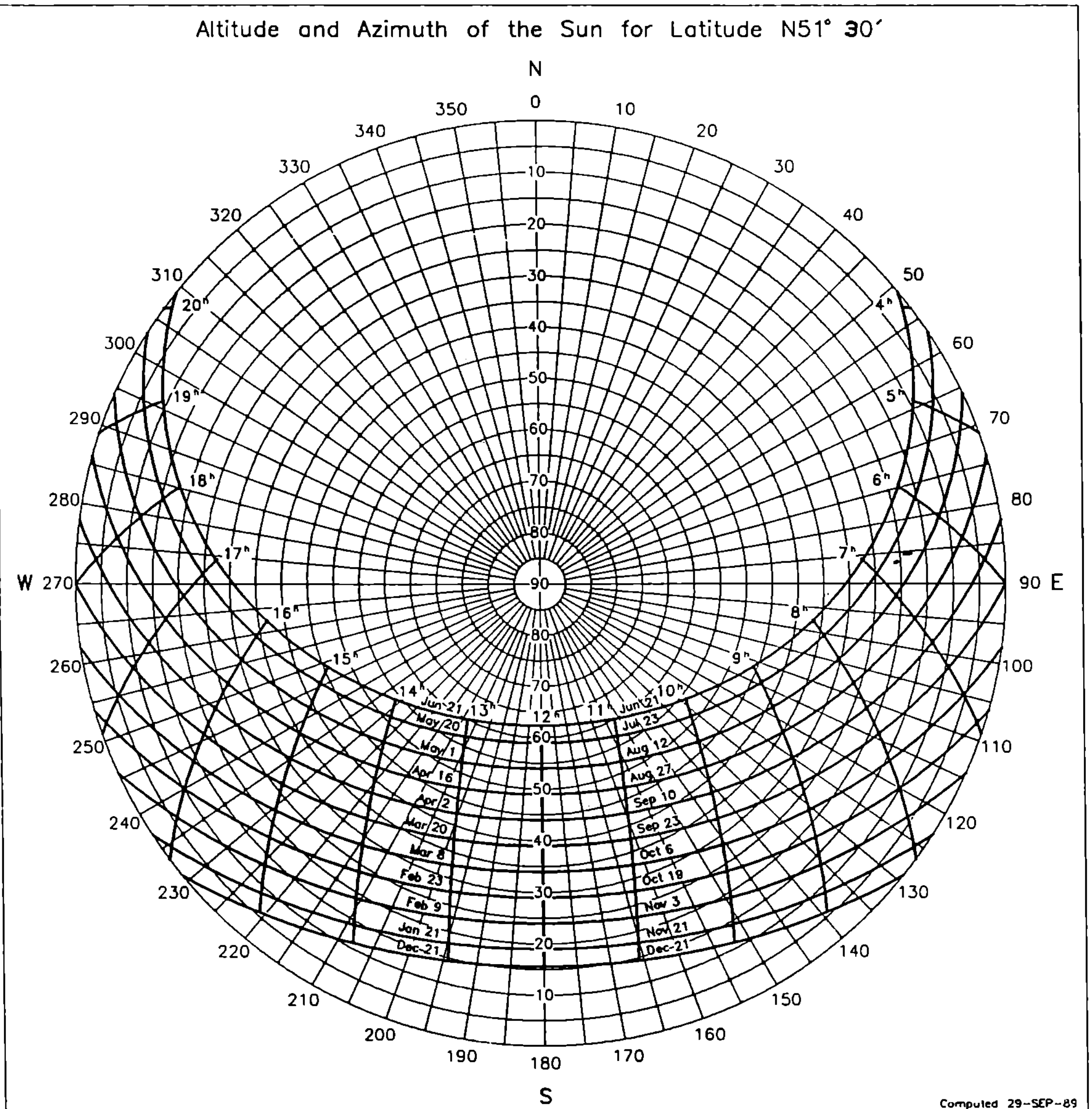


Figure 3.2 The relative altitudes of the sun and the tree crop, and the effect of shadows cast on woodland rides.

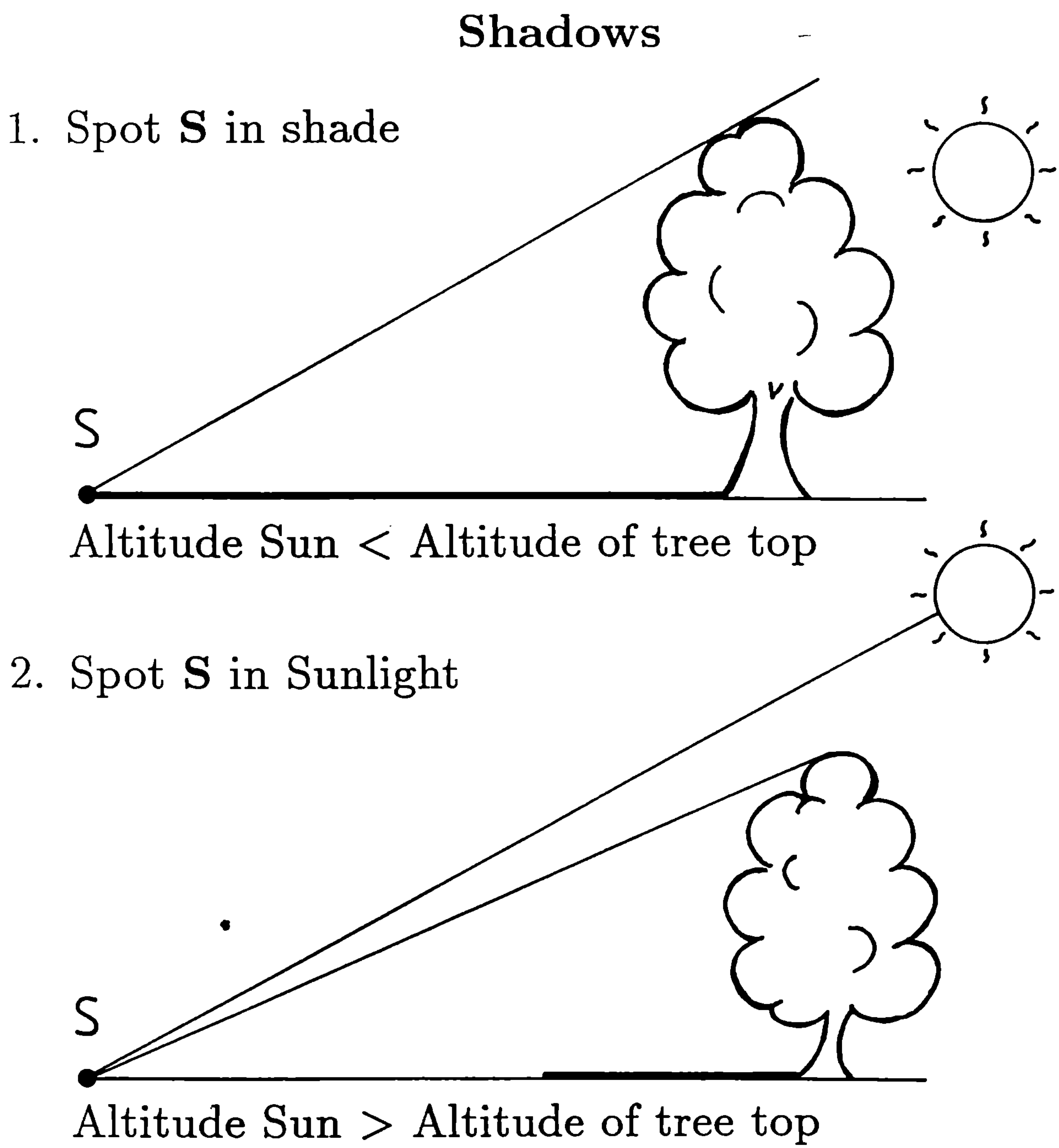


Figure 3.3 Light modelling in woodland rides. Formula for the calculation of the altitude of the surrounding crop, and diagram of a hypothetical ride system in Micheldever Forest, West Downs Forest District.

Altitude and Azimuth of Sun – h, Z

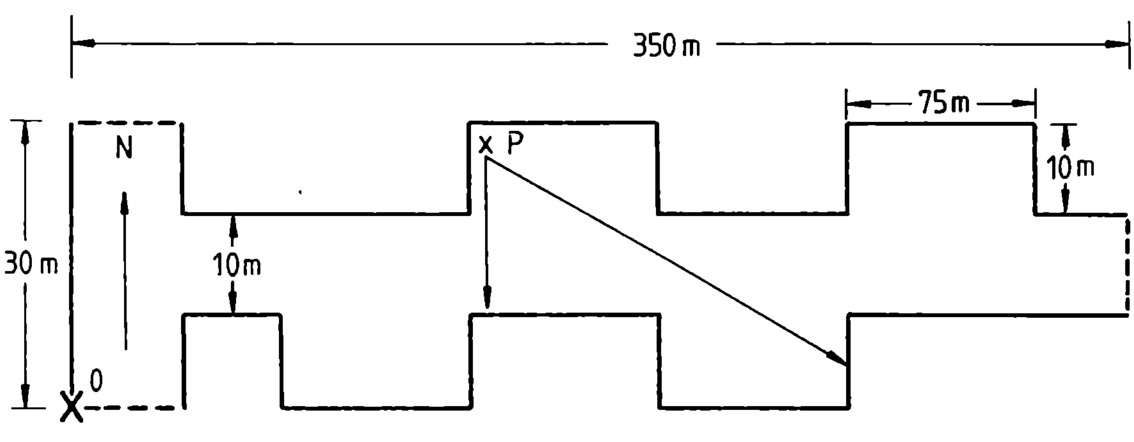
Longitude and Latitude of place – λ, ϕ

Position of Sun relative to Earth – GHA, δ

Altitude of Trees

$$h_T(Z) = \tan^{-1}(H/D)$$

Micheldever Forest



Trees 22 m

Figure 3.4 Graphs showing maximum hours of sunlight and energy for a point, '<u>P</u>', in a hypothetical ride system in Micheldever Forest (see Figure 3.3).

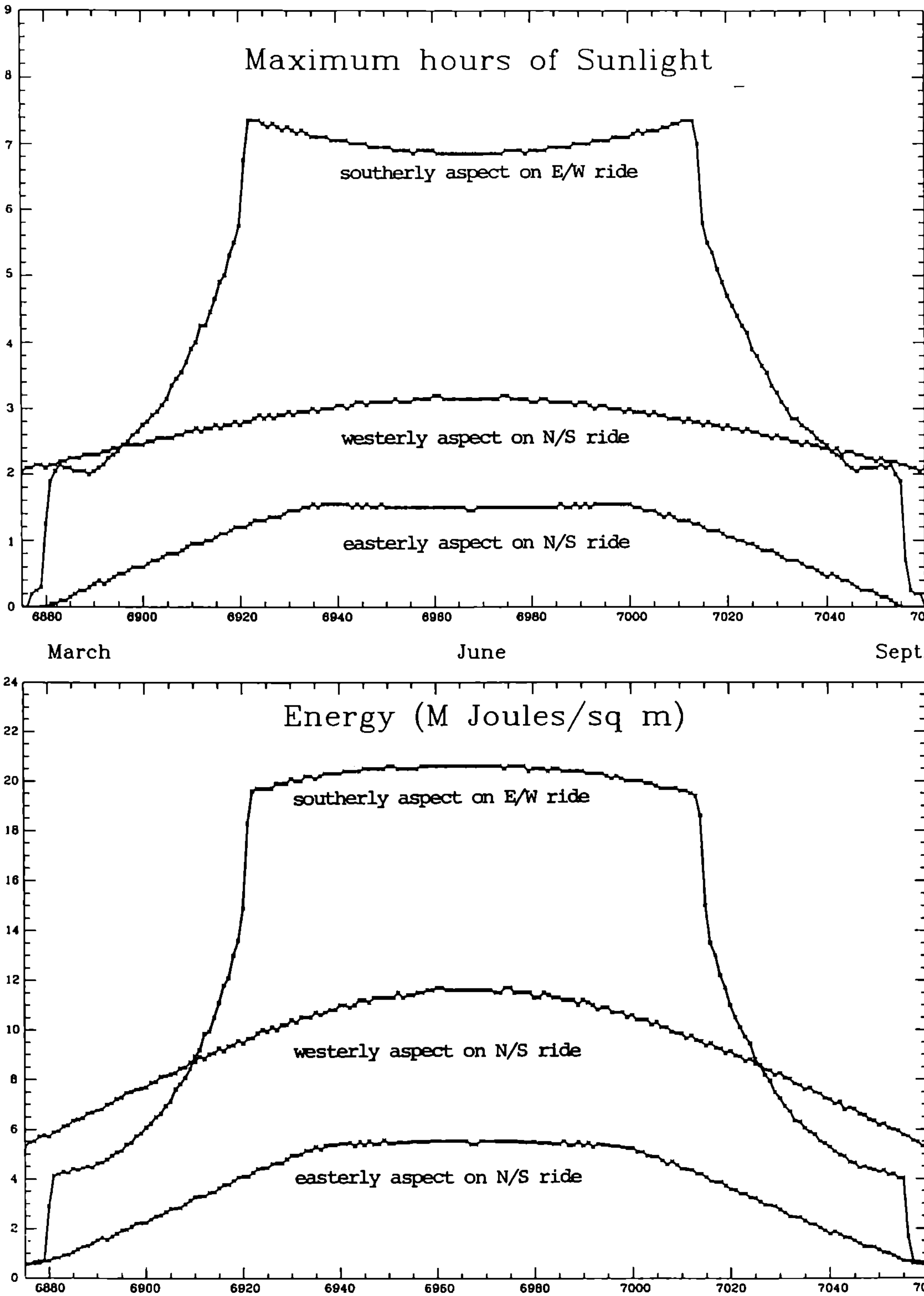
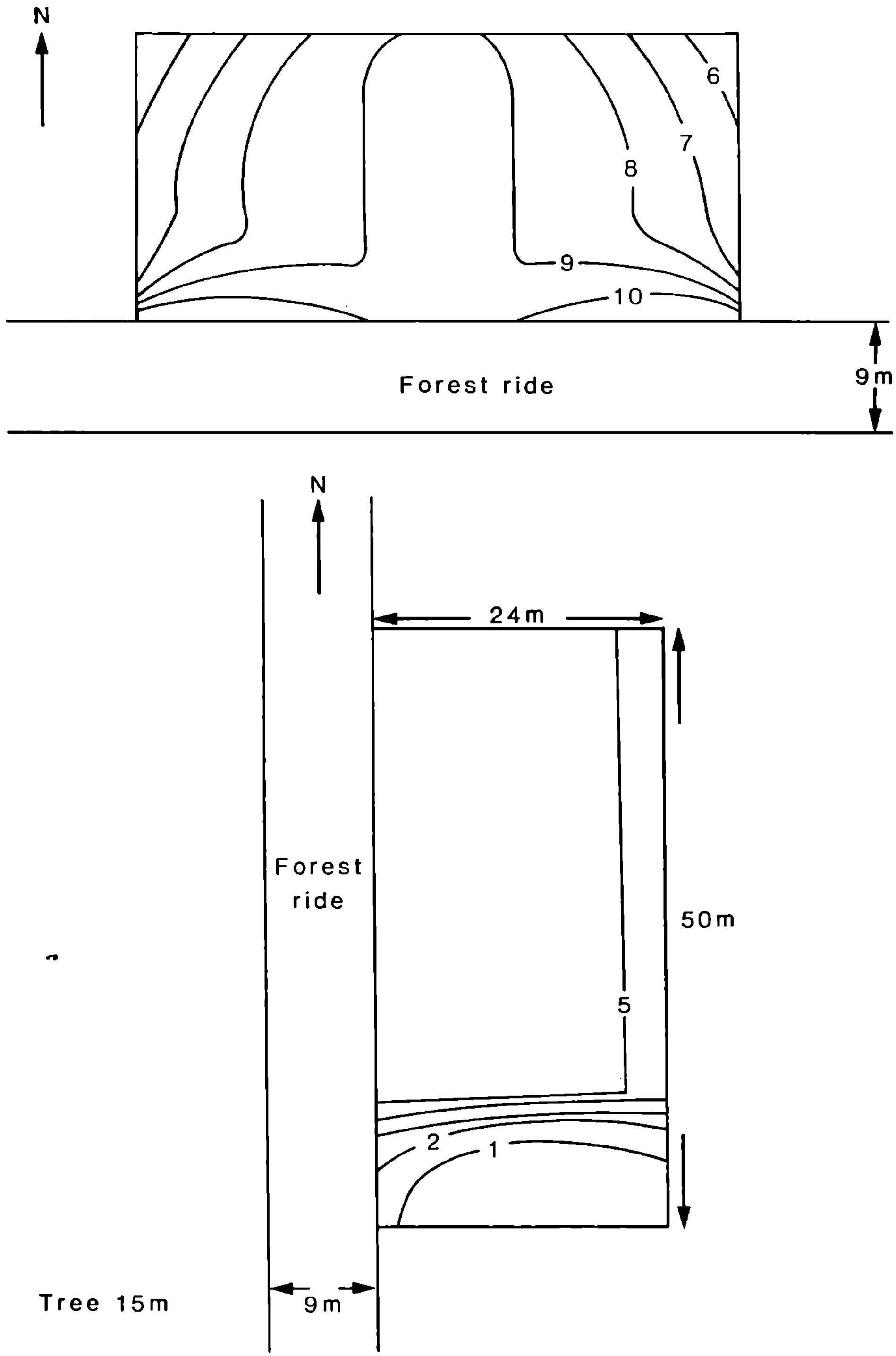


Figure 3.5 Hours of sunlight contour-maps for bays 24 m x 50 m, orientated E/W and N/S, surrounded by trees 15 m tall on 22 June (51°N).



Paper 4

Ride Orientation and Invertebrate Activity

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Abstract

Ride orientation is critically important with regard to the sunlight hours received. This influences the development of ground flora within forest plantations which in turn affects the number and diversity of invertebrates. Ground beetles (Carabidae) do not appear to show any preference for a particular orientation, although ground spiders (Lycosidae) were more abundant on south-facing edges. Butterflies have shown a rapid response to edge treatments. Systematic monitoring has revealed a marked increase in their abundance even in the first year in response to sunlight, shelter and floristic changes. The proportions and potential of rideside bays with different orientations are compared.

Introduction

The post-war forestry programme in southern England involved a considerable amount of planting-up of the derelict woodland, scrub, and steep downland that was available during that period. As a result of this, there is now a large area in the same sort of age class. In fact, after the war, over 35 000 hectares were planted in each of the next three consecutive decades, compared with 12 000 hectares for each pre-war decade. Areas of standing timber reaching the age of second thinnings and more are common and consequently there is a considerable amount of shading of forest rides. During the first 15 years or so after planting, these woods continued to provide a valuable refuge for plants and animals, especially along the rides, where these were grassy and the existing turf had been retained and managed by regular cutting.

In the south of England on these sites there was an emphasis on planting beech, *Fagus sylvatica,* which is one of the most shade-casting trees. Estimates from the Forestry Commission sub-compartment database suggest that this represents about 25% of the forest cover in the post-war planting period. Being aware of the declining populations of butterflies generally, although some of our commercial forests are strongholds for good numbers and rarities, forest managers sought advice on the best treatment for rides in this type of woodland. The objective was to enhance the wildlife, particularly to encourage the more noticeable insects formerly more abundant in these areas. The initial aim was to concentrate on the response of commoner insects, those which were expected to respond to the proposed opening-up of the ride system.

Research

Micheldever Forest contains many compartments of pure beech of similar age class planted after the Second World War. The crop height was approximately 22 m when the studies were started in 1986/87, and various options were worked-out before the involvement of the Royal Greenwich Observatory. It was soon recognised that considerable benefit could be obtained from removing some of the tree canopy on the southern edge of an east/west ride in order to allow more sunlight to fall on the ride and the northern, i.e. south-facing, edge. The aim was to cut back the tree crop to obtain a 1:1 ratio, based on the crop height on the south side of a ride. For example, with a crop height of 11 m, the minimum ride width should be 11 m in order for sufficient light to reach the surface of the ride. This rule was based on the latitude of southern Britain, and adjustments are needed for more northerly latitudes (Carter and Anderson, 1987; Carter, 1989).

Invertebrate monitoring in the Micheldever rides has been carried out, using a number of pitfall traps positioned between the cut-edge and the ride itself. These have been set-up along rides of different orientation, within Black Wood, Dodsley Wood and Waltham Trinleys. In addition, malaise nets were put up in order to compare north and south edges, and east and west edges. Weekly butterfly transects have also been organised, along the lines of the standard Pollard walk technique (Hall, 1981). These transects have now been carried out for three consecutive years.

Large numbers of carabid beetles (Table 4.1) were sampled from the pitfall traps during the latter part of 1987, one year after the implementation of edge treatments. However, they failed to show any preference for one ride orientation over another, or for any particular aspect. In contrast, ground spiders (Lycosidae) (Table 4.2) did show some pattern. These spiders tend to be active in the daytime, especially in sunshine, and it was probably as a result of this that differences in the number caught showed up. As would be expected, the northerly and southerly aspects were those which showed the greatest contrast. When easterly and westerly aspects were compared, the former were found to be slightly poorer in their invertebrate fauna. When all the data are combined, no significant differences can be found between the easterly and northerly aspects. The southerly aspect is marginally favourable when compared with the westerly aspect.

Table 4.1 Totals of the five commonest carabid beetles from 24 pitfall trap catches that were used to compare the ride orientation and aspect responses in pure beechwood at Micheldever Forest, Hampshire.

Carabidae (ground beetles) July-December 1987	
Pterostichus madidus	1,057
Nebria brevicollis	782
Abax parall.	146
Carabus violaceus	10
Pterostichus niger	10

Table 4.2 Totals and peak activity period of the four commonest spiders from 24 pitfall trap catches that were used to compare the response of ground spider activity to ride orientation and aspect in pure beechwood at Micheldever Forest, Hampshire.

Lycosidae (wolf spiders)		
Pardosa prativaga	487	May-June
Pardosa amentata	298	April, May (June)
Pardosa lugubris	61	September, June
Agelenidae		
Coelotes terrestris	450	August-October

Butterfly transect results (Tables 4.3 and 4.4) indicate that a fairly rapid response to changes in the vegetation has occurred; the south-facing edge showing a very marked increase in butterfly numbers and species even within 1 year of cutting new rides through a compartment of pure beech in Black Wood. Ratios of butterfly numbers to compare ride orientation did not show a clear overall pattern in 1987, but by 1988 the differences were more striking. However, vegetational succession has not been favourable on all sites. At Dodsley wood, a former ancient woodland site, cutting-back of the ride edge gave rise to large expanses of bluebell, *Hyacinthoides non-scriptus,* which is a useful nectar foodplant for the early butterflies. Unfortunately, 18 months later, this had been swamped by a more grassy vegetation, including tufted hair-grass, *Deschampsia cespitosa.* In contrast, the development of vegetation at Black Wood (which was a sheep walk in the eighteenth century) was from the 1986 starting-point largely devoid of any ground flora, and so increases in the invertebrate fauna largely mirrored changes in the ground flora.

Much of this early research has been concerned with long edges rather than bays, and the understanding gained has enabled prescriptions to be made regarding the optimal size and shape of bays. From light-contour maps produced from a model developed by B.D. Yallop and C.Y. Hohenkerk (1991, this volume) of the Royal Greenwich Observatory it is now possible to calculate the best orientation and dimensions for these bays. A south-facing 30 x 10 m rideside bay in a 10 m high crop is likely to receive adequate sunlight conditions of 10 h in mid-summer for ground invertebrates and butterflies; any further widening is unlikely to increase the sunlight hours received in the centre of the bay by any significant amount. However, a 30 x 10 m bay in the same tree crop orientated along a north/south ride, will only be well-lit for two-thirds of its length, and then for only 5 h duration. Therefore, much longer bays on north/south rides would have to be provided in order to be beneficial; these would never have the same number of sunny hours and so would be of less value in terms of overall response compared with east/west rides.

Table 4.3 Comparison of butterfly numbers for different woodland ride systems within Micheldever Forest, Hampshire. Annual totals from transect walks; ratios between rides of contrasting orientation or aspect in parentheses.

	Site	Ride orientation	
		180^0 N-S	90^0 E-W
1987	Blackwood II	67 (1.0)	39 (0.6)
1987	Waltham Trinleys	47 (1.0)	39 (0.3)
1987	Dodsley Wood	193 (1.0)	427 (2.2)
1988	Blackwood II	327 (1.0)	429 (1.3)
1988	Waltham Trinleys	255 (1.0)	429 (1.6)
1988	Dodsley Wood	688 (1.0)	899 (1.3)
	Site	**Aspect of edge**	
		North	South
1987	Blackwood I	7(1.0)	32 (4.5)
1987	Blackwood III	37 (1.0)	49 (1.3)
1988	Blackwood I	87(1.0)	342 (3.9)
1988	Blackwood III	97 (1.0)	241 (2.5)

Table 4.4 Yearly totals of butterflies recorded by the transect census method on eight newly created rides in pure beechwoods within Micheldever Forest, Hampshire. The ride widths were made equal to the crop height and cut during the winter of 1986/87.

	1987	1988	1989
Brimstone	19	148	170
Common blue	0	2	194
*Green-veined white	93	238	330
Hedge brown	16	139	267
Large skipper	32	115	217
Large white	29	276	125
Meadow brown	130	734	1,377
Orange tip	2	12	12
Peacock	55	507	534
Red admiral	27	84	82
Ringlet	144	183	403
Small copper	2	8	10
Small skipper	13	88	291
*Small tortoiseshell	47	74	71
Small white	108	118	259
Comma	37	89	270
*Speckled wood	83	305	365
Silver-washed fritillary	7	12	23
White admiral	4	3	4
Painted lady	1	214	6
Purple hairstreak	4	1	5
Purple emperor	1	0	1
Marbled white		2	15
Brown argus		1	15
Holly blue			23
Small blue			1
Total number of species	21	23	26
Total number of individuals	854	3,453	5,065

*These were the only species recorded within the shaded-out rides in 1986 before regular monitoring began.

Acknowledgements

It is a pleasure to thank Patrick Fleet, Peter Frizzell, Robert Manasse, Matthew Oates and David Whiting for monitoring invertebrates in this study.

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Paper 5

Woodland Edge Management for Butterflies

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Abstract

The majority of resident British butterflies occur in woodland where they breed mostly in rides and other open spaces. Three factors influence butterfly populations in woodland rides: the level of shade, composition of the vegetation, and vegetation structure. Ride and edge management for butterflies aims to create variety in these factors, so that suitable conditions can be created for a range of species. Precise objectives will vary between sites, and may be biased to favour a particularly rare species. Little is known about which regimes work best in practice, and more research is needed. However, ride and edge management may not be a panacea for all woodland butterflies.

Introduction

Nearly three-quarters of the 57 resident British butterflies regularly breed in woodland and all but five rely on open spaces such as rides, glades, or clearings. Many of them are more typical of open, non-woodland habitats such as grassland or heathland, but will breed wherever there is unshaded grassland within woodland. Species in this category include the common blue, *Polyommatus icarus;* meadow brown, *Maniola jurtina;* and small skipper, *Thymelicus sylvestris.* The highest priority for conservation are the 17 species that are more or less confined to woodland habitats, at least over a large part of their British range. About half of these are associated with woodland edges or newly-cleared woodland. The wood white, *Leptidea sinapis,* is perhaps the classic edge species and, in Britain, does not breed outside of woodland. The chequered skipper, *Carterocephalus palaemon,* is confined to woodland grassland, but is now found only in north-west Scotland. Also associated with woodland grassland, and far more widespread, is the comma, *Polygonia c-album.* Newly-cleared deciduous woodland is preferred by the heath fritillary, *Mellicta athalia;* high brown fritillary, *Argynnis adippe;* the pearl-bordered fritillary, *Boloria euphrosyne;* small pearl-bordered fritillary, *Boloria selene;* and the Duke of Burgundy fritillary, *Hamearis lucina.* The brown hairstreak, *Thecla betulae,* congregates on woodland edges in order to mate, and breeds on young blackthorn, *Prunus spinosa,* usually in nearby hedgerows. The remaining true woodland butterflies breed either in more shaded parts of the wood or in the tree canopy. However, two of the former, the white admiral, *Ladoga camilla,* and the silver-washed fritillary, *Argynnis paphia,* rely on open areas for abundant nectar-sources. Some of the tree-feeding species often breed on plants growing on woodland edges, such as sallows, *Salix* spp., which are preferred by the purple emperor, *Apatura iris.*

The butterflies of open spaces in woodland thrived for many centuries under the traditional management of coppicing, but declined seriously over the last 150 years when this practice was replaced by high forest systems. The latter are too shady for too long a period, and provide gaps too infrequently, to enable these specialised species to survive at their former levels of abundance. The loss of worked native coppiced woodland over the last 50 years has been around 90%. The early successional woodland species are now among the most endangered of all butterflies, and several are listed in the Red Data Book, including the high brown and heath fritillaries. Moreover, their decline may indicate similar losses among less well-known insect groups. Such species have become increasingly reliant on woodland edge habitats, notably rides and glades; or on young conifer plantations on former broadleaved sites which simulate coppice conditions in their early stages. The latter provided important habitats for butterflies during the 1950s, '60s and '70s, when many lowland sites were being planted with conifers. Such habitats may become far less abundant in the future, following the introduction of the Broadleaves Policy by the Forestry Commission in 1985. Although the inclusion of broadleaved species is likely to be beneficial for many other forms of wildlife, the management as high forest will provide few suitable gaps in broadleaved canopies for coppice butterflies.

The success of many butterfly species under coppice systems was probably due to an increase in temperature following cutting, which may be as great as 8°C in the soil during the summer months (Ash and Barkham, 1976). However, the period for which these clearings remain suitable for breeding butterflies is very short within the succession. Butterfly colonies generally reach a peak 2-3 years after cutting, and then rapidly decline, so that by the sixth year after cutting the colonies become extinct, because the vegetation has regrown. The important point is that because these species live in such a very short-lived habitat, their survival is dependent on active management. In traditional coppice management the butterfly colonies are able to move around from clearing-to-clearing. However, there is an important contradiction in that these species are not particularly mobile, as would be expected. Studies of the heath fritillary in the Blean Woods, Kent, have indicated that coppiced clearings greater than 600 m apart are not colonised during the time period for which they remain suitable. In view of this, ride vegetation may be important in itself, but rides themselves may perform a vital function as connecting corridors between habitats.

Surveys and research

In a recent review for the Nature Conservancy Council, 53 woodland sites in central southern England were considered to be of national or regional importance for their butterfly populations. The main interest on 46 of these sites was in the rides, glades or young plantations; and 36 were commercially-managed woods with a large conifer element, 22 of which were managed by the Forestry Commission. The creation and management of rides, glades and edges is therefore likely to play a crucial role in the future survival of endangered woodland butterflies. It will also be of great importance to the conservation of many of the open grassland species, which are under mounting threat in the wider countryside.

Three main factors influence butterfly populations in woodland rides:

1. the level of shade;
2. the composition of the vegetation;
3. the structure of the vegetation.

The effect of shade on different butterfly species has been studied extensively by Warren (1985), and more recently by M.L. Hall and J.N. Greatorex-Davies at the Institute of Terrestrial Ecology (ITE), Monks Wood. Generally, the majority of species require very open sunny rides, but a few such as the wood white and ringlet, *Aphantopus hyperantus,* prefer partially shaded conditions (10-40% shade). Only two species, the speckled wood, *Pararge aegeria;* and green-veined white, *Pieris napi,* actually prefer fairly shady rides (40-90% shade). The level of shade in a ride depends on three factors: the width of the ride, height of surrounding trees, and orientation. The effect of these variables has been modelled by Warren (1985).

The composition of the vegetation is important as most butterflies breed on only one or two specific food-plants, and many require an abundant supply of nectar, although most will feed from a wide variety of flowers. Species such as the purple emperor, which breeds on sallows, may well rely on edge habitats in many of its colonies because they have been planted with conifers; and the only locations in which these foodplants will occur may be along the edges of rides. The grizzled skipper, *Pyrgus malvae,* is very specific, relying on wild strawberry, *Fragaria vesca,* as its foodplant. If this plant is absent from an area, then so too are the butterflies.

However, butterflies will only breed on food-plants that are growing in exactly the right situation. Consequently, the structure of the vegetation is of the utmost importance. Unfortunately, this aspect is relatively poorly understood and has only recently been recognised following autecological studies. The grizzled skipper seems to prefer wild strawberry plants which are growing in fairly sparse vegetation, such as on exposed rideside banks. Dr J.A. Thomas at ITE, Furzebrook, has shown that the pearl-bordered fritillary prefers small violet plants growing in sparse or base vegetation, while the small pearl-bordered fritillary prefers slightly larger plants growing in taller vegetation. The wood white, which breeds on various legumes, tends to select taller plants that protrude through the vegetation on the edges of partially shaded rides. In short, some species like short vegetation, some prefer taller herbs, and others utilise light scrub or taller shrubs. Therefore, although the management of the vegetation is vital to the survival of many butterflies, it is the subject about which researchers and managers know least.

The main aim of managing rides and edges for butterflies is to create variety in as many of the above aspects as possible, so that suitable conditions can be created for a range of species. Clearly, the precise objectives will vary between sites and may be biased to favour a particularly rare or important species. These aims and objectives need to be decided before the ideal management option can be chosen, although this may need to be modified due to other factors such as cost or available machinery.

There are many ways in which systems can be devised in order to create these varied conditions. The easiest way to introduce variety in management is to zone the ride, so that different strips receive different treatments. Various options are described in an NCC booklet (Warren and Fuller, 1990). However, very little is known about which regimes work best in practice or whether they will continue to produce good results in the longer term. There is a need for more long-term site monitoring, as some dramatic changes may not be detected by short-term studies. Although the importance of cutting ride vegetation is appreciated, it is not fully understood how often this should be carried out, or at what time of year. Cutting of alternate sides each year may be too frequent for species such as the wood white, and the standard autumn cutting may be unsuitable on many soils in the longer term. Another important consideration is what to do with the cut material; will nutrient build-up lead to botanical changes if the material is not removed? The effects of different types of machinery and heights of cutting are not known and require evaluation. Futhermore, the scale on which cutting is undertaken may be important with regard to each of the zones, and optimum scallop sizes need to be investigated.

Conclusion

It is clear that rides and edges can support a large number of butterflies, including some rarities, and it is possible to prescribe several general cutting regimes which will probably produce good results in the short-term. However, a great deal of further research is needed before suitable conditions can be provided for the demanding, high-priority species. Even then, there may be some former coppice species which cannot be catered for by edge management alone. For example, the high-brown fritillary, which was once very abundant in coppiced woodlands, is now endangered. This species does not seem to breed in rides, and has not survived along edges as a whole. Rides and edges should therefore always be seen in the context of the management of the whole wood, not as the panacea which may solve all of the problems facing woodland butterflies. If suitable habitats for these species do not exist elsewhere in a wood, they are unlikely to survive in the ride systems simply because these are being managed.

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Paper 6

Woodland Edge Management for Invertebrates

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Abstract

Open areas in woodland may be used by a wide range of invertebrates. The amount of shade in woodland rides is shown to be negatively correlated with invertebrate numbers, and modelling has enabled prescriptions to be made with regard to ride width in order to satisfy light requirements of these species. Management options include the creation of box-junctions, linear coppicing on ride edges, the cutting of ride-side scallops and the alternate cutting of ride-side herbaceous vegetation. There remain a number of areas in which research is urgently needed, including the need for further monitoring where management work is in progress.

Introduction

The current emphasis on open rides and glades and edge management is of considerable importance to invertebrates for three main reasons. First, these areas are important for species that exploit the early seral stages of woodland succession which were created by traditional coppice management. Many of these invertebrates have become far less common, and often more restricted in range, as coppicing has declined and woods have become increasingly shady. Second, open areas are at present a minor part of most woodlands. There is comparatively plenty of shaded woodland, especially in the form of neglected coppice and high forest. Shade tolerant species are therefore unlikely to be adversely affected by an increase in open areas within woodland. Third, open areas within woodland are generally richest in insect species and numbers.

Several groups of invertebrates may exploit sheltered, open woodland rides and glades, and these include:

1. Those confined to, or normally associated with, open areas within woodland over at least part of their range. At least 60% of the 126 species of nationally scarce and Red Data Book macromoths generally associated with woodland, are associated with the open, early seral stages of woodland succession rather than mature or shaded woodland (Waring, 1989).

2. Rare grassland species, for example the marsh fritillary butterfly (*Eurodryas aurinia*), in areas where the amount of unimproved herb-rich grassland outside woodland is low.

3. Common grassland species.

Many mobile species utilise edges and rides, often in response to increased abundance of nectar-yielding plant species. Other species use these areas as hunting grounds, notably dragonflies and some predatory flies which often use rides and glades as good resources of insect food items.

Since 1945, about 30% of ancient woods have been largely clearfelled and planted with conifers. Many scarce or rare invertebrate species that rely on open areas within woods are still present in some of these plantation woods. This is undoubtedly due to the fact that these woods have been managed more recently than much remaining broadleaved woodland. Open areas were created as broadleaved trees were felled and young conifers planted. To some extent this provided a link with the time when the woods were last coppiced. Where invertebrate species associated with the early seral stages of woodland succession were still present, they often flourished for a time. However most of these woods are now rapidly becoming unsuitable for these invertebrates as the conifers grow and cast increasing shade.

Between 1985 and 1988 the Nature Conservancy Council contracted the Institute of Terrestrial Ecology to provide management guidelines for the conservation of invertebrates, especially butterflies, in plantation woodland on ancient woodland sites (Hall and Greatorex-Davies, 1989). As part of the work, the effects of woodland edge management on butterflies and other invertebrates was studied.

Methods and results

Part of this study was to examine the relationship between shade and invertebrates in woodland rides. The two main factors considered were the potential irradiance from the sun reaching the centre of each ride studied and the extent to which open sky was observable from the centre of each ride. The numbers of species and individuals of both butterflies and heteropteran bugs showed a highly significant positive correlation with increasing potential irradiance and open sky. Open and sunny rides contained a much richer fauna than shaded and closed rides. When data for shrub-feeding and herb-feeding heteroptera were analysed separately, the former still showed a negative correlation with shade. Chrysomelid beetles were also more abundant in open rides.

A simple modelling approach was adopted for predicting the ride widths required to provide light conditions suitable for particular species to use for breeding, depending on the height of the adjacent tree crop (Figures 6.1 and 6.2). For example, the pearl-bordered fritillary, *Boloria euphrosyne*, tended not to occur in rides with more than 20-25% shade (the amount of open sky obscured by the tree canopy). The model suggested that in crops 20 m tall, the ride width should be approximately 30 m. Where the crop height reaches 25 m, ride width would need to be approximately 40 m. This is unusually wide for most forest rides and may well be unacceptable to foresters, but it is important to realise that wide sunny rides are essential for the long-term survival of many invertebrate species within forests.

Figure 6.1 In 18 rides, a tree of average height for the compartment was selected from each side of the ride and its height measured. The angle from the base of a tree opposite to the top of the trees of known height was calculated trigonometrically (tangent). The average of these two angles was then plotted against the known shade value of the ride.

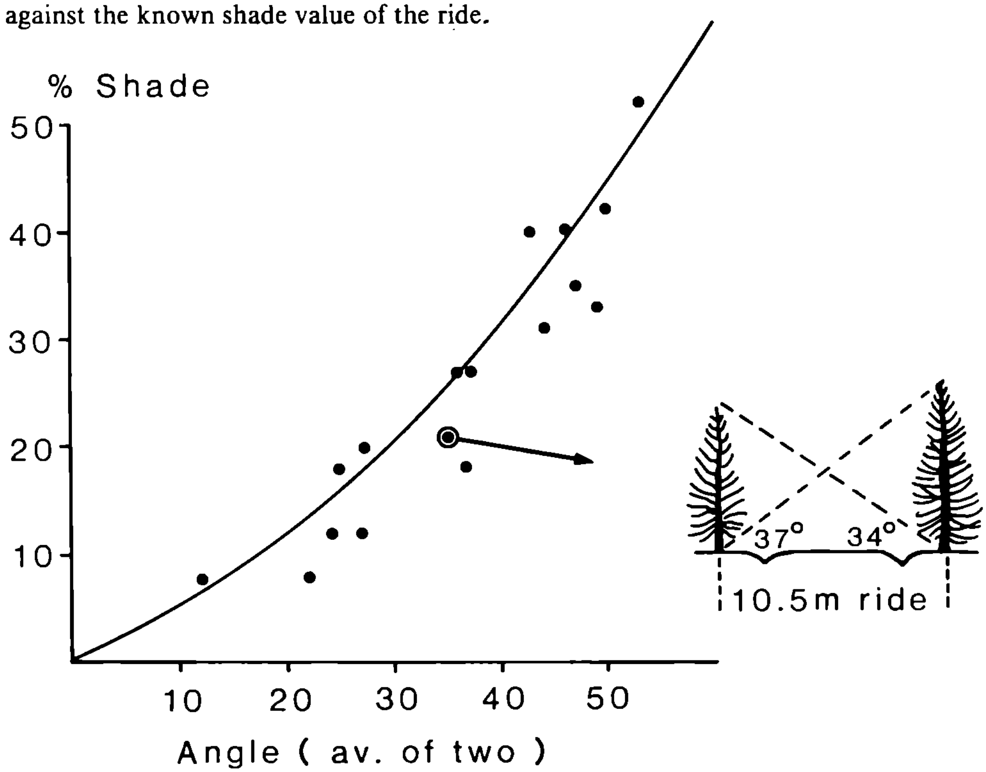
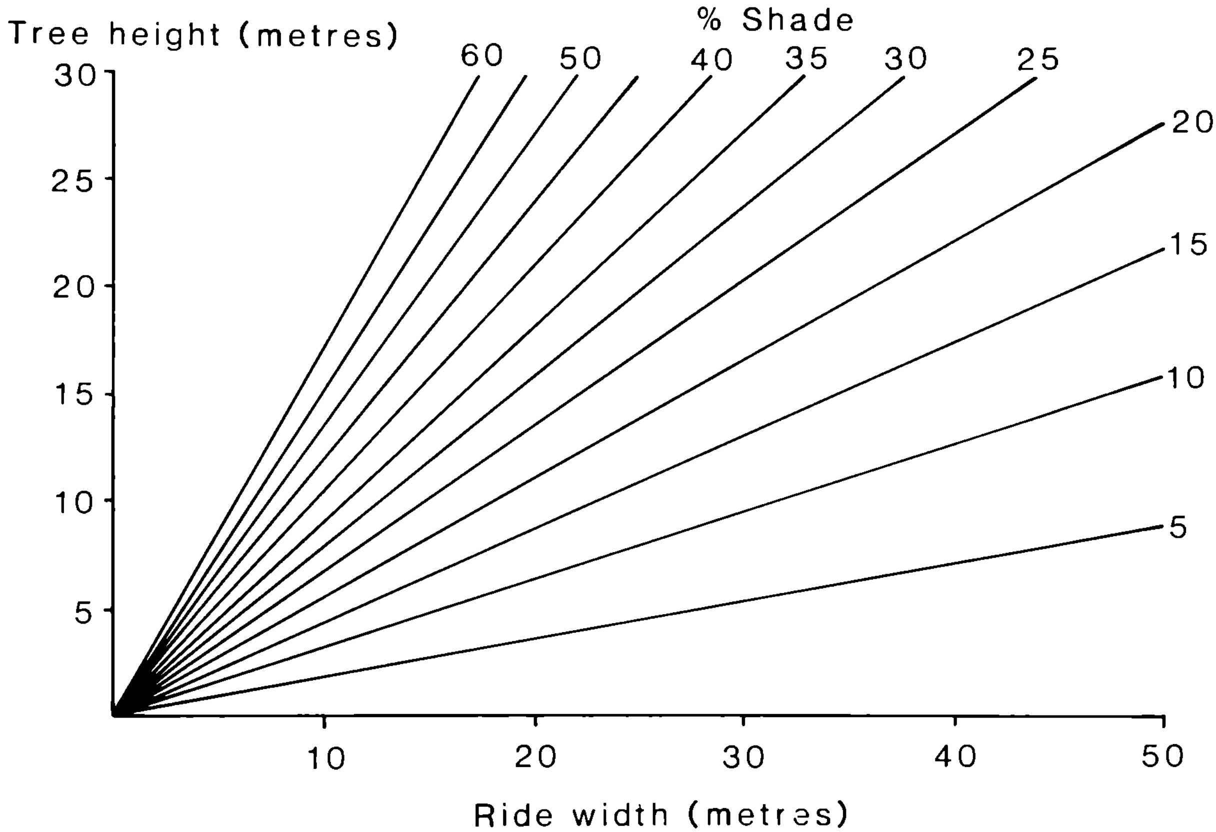


Figure 6.2 This diagram allows the user to predict how much shade will affect a ride, knowing its width and the height of the adjacent trees. A ride 30 m wide will be almost 25% shaded when the trees are 20 m high. Conversely, trees 20 m high will cast between 35% and 40% shade on a ride 20 m wide but only 18% shade if the ride is 40 m wide.



Management principles

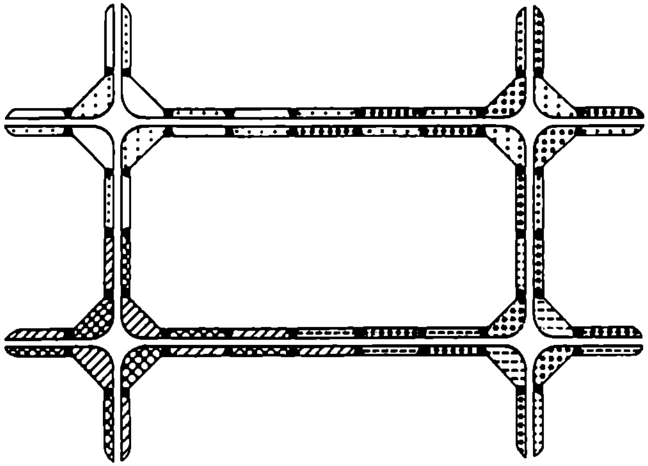
In drawing up conservation management plans for invertebrates in plantation woodland a number of important principles need to be considered.

1. The maintenance of open areas.
2. The need to maintain structural and temporal diversity, usually with the use of two or more rotational management systems.
3. The overlaying of management for individual rare species in conjunction with general conservation management where this is appropriate.
4. The careful selection of the most suitable areas for management within a woodland.
5. The need to plan for long-term management. Managers should be prepared to be flexible, so that management plans may be modified in the light of experience and new knowledge.

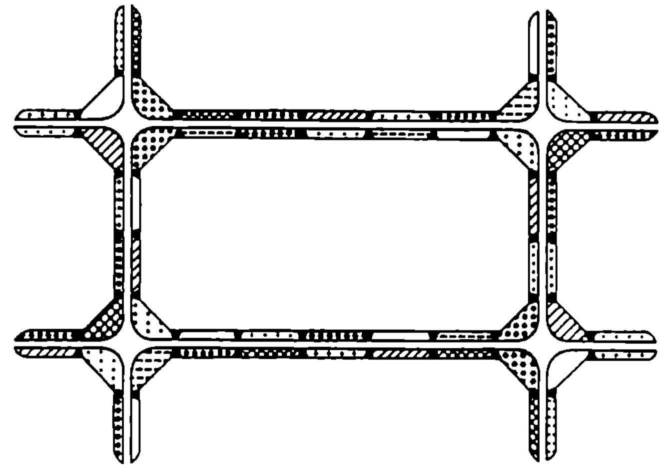
It is important to emphasise the need for consistent long-term management. Unlike plants which can survive an unfavourable period for a time as dormant seed or in a non-flowering vegetative state, invertebrates require the continual availability of both food and habitats in the right conditions if they are to survive. Many species appear to have poor powers of dispersal. Because of the isolation of many woods, such invertebrates, once lost from a wood, are very unlikely to recolonise it should conditions again become suitable, unless there is a nearby donor colony.

Figure 6.3 Systems of ride widening.

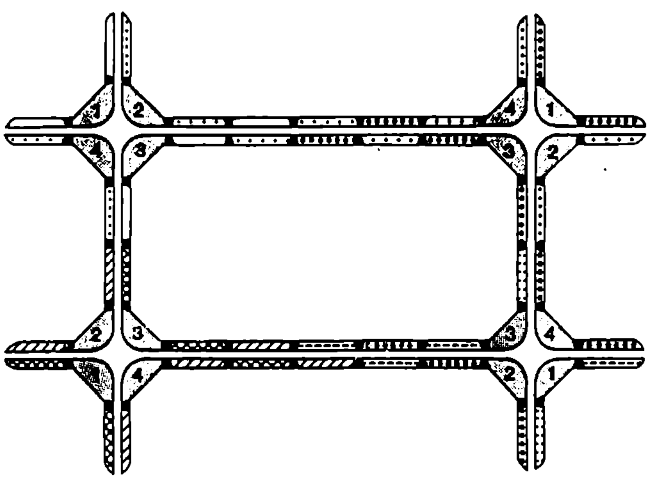
SIMPLE CYCLIC SYSTEM. Linear coppice and box junction management on an 8 year rotation.



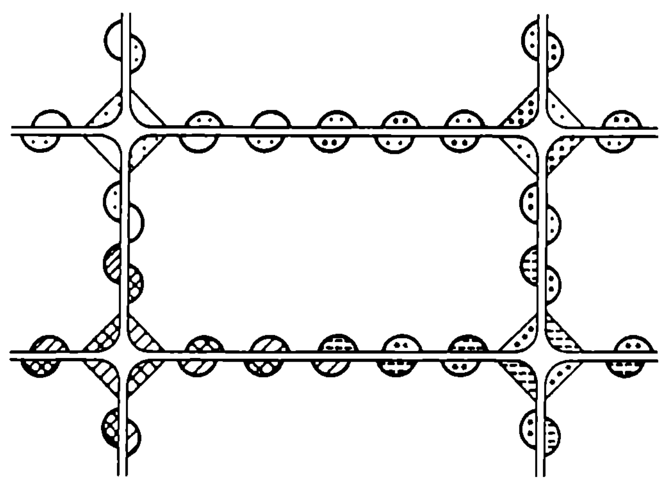
PATCHWORK SYSTEM. Patchwork of linear coppice and box junctions on an 8 year rotation.

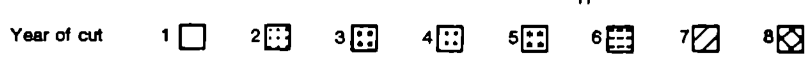


2 TIER CYCLIC SYSTEM. Linear coppice on an 8 year rotation; box junctions on a 4 year cycle.



Simple Cyclic scallop and box junction management on an 8 year rotation.





Recommendations

Permanent glades can be created at ride intersections by the removal of crop corners. These are often referred to as box-junctions. The four segments should be managed on a rotation so that habitat at different stages of development is always present at any one time. At Bernwood Forest, Oxfordshire, several box-junctions have been created over the last 10 years. This wood is one of the Forestry Commission's Forest Nature Reserves, designated as such largely because of its importance for butterflies. The four segments of each box-junction are cut in set rotations from annually to five-yearly. On one segment, cutting once a year has maintained suitable habitat for the pearl-bordered fritillary even after 7 years of management. This is probably largely because violets, *Viola* spp., are rather more abundant on this segment than on other segments. This may only be short-term, and is probably the result of past management or an intrinsic feature of the area. Other segments are also utilised by this species, especially those cut biennially.

If a 'coppicewood' ground-flora is desired, which would benefit the pearl-bordered fritillary and other similar species, a longer rotation of say 8 years, will probably be necessary in the long-term. The scrub regrowth needs to be sufficiently dense for the canopy to close within the length of the rotation, and so shade out the open-site plant species. Shade-site species, such as violets and primroses, *Primula vulgaris*, which survive the closed canopy stage, can then quickly grow, flower, and set seed when the area is next cut. An even longer rotation of 16 years or more may produce a more readily marketable crop but will reduce the amount of newly cleared coppice available at any one time for species needing this habitat.

There are a number of ways in which rides can be widened. Linear coppicing along ride edges may be particularly beneficial for some species. Strips of linear coppice should be managed on rotation and could complement box-junction management (Figure 6.3). Rides should be widened to the desired width (at least 30 m) at the outset of conservation management in order to encourage maximum deciduous regrowth. Linear coppicing has been carried out at Somerford Common in Wiltshire. The treatment has initially created the open, and sparsely vegetated areas which are exploited by some woodland butterflies for breeding. However, it is not known how long the 'coppicewood' ground-flora will remain abundant in successive rotations, particularly if scrub regrowth is poor.

A series of glades (scallops), created at intervals on each side of the ride provides an alternative to linear coppicing, and may also lessen the likelihood of windthrow along the exposed ride edge.

Some of the invertebrates that require the mature tree and shrub habitat can be provided for by allowing blocks of deciduous trees and shrubs to grow to maturity at intervals along both sides of rides between strips of linear coppice. These blocks may also help to reduce wind-funnelling.

Coppicing deciduous regrowth in woodland glades (such as box-junctions) and along ride edges is a relatively expensive form of management and may not produce a readily marketable crop. A common practice instead is to flail the ride edge shrub regrowth every 4-6 years. However the flailed wood debris may hinder regeneration of the woodland ground-flora and encourage a more vigorous weedy regrowth of less desirable species. On 10 m wide strips of linear coppice, flailing may not be practicable, and in any case the shorter rotation may be of insufficient duration to shade out the open site perennial herbs and grasses, assuming sufficient density of coppice regrowth.

In economic or silvicultural terms it may be considered more desirable to widen the rides in stages as the adjacent crops grow. In this case one or more rows of conifers should be removed along one or both sides of the rides at each thinning. This maintains the openness of the rides as the crop height increases. Alternatively successive crops of Christmas trees can be grown along the ride edges. However neither of these options is as satisfactory as linear coppice. In the first case the deciduous trees and shrubs and the woodland ground-flora are suppressed by the growing conifers. The second option is particularly likely to result in a herbaceous sward dominated by coarse grasses.

Apart from the scrub margins of rides, the herbaceous vegetation of the rides themselves, (i.e. between the ditches), needs to be managed in such a way as to maintain structural diversity and floristic richness and diversity. The central 2-3 m of main grassy rides normally needs to be mown at least annually to maintain easy access. The outer margins of the ride can be cut on a longer rotation. This has often been done on nature reserves in alternating strips cut biennially. However, longer rotations (3-4 years) may be better for producing the desired results on some sites.

A number of problem plants, such as tufted hair-grass, *Deschampsia cespitosa*, may occur in increasing abundance on newly-widened rides. In order to reduce the dominance of such grasses, and perhaps bramble, *Rubus fruticosus*, scarification of the soil at the time of cutting may help. The provision of bare ground allows seedling establishment of more desirable species. Forest roads and tracks made up of road-metal often produce a very rich and diverse vegetation within a few years of being laid or re-graded, particularly along their edges.

The area recommended for conservation edge management for invertebrates usually falls well within 10% of a woodland's total area, which is within the allocation recommended by the Forestry Commission for amenity and conservation purposes. Furthermore, management plans may only require that a proportion of the ride system is managed for invertebrates.

Future research needs

There are a number of areas in which information is lacking, and these require urgent research. There is a need for continuing monitoring of invertebrates generally. Work is needed to establish the best rotation lengths for ride edge coppice and box-junctions on different sites, and to investigate ways in which the ground flora can be improved. It may be feasible, and desirable, to re-coppice unplanted areas of broadleaves (often referred to by foresters as low grade broadleaves) within commercial plantations. Deer pose a serious threat to young coppice regrowth in many woods. This problem needs to be considered. Studies of mowing frequency and timing are urgently required and research needs to address the question of cutting machinery, height of cutting, the control of certain weed species and the feasibility of alternatives such as grazing. There is also a need for some autecological studies of plants such as violets and primroses. The re-establishment of desirable species of plants and insects should be considered in some instances.

Acknowledgements

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Paper 7

Effects of Woodland Edges on Songbirds

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Abstract

There is a dearth of information regarding the effects of edges on songbird populations, although some external edges have been shown to harbour relatively high densities of several breeding bird species. Rides may also benefit some species, particularly warblers, especially where there are wide belts of ride-side scrub or coppice and where this vegetation contrasts greatly with the surrounding crop. Rather less is known about edges where different compartments converge. The important factor in all of these situations is the complexity of habitat structure, usually defined as the presence of a well-developed shrub layer. Further research, including studies of breeding success and of long-term population responses to habitat manipulation, are required before an adequate understanding of the processes behind avian edge effects can be reached.

Introduction

Knowledge of how woodland edges affect the distribution and abundance of songbirds is rather limited. However, it is possible to make broad comparisons between different types of edge in terms of the responses shown by songbird populations, and various hypotheses can be advanced to account for these responses. This paper reviews this subject in relation to British woodlands and makes suggestions for future research.

There are three main types of woodland edge that can influence distribution and/or abundance of songbird species within woodland: (1) rides, (2) compartment boundaries, and (3) external woodland edges. Studies of the effects of edges on songbirds usually entail examination of the patterns of bird distribution with respect to distance from the edges and then an assessment of which species select or avoid edges. Possible negative impacts of edge management, as well as the potential benefits, should be considered. This is important because it has been shown that predation pressure for ground-nesting birds (and perhaps for other species) can be higher at the forest edge than within the forest (Andrén and Angelstam, 1988).

Rides

Management involving the widening of rides and the creation of ride-side strips of shrubby vegetation, may potentially benefit three groups of birds. Two of these groups comprise summer visitors. First, most of the woodland warblers occurring in Britain can respond positively, with the exception of the wood warbler, *Phylloscopus sibilatrix.* Chiffchaffs, *Phylloscopus collybita,* in particular, are associated strongly with rides and the edges of glades in some woods. Second, other summer visitors, such as nightingale, *Luscinia megarhynchos,* and tree pipit, *Anthus trivialis,* also seem to respond positively to ride management in some woodlands. Third, there is a small number of resident species, including dunnock, *Prunella modularis,* and wren, *Troglodytes troglodytes,* which are associated with rides in some woodlands.

Knowledge about the responses of these birds to ride creation and management is fragmentary. There have been no systematic studies or extensive surveys of the use that birds make of rides for breeding and feeding. There is a lack of information regarding which types of bird communities are associated with particular forms of vegetation structure along rides. It is evident that the responses of bird communities to ride management are very variable and do not always conform to predictions. For example, I have studied bird distribution in a 50 ha oakwood (Sheephouse Wood, Buckinghamshire) where ride management has involved the substantial widening of several rides since 1984/85. To date, effects on bird distribution within the wood have been barely discernible with the possible exception of chiffchaff. Several territories of this species have been associated with rides in recent years, although so far the ride management does not seem to have increased the overall chiffchaff population in the wood.

The primary factor influencing the use of rides by breeding songbirds seems to be the gross vegetational structure at the edge. In situations where the boundary between stand and ride is abrupt (i.e. with little or no ride-side scrub or coppice) few birds select the ride edges (Fuller and Whittington, 1987). The situations which appear to benefit songbirds are those in which a substantial scrubby margin is present at the ride edge. Although detailed prescriptions based on scientific evidence do not exist, it is likely that these strips should be at least 5 m wide in order to have maximum benefit.

The effects of rides on bird distribution within woodland may be most marked in woods where the ride-side vegetation structure and composition contrasts with that of the adjacent stand. In other words, ride management may enhance bird communities the most in those woods which have very little young growth vegetation within them. An example, is provided by some conifer plantations of thicket stage or older, where birds such as willow warbler, *Phylloscopus trochilus,* can be associated strongly with those broad rides flanked by broadleaved shrubs (author, unpublished). In such plantations, the ride-side vegetation forms a particularly striking contrast with the crop and, therefore, may have a marked effect on the numbers of warblers that occur in the wood. A very different situation occurs in actively coppiced woods where young growth habitats are widely available within the stands themselves. In these woods rides may have relatively little effect on warbler populations.

Compartment boundaries

With regard to compartment boundaries, it is more difficult to predict which species are likely to benefit. Studies in Scandinavia have demonstrated clear positive edge effects at boundaries between clearfells and mature coniferous forest (Hansson, 1983; Helle, 1983) but no comparable research has been reported in Britain. The study at Sheephouse Wood has examined changes in bird populations on the edges of a 2.6 ha clearfell, established 7 years ago. However, there is still no evidence of an edge effect on birds having developed.

Studies of coppiced woodland in Bradfield Woods, Suffolk, have shown a marked change in the structure of the shrub layer at the edge of some coppice panels (Fuller, Ray and Henderson, 1989). The density of the shrub layer was suppressed at the edge of young panels growing adjacent to old coppice. Such effects are likely to have implications for the distribution of birds within coppiced woodland and also for forest design. If there are edge effects across compartment boundaries, then there are two possible mechanisms which may account for them. The first is the foliage profile, particularly the shrub layer, which may be better developed at the edge of a compartment or vice versa (Helle, 1983). Secondly, it is possible that greater food resources, in the form of insects and berries, will exist at compartment edges (Helle and Muona, 1985).

External edges

Several species show strong preferences for the external edges of woods. Four species of woodland warblers (garden warbler, *Sylvia borin;* blackcap, *Sylvia atricapilla;* willow warbler and chiffchaff) show a clear response to these edges in many woods, as do some of the young-growth residents such as dunnock. In addition, there is a further group of resident species often associated with external edges. These include blackbird, *Turdus merula,* long-tailed tit, *Aegithalos caudatus;* and chaffinch, *Fringilla coelebs.* On the other hand, there seem to be very few British woodland breeding birds that avoid external edges.

A clear example of external edge effects was given by a study in Bardney Forest, Lincolnshire, which examined densities of birds in relation to increasing distance from woodland edge, in three stand types (Fuller and Whittington, 1987). Warblers and chaffinch, in particular, showed pronounced selection of the edge in all stand types. Other species showing strong edge effects were song thrush, *Turdus philomelos;* blackbird and wren. In contrast, robin, *Erithacus rubecula,* and tits showed no preference or avoidance of edges. Similar results were obtained from woods in the Vale of Aylesbury, although it was clear from this study that external edges varied considerably in the densities of birds they supported (Fuller, 1988).

Several possible factors may account for these strong external edge effects. The habitat structure is often more complex, with a well-developed shrub layer, in the outer 50 m or so of many woods than it is internally (Fuller and Whittington, 1987). It may be that those edges which are relatively poor for birds are ones which lack a complex vegetation structure (Fuller, 1988). Furthermore, the microclimate at many external edges, in terms of light and warmth, may be more suitable for many plants and insects.

Future research requirements

There are a number of problems associated with studying edges and their effects on bird populations that need to be overcome in designing new projects. Changes in habitat structure may be rather slow, which may require sites to be studied over very long time periods to assess how bird communities respond. Site fidelity by individual birds may also obscure colonisation and redistribution patterns and may give rise to time-lags in the response of birds to edge management (cf. Wiens, Rotenberry and Van Horne, 1986). There is also a problem of scale. Many birds, even quite small species, have territories which may extend along many metres of ride edge. Consequently, very large scale treatments may be required in experimental studies to obtain satisfactory sample sizes.

Most of what is known about birds and edges concerns breeding birds, and very little at all is known about the impact of edges outside of the breeding season. As well as studying individual species it is also desirable to study trends occurring in community structure and organisation, such as changes in bird density and diversity, from the centre of a woodland stand towards the edge. Where new edges are created, it would be useful to study which species colonise, and whether population changes occur in those species that are already established in the vicinity. Does the creation of edges actually cause redistribution of birds, rather than a change of their overall abundance? It seems likely that this may happen in some situations.

In addition to considering spatial patterns in the abundance of a species, it is important to address the issue of habitat optimality. Long-term studies of distribution in relation to population level would be valuable in this respect, especially if they incorporate assessments of breeding success. This is important in view of the high predation pressure that exists at some edges (Andrén and Angelstam, 1988). Although there are marked concentrations of some species at the edge of woodland where it adjoins open country, is it possible that these populations suffer higher predation than those, generally smaller, populations that use internal edges? It is conceivable that edges may be a case where the optimum habitat, in terms of breeding success, is not necessarily the preferred habitat as measured by population density. Under such circumstances external edges might even act as 'population sinks' (Wiens and Rotenberry, 1981). Or have songbird species nesting at edges become adapted to increased predation pressure by adopting particularly cryptic or inaccessible nest sites?

With respect to the three types of edges, research needs for songbirds may be summarised as follows:

1. Rides — On what physical scale should management be carried out, i.e. how does the width of the ride and of the ride-side vegetation affect birds? What rotation length should be employed when cutting the marginal scrub in order to create the optimum habitat structure for songbirds? How do effects of rides on the distribution and abundance of birds vary in different types of woodlands?

2. Compartment boundaries — How common are compartment edge effects in British forests and what are the underlying mechanisms? Are these edge effects apparent only when one side of the edge is an open clearfell? Could the size and layout of compartments be manipulated to increase bird populations by enhancing beneficial edge effects?

3. External edges — A fuller understanding of edge mechanisms is required, as some external edges support far higher bird populations than others. Does the aspect of the edge and the nature of the adjacent countryside affect the community of birds found at the woodland edge? How does the breeding success and nest site selection of songbirds at external edges compare with that at internal edges?

It is important to recognise that many woodland plants and animals are not edge species. As far as breeding birds are concerned, only about one-third of the British woodland breeding avifauna is really associated with edges (Fuller and Warren, in press). However, a very large proportion of the conservation effort in woodland, both within and outside nature reserves, is focused on managing edges, especially rides. It is necessary to define the benefits of edge management in the context of the whole forest ecosystem. How can edge management become part of a more integrated approach to woodland management for wildlife?

Acknowledgements

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Paper 8

Gamebirds and Woodland Edges

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Abstract

A large proportion of lowland woods are managed for gamebirds, especially pheasants. The management of edges is critical in maximising the density of pheasants within a woodland. External edges are particularly important, and internal edges along rides are also used. Rides should be >30 m wide to be beneficial. Two features of a woodland which influence the density of birds are: (1) the length of edge, and (2) the extent of shrub cover within this zone. Small woods with a relatively greater edge to area ratio, and good shrub cover, are likely to hold greater densities of birds. Modelling enables the prediction of pheasant densities in woods of different size and composition and can take into consideration any proposed changes in management.

Introduction

The pheasant, *Phasianus colchicus,* is the most numerous gamebird in Britain today, and comprises about 80% of all recorded species shot. This probably totals over 10 million birds per annum. Woodlands provide the commonest wintering areas for pheasants, and it is estimated that 60% of all lowland woods are used for shooting. As the pheasant is one of only a few species whose conservation can be of financial benefit to landowners and tenant farmers, its management can be important in the maintenance and diversity of agricultural systems. This may be most notably achieved through the planting, retention and management of woodland. Therefore, it is suggested that pheasant shooting can provide the financial incentive for many landowners to implement forms of management which would otherwise be uneconomic, but have indirect benefits for non-game species.

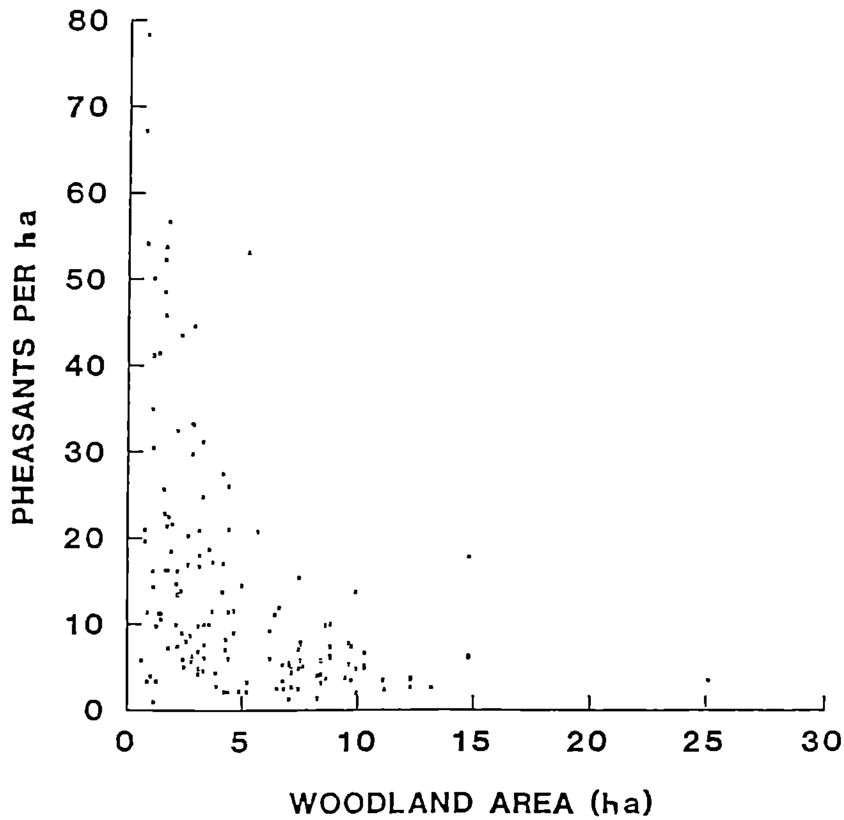
Research

A 3-year project, largely funded by the Forestry Commission, has been carried out by the Game Conservancy to study pheasants and woodland. One of the main aims of this project was to investigate the importance of woodlands to pheasants. It is known that not all woodlands are as attractive to pheasants as others. The basic requirements for a pheasant are warmth, food and shelter. The project set out to establish which types of woodland, and which features, can provide the most suitable conditions for pheasants. This was approached in three different ways. Firstly, counts were made of males and females driven from different woodland drives during winter. Over 150 woodland drives were counted in various parts of Britain, and the habitat was examined at a later date. The habitat was then related to the bird density in each case. Secondly, ratio-tracking was undertaken of about 30 individual birds in a diverse area of woodland, in order to examine habitat selection. Lastly, a number of breeding surveys were carried out. Some 150 kilometre-squares were surveyed and sampled for breeding males. An index of the number of females and of non-territorial males in each of these areas was also obtained.

Initial results

From these three approaches, it was possible to show a number of features. From the shoot visits, it was found that pheasant density was highest in small woods, and tailed off quite dramatically as the woods increased in size beyond 2-3 ha (Figure 8.1). Pheasant density was also found to be positively related to the length of edge (Figure 8.2). As pheasants are largely woodland-edge birds, small woods are more attractive to them, having a greater length of edge per unit area. Shrubby cover in the woodland area, especially around the edge, was found to be very important. Radiotelemetry was used to provide a more detailed picture of habitat use in woodlands by

Figure 8.1 The relationship between size (ha) and pheasant density (birds per ha).

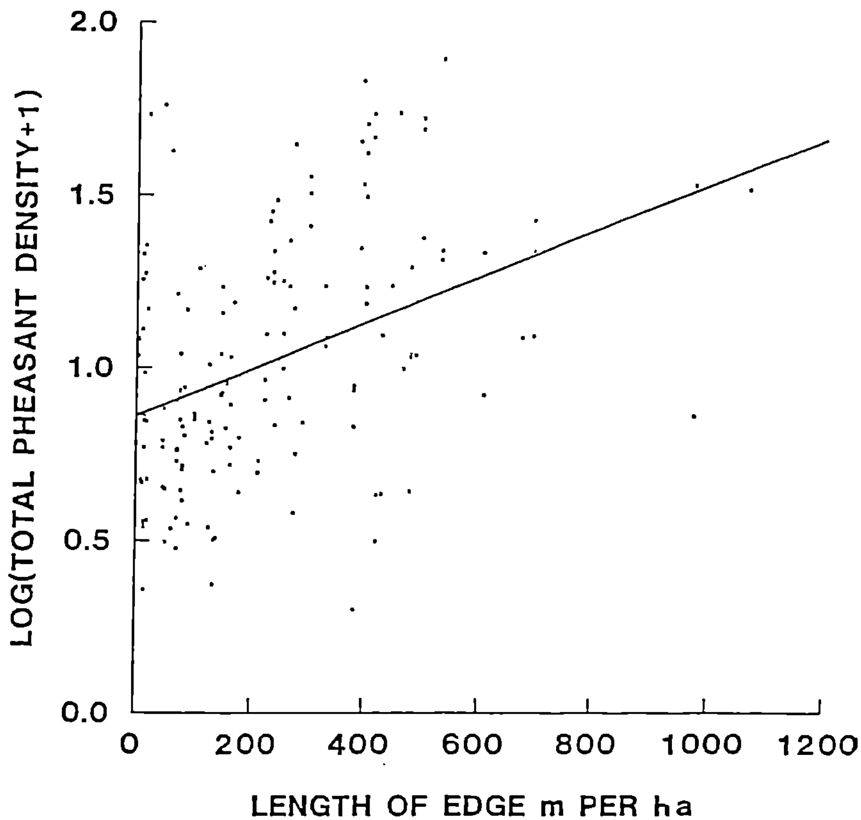


pheasants. From this, it was shown that, for the majority of time, pheasants utilise the edges of woodlands. Very little variation in edge use was observed between males and females, or throughout the duration of the study (November-March).

Having established the existence of an edge effect along external woodland edges, comparisons were made of other forms of edge against true woodland edges to establish whether these could act as substitutes, and provide similar conditions (Figure 8.3). To begin with, 15 m wide woodland rides were sampled. These edges were used by both males and females, in the same way as true woodland edges although not to the same extent. In addition to ride edges, forest tracks were also studied. These were no wider than 5 m, and were used only for access or timber extraction. These did not appear to produce an obvious edge effect. While 15 m wide rides were used to some extent, their suitability would be enhanced by widening, perhaps up to 30 m in width, so that more shrubby cover could develop. From the pheasants' point-of-view, this would more closely simulate a true woodland edge.

In the spring, pheasants move out of woodland to their breeding sites, which are typically external woodland edges. At this time, the males establish and defend their territories along these edges, and display to hen birds. However, not all males obtain territories, and so there remains a proportion of non-territorial males. Long-term studies have found that the number of territorial males in an area does not fluctuate very much from year to year (Figure 8.4). This also seems to be independent of total pheasant density in the area. The number appears to be determined by the availability of suitable breeding sites, which in turn is influenced by habitat quality, i.e. the length of edge and shrub cover. Therefore, counts of the number of territorial males can be used as indicators of habitat quality.

Figure 8.2 The relationship between the length of woodland edge (metres per ha) and pheasant density (log +1).



Further work

Assessments of the percentage of woodland within 155 kilometre-squares were made and could then be related to the density of breeding males. This showed that the density was highest at levels of woodland between 30-35% (Figure 8.5). Again, this is linked to the availability of woodland edges. If the percentage of woodland within an area is increased beyond 30-35%, it is predicted that the length of edge to area ratio will decrease, resulting in a decrease in the density of breeding males in the area.

In order to make a more detailed study of these woodland edges, they were classified into three different types. The first type incorporated edges with less than 25% shrub cover (Type 1). The second were edges with between 25 and 50% shrub cover (Type 2), and in the third category were edges with greater than 50% shrub cover (Type 3). When breeding male density was related to edge type, it was found that the density was highest in edges with the most cover.

In addition to these studies of different woodland types and different edge types, a study was made of the different crop types (Figure 8.6). For example, woodlands opening out on to pasture, spring crops, or winter crops. It was found that, for both males and females, the densities along woodland edges adjacent to pasture were less than those where woodland opened out on to crops. There was no significant difference between the density along edges adjacent to winter crops when compared with those adjacent to spring crops.

Figure 8.3 Use of external woodland edges, ride edges and track edges by pheasants during winter.

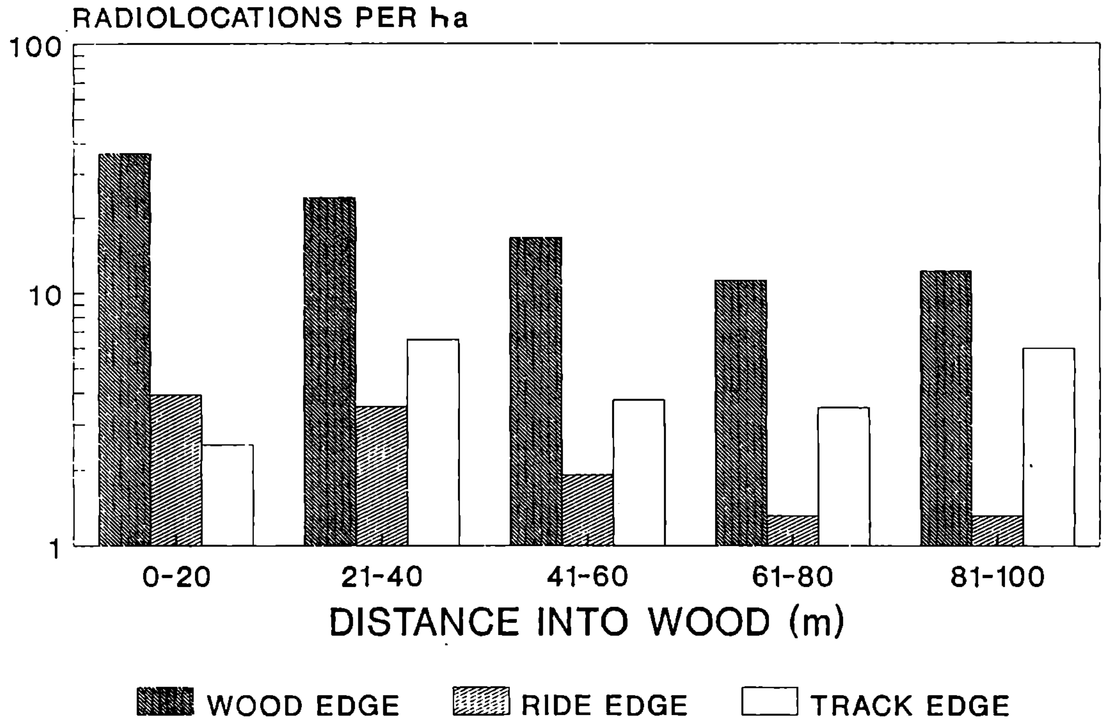


Figure 8.4 Changes in the number of breeding pheasants on Knoll Farm, Damerham.

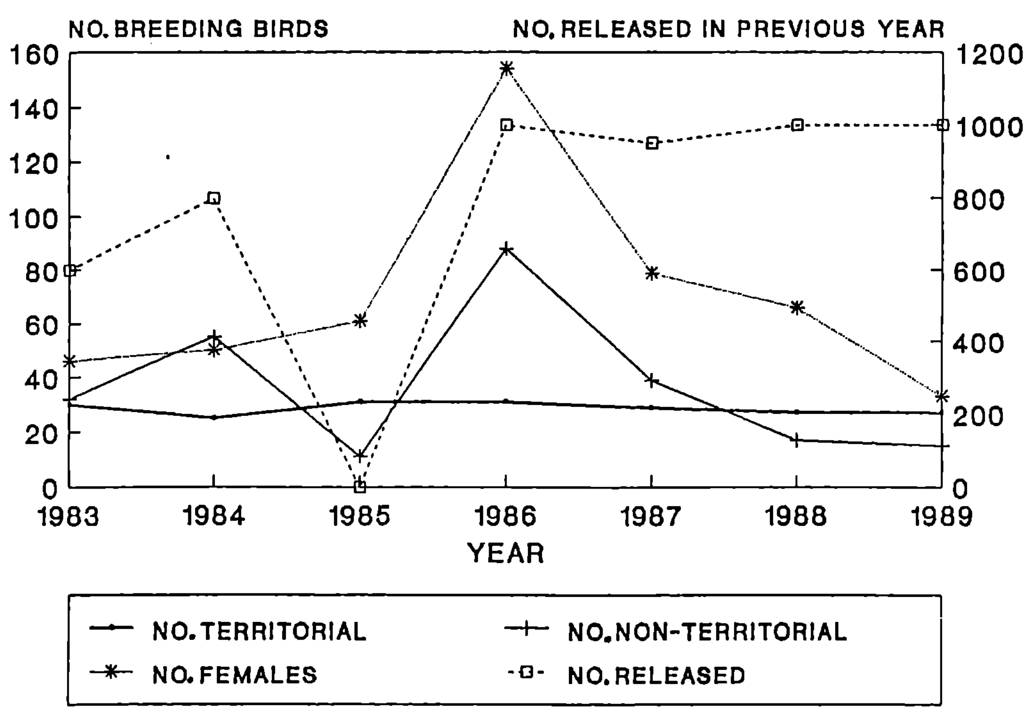


Figure 8.5 The effect of percentage area of woodland on the density of territorial male pheasants.

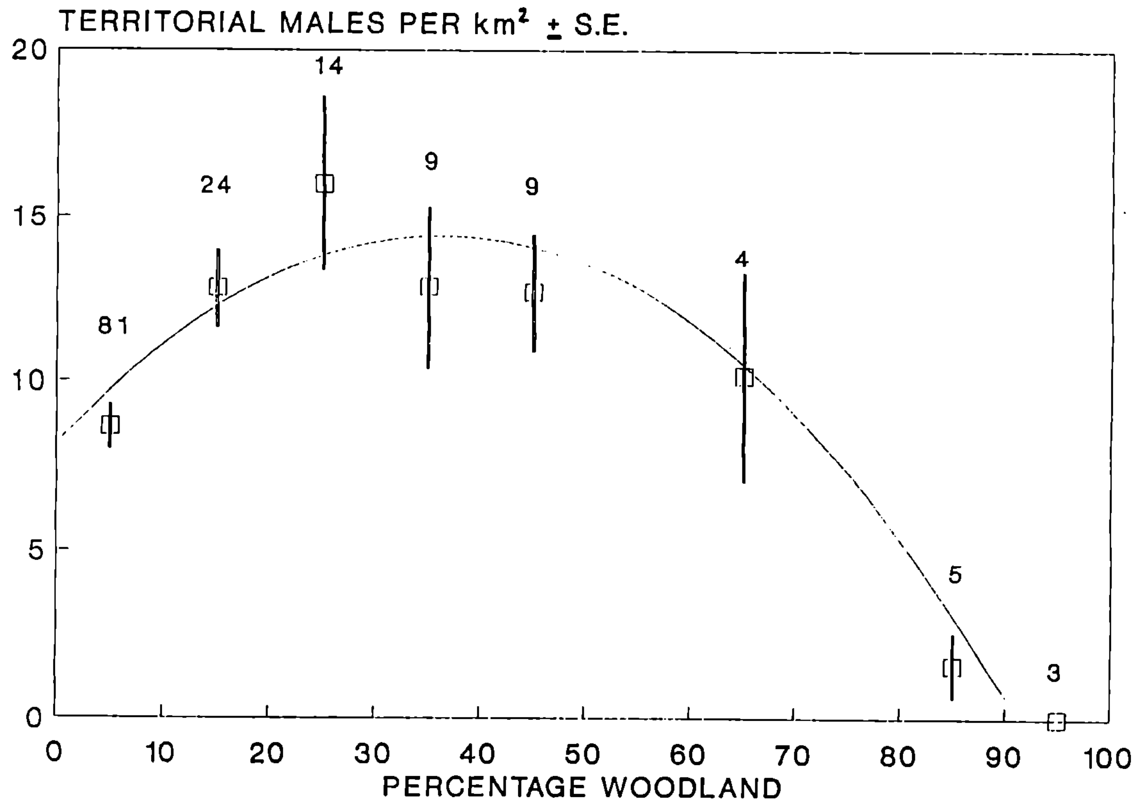
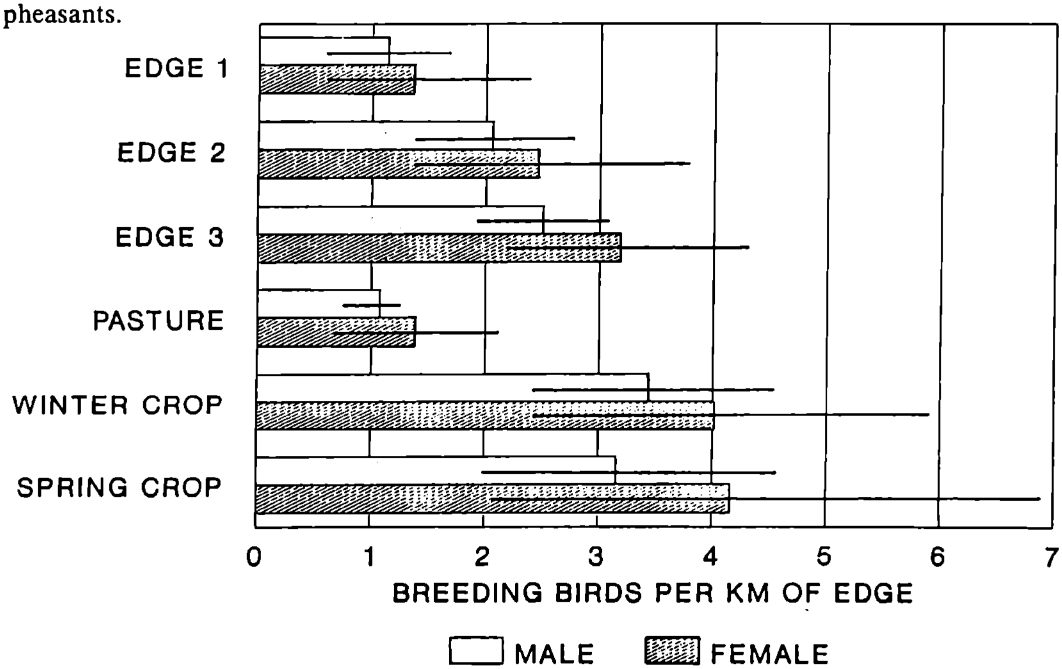


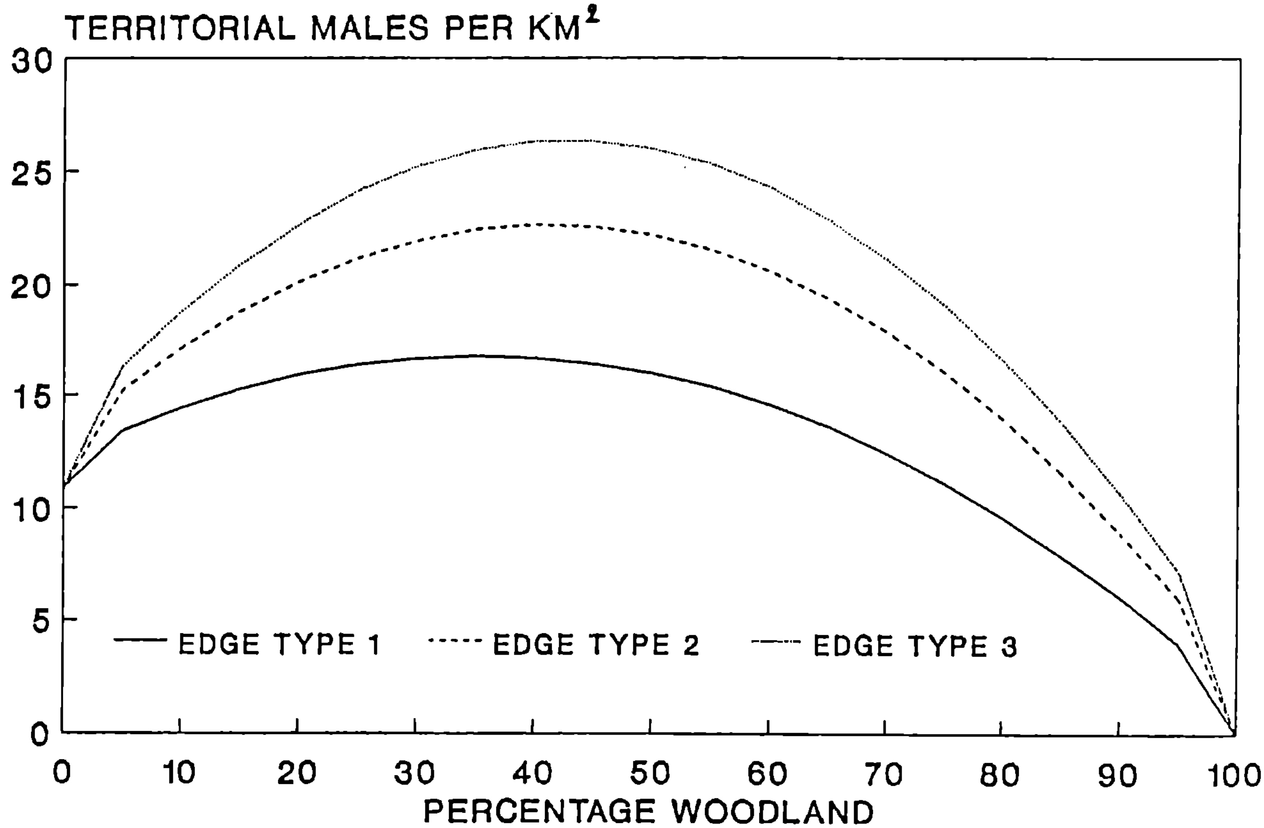
Figure 8.6 The effect of woodland edge type and crop type along woodland edge on the density of breeding pheasants.



Conclusions

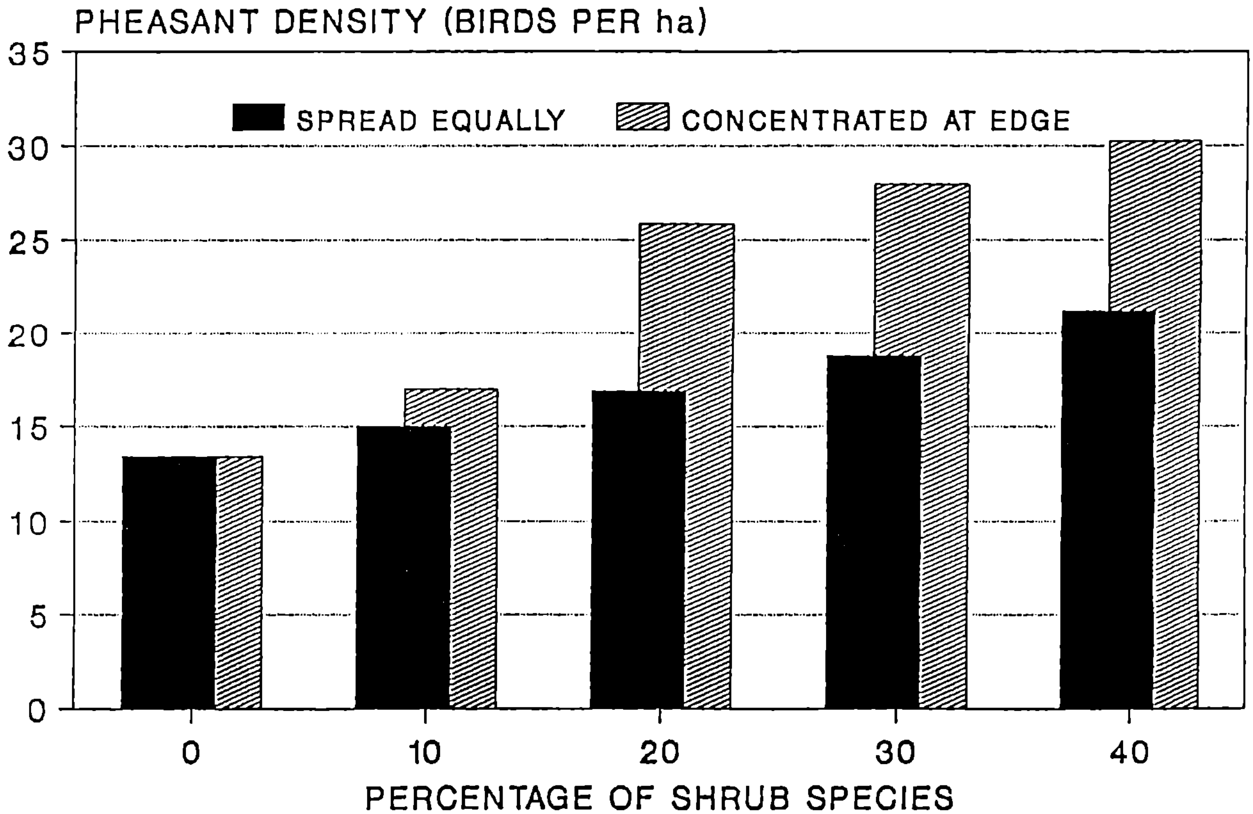
Based on all of the information collected in the study, it has been possible to develop a predictive model for the density of breeding males in response to different forms of management. If the extent of woodland in an area is about 10%, then an increase to 20% by planting would increase the numbers of territorial males to some extent. However, if the woodland edge was managed appropriately, to bring about a change from a Type 1 edge to a Type 3 edge, i.e. increased shrub cover, then the increase in male density would be much greater. Once the extent of woodland in an area is about 30-35%, then increasing this to around 50% is unlikely to bring about any significant increase in the density of breeding males. In woodland of this extent, management of the external edges is likely to give greater benefits. In situations where woodland occupies some 50% or more of an area, further planting may actually be detrimental for the numbers of territorial males, due to the consequential decrease in the edge to area ratio (Figure 8.7). As shrub cover has been shown to be the single most important habitat variable influencing the density of pheasants, it has also been possible to model the effects of shrub planting within a woodland block (Figure 8.8). Two planting options exist: (1) to plant the shrubs evenly throughout the woodland, and (2) to concentrate the shrubs around the woodland perimeter. In a hypothetical 1 ha wood with no shrub cover, the predicted winter density would be approximately 13 birds per hectare. If 10% of the woodland species are shrubs, planted evenly throughout the woodland, then the density would increase to about 15 birds per hectare. However, if the shrubs species are planted around the edges, then the increase in density would be marginally greater, up to about 17 birds per hectare. An additional 10% of shrubs species, to bring their overall level in the woodland to 20%, would increase densities by two birds per hectare if planted evenly. Edge planting at this level is predicted to increase densities quite dramatically, as 20% would result in a complete shrub cover around the edge of the 1 hectare wood. Density of birds may reach as many as 25 per hectare under these circumstances.

Figure 8.7 Predicted numbers of territorial males with increasing woodland with three edge types in areas of winter wheat.



These results not only emphasise the importance of edges, but also that of shrub cover, especially around woodland edges. Future work is planned which will examine the different ways in which edges are managed, to see how different forestry practices can affect pheasant density and to establish which of these forms of management create the best edges for these birds.

Figure 8.8 The effect of including an increasing proportion of shrub species into a 1 ha wood on winter pheasant density.



Paper 9

Edge Management and Small Mammals

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Abstract

Although there are few data available on the impact of edge management on small mammals, it is possible to identify a number of general principles based on our knowledge of individual species in more extensive habitats. Generally, edge management is unlikely to affect species richness, but distribution and relative abundance may change. Densities of both field voles, *Microtus agrestis,* and bank voles, *Clethrionomys glareolus,* are likely to show an increase; and shrews, *Sorex araneus,* and bats will probably also increase. It seems likely that there will be a concentration of activity in the edge ecotones which may also act as dispersal corridors. The management of edges will also have effects on the community food chain, with the concentration of rodents influencing weasel, fox, stoat, kestrel and owl populations.

Introduction

This paper concerns the effects of edge management on mammal populations. Broadly speaking, there are two ways in which woodland management can be approached in order to bring about changes in the habitat for mammals: the diversification of the tree crop and the diversification of the field/shrub layer. Edge management is usually concerned with the latter and therefore this is the subject of this review.

There are approximately 22 small mammal species found in British woodlands (Table 9.1), ranging from shrews, mice, voles, rabbits, hares, squirrels and carnivores up to the fox, *Vulpes vulpes.* Of these, edge management could have a critical effect on dormice populations, *Muscarelinus avellanarius,* by providing suitable corridors for dispersal. Edge management is unlikely to greatly affect squirrels, unless it involves an increase in the diversity of the tree species around conifer plantations with red squirrel, *Sciurus vulgaris,* populations. This could improve the cover and food supply for red squirrels, though an increase in broadleaved species, especially large-seeded species, possibly along a ride or roadside, may encourage grey squirrels, *S. carolinensis;* to move into the area (Gurnell and Pepper, 1988). In general, edge management is likely to have less effect on species with large territories or home ranges, due to its limited scale in relation to woodlands as a whole. Small mammals such as mice, voles and shrews are more likely to be influenced, though this will influence dispersion, and possibly numbers of predators.

The management of woodland rides may affect small mammals in four ways: species richness, population density, persistence in time and spatial distribution. Ride management may be seen as the creation of a habitat patch within a more uniform stretch of woodland and in many instances it is the creation of a grassland-scrub type habitat. In creating or maintaining such a habitat, good cover and more diverse food are likely to be provided.

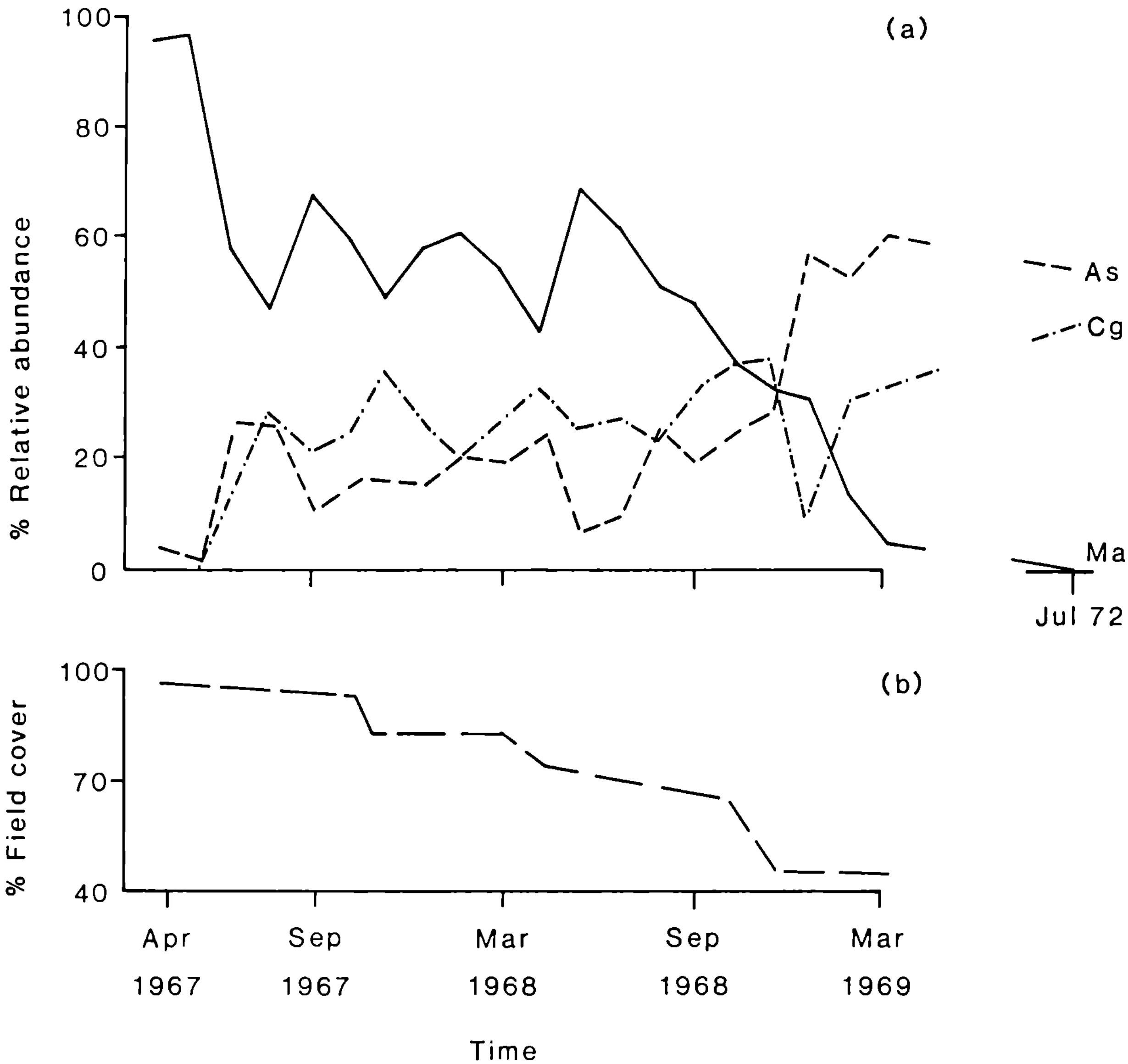
It is known that small mammal populations within afforested areas show a patchy distribution (Gurnell, 1985; Banach, 1987; Mazurkiewicz and Rajska-Jurgiel, 1987). They respond to different forest management regimes and changes in habitat, particularly the amount of field cover (Ferns, 1979 a and b). Niche separation occurs, such that a high density of *M. agrestis* in grassland habitats usually excludes other species. However, where there is more scrub present, woodmice, *Apodemus sylvaticus;* bank voles, *Clethrionomys glareolus;* and *M. agrestis* may all coexist at high densities (Gurnell, 1985). It seems likely, therefore, that small mammal

Table 9.1 Small mammals found in British woodland

Species	Microhabitat	Food
Bats (Order Chiroptera)	Woodlands and scrub	Insectivore
Hedgehog (*Erinaceus europaeus*)	All lowland habitats	Insectivore
Mole (*Talpa europaea*)	Fossorial	Insectivore
Common shrew (*Sorex araneus*)	Grassland/scrub or woodland with dense field cover	Insectivore
Water shrew (*Neomys fodiens*)	Water bodies in woodlands	Insectivore
Water vole (*Arvicola terrestris*)	Water/grassy habitats	Herbivore
Bank vole (*Clethrionomys glareolus*)	Dense field cover, arboreal	Folivore/ granivore
Field vole (*Microtus agrestis*)	Dense field cover of grasses and forbs	Folivore
Wood mouse (*Apodemus sylvaticus*)	Mature woodland habitats	Granivore/ Insectivore
Yellow-necked mouse (*Apodemus flavicollis*)	Mature open woodland with good understorey and little ground cover	Granivore/ Insectivore
Harvest mouse (*Micromys minutus*)	Tall grass, herbs and shrubs	Granivore/ Insectivore
Common dormouse (*Muscardinus avellanarius*)	Deciduous woodland with dense shrub layer	Granivore/ Insectivore
Fat dormouse (*Glis glis*)	Deciduous woodland	Granivore
Squirrels (*Sciurus* spp.)	Mature forests and arboreal	Granivore/ fungivore/ herbivore
Rabbit (*Oryctolagus cuniculus*)	Woodlands, especially grassy areas	Herbivore
Hares (*Lepus* spp.)	Woodland/agricultural edges	Herbivore

Figure 9.1 (a) Changes in the relative abundance of wood mice, *Apodemus sylvaticus* (As); bank voles, *Clethrionomys glareolus* (Cg); and field voles, *Microtus agrestis* (Ma).

(b) Relative changes in field cover in a young Japanese larch, *Larix kaempferi,* plantation in south-west England.
(From Gurnell, 1985; after Ferns 1979 a, b)



populations will show a response to ride management; the impact being dependent upon the tree crop species, its age and silvicultural practices applied, in addition to the management regime applied to the edge. The precise response will vary according to the habitat requirements of each species, briefly outlined below.

Mice

Yellow-necked mice, *Apodemus flavicollis,* prefer mature, open woodland, while woodmice, *A. sylvaticus,* may be found in all habitat types (Gurnell, 1985). Edge management is unlikely to affect the density of *A. sylvaticus* over a forest area, but it may change their spatial distribution (Geuse, 1985). They may utilise edges as dispersal corridors.

Voles and shrews

Edge management is likely to improve the habitat for these species. Field voles, *M. agrestis,* are herbivores and are already found in young plantations, in glades and along rides. Their presence reflects their preference for grassy restock areas or early plantation stages, in which densities are likely to be highest. Field voles usually only have a short-term residency in these situations. In early successional habitats, for example, numbers decline as trees shade out the field and scrub vegetation (Figure 9.1). Edge management, if maintained, may change the habitat sufficiently to encourage these animals to become permanently settled in a woodland. Bank voles, *C. glareolus,* might be expected to show an increase in density over small patches (Geuse, 1985; Geuse, Bachau and Le Boulenge, 1985; Mazurkiewicz, 1986). Work by Ivanter (1975) has illustrated the tendency for forest interiors, particularly of conifer forests, to hold very low densities of *C. glareolus* (Table 9.2). If management gives rise to increased light levels and a corresponding increase in ground vegetation, then vole populations are likely to show an increase. The data given in Table 9.2 may not hold true with regard to managed rides, due to the differences in scale between external forest edges and rides. However, it does indicate that greater numbers of *C. glareolus* occur at forest edges in a range of forest types. It would be useful to examine whether the same occurs along managed rides.

Shrews, *Sorex* spp., might be expected to show a similar response. There is some evidence from work by Wolk and Wolk (1982) in Poland that the greatest numbers of shrews are found in early plantation stages between 6-15 years, i.e. pre-thicket, where the ground cover is likely to consist of a mixed grass-scrub vegetation. Similarly, shrews and harvest mice, *Micromys minutus,* occur in higher numbers in stands of young coppice within a managed coppice woodland (Gurnell, Hicks and Whitbread, in press). Therefore, any increase in the amount of ground and field vegetation is likely to increase the habitat available to shrews and harvest mice.

Table 9.2 Number of bank voles at forest edges and in the centre of forest blocks (Individual/100 trap nights)

Forest type	Edge	Centre
Dry pine	3.1	0.5
Moist pine	4.4	1.0
Bog pine	2	0.3
Boreal spruce	6	1.3
Mixed	7.3	1.3
Old deciduous	4.1	1.7
Thicket	6.4	0.8

from Ivanter (1975)

Dormice

Dormice, *Muscardinus avellanarius,* are specialists and have a localised and intermittent distribution. Consequently, small patches of suitable habitat (e.g. shrubby vegetation) may be important for the dynamics of *M. avellanarius* in a particular area. Ride management may create more permanent, transient or dispersal habitats which will favour *M. avellanarius,* but it is necessary to investigate the long-term impact on the dynamics of the population. This will depend on two factors: the main forest habitat and its management (see Bright and Morris, 1989) and the ride/edge habitat and its management. Interactions between these are also likely to be important.

Bats

It is recognised that increasing the shrub habitat on edges is likely to lead to an increase in food availability for bats (Mayle, 1990). Corridors of native broadleaved trees and shrubs such as birch, *Betula* spp.; willow, *Salix* spp.; and wild cherries, *Prunus* spp.; are especially valuable in providing habitats for moths. Therefore, with appropriate management on ride edges, and the edges of waterbodies, increased foraging activity by bats might be expected. Roosting bats may also utilise edges. They are dependent on the availability of tree holes and this in turn requires that sufficiently mature trees are available, in which woodpeckers can form nest-holes. The retention of broadleaved trees beyond normal rotation length, particularly in corridors such as ridesides, is likely to have the greatest benefit for bats roosting in woodland.

Community impacts

An important factor in considering the impacts of edge management on mammal populations is scale. The home ranges of small mammals can be quite large compared with the width of rides and roads, whether these are managed or unmanaged. Certain species may be more reluctant to cross rides (e.g. bank voles) than others (e.g. mice) (Bakowski and Kozakiewicz, 1988). There is also considerable variation in home range sizes between and within species (Table 9.3). Home range size will vary according to the species, the sex, and the time of year at which it is assessed. Sampling and estimation methods will also influence the home range calculation. Small mammals are unlikely to solely persist in the edge ecotone, but will also use the forest interior as part of their home range. It seems probable that the impact of edge management will be greater for those species with smaller territories/range sizes, such as voles. Managed rides may also provide dispersal corridors, especially if they link larger patches of grassland, and this may be particularly important for *M. agrestis* and harvest mice, *Micromys minutus*. Specific effects will depend on the ride characteristics and the scale of the management.

Table 9.3 Home ranges (m^2) of selected small mammals found in woodlands

Species	Home range (m^2)
Field vole	150- 1 000
Bank vole	200- 2 000
Yellow-necked mouse	1 000- 3 000
Wood mouse	250-10 000

Bats will travel up to 5 km to important foraging sites (Swift, 1981), although a distance of approximately 1 km is more usual (Nyholm, 1965; Swift and Racey, 1983; and Catto, 1988). A recent study on the activity of woodland bats (Walsh, unpublished, BSc Hons. Thesis) has shown bat activity to be significantly higher in pond- and ride/road-side habitats and especially along rides where there are also bays/glades. Bat activity correlated with the proportion of shrub in the 2-4 m layer and with the numbers of small (2 mm) insects, although numbers of small insects did not correlate with the proportion of shrub, but with the proportion of ground layer. Bays/glades provide areas of increased ground and shrubby vegetation, as well as sheltered areas where swarms of small insects gather; bats will forage preferentially in these areas of high insect density.

Edge management, especially increasing the proportion of bays/glades in the habitat, could be expected to improve the survivorship of woodland bat populations, as food availability has been shown to be critical to bat survival at certain times of the year (Mayle, in press).

In addition to its effects on populations of individual species, edge management is also likely to have an impact on the food chain. Clearly, increasing densities of small mammals are likely to attract predators, especially weasels, *Mustela nivalis;* and raptors (Mazurkiewicz and Rajska-Jurgiel, 1987). A substantial increase in the numbers of rodents commonly stimulates both functional and numerical responses in local predators, whether rodents are the normal prey or not (see King, 1985). King (1975) has shown that *M. nivalis* populations occupying grassland habitats can live well on much smaller territories than those occupying woodland. *M. nivalis* and stoats, *M. erminea,* feed mainly on rodents and the breeding success of either species is closely correlated with rodent density. The breeding success of tawny owls, *Strix aluco,* has also been shown to be controlled by the density of woodland rodents, especially voles (Petty, 1987). Barn owls, *Tyto alba,* are a sensitive species and tend to be out-competed in woodland habitats by *S. aluco.* However, this does not seem to occur on woodland edges, where the success of *T. alba* populations is likely to be increased by improvements in prey availability through edge management.

The management regime may also influence the ease of predation. If grassy areas along forest rides are cut very closely, cover will be greatly reduced. This may have the effect of making small mammals more vulnerable to predation. However, subtle adjustments to the cutting height, where the sward is cut back to approximately 1 m in height, may still allow sufficient cover for small mammals and lessen the predation impact.

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Paper 10

Grazing Animals: Their Impact and Potential Value in Ride Management

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Abstract

The impact of herbivores on vegetation and their use in forestry and nature reserve management are reviewed. Herbivores can create and maintain diversity in herbaceous plants but may reduce diversity of other shrubs, trees, or some faunal groups. Grazing regimes suitable for the maintenance of floristic diversity have little in common with those recommended for weed control in forestry. It is suggested that animals should be deployed in specific areas or at varying stocking rates to create or maintain structural diversity.

Introduction

Wherever timber production is a priority, grazing animals are controlled or excluded from British forests. In spite of a long history of allowing grazing in many woodlands, the need for animals in modern commercial forestry has never been considered sufficient to justify the damage they can inflict. A number of recent developments gives us reason to re-examine the use of animals further. Perhaps the most important of these is the increased interest in wildlife conservation in forests. Rides and forest edges, because of their diversity, have become the focus of research and management activity. Other important developments include the increasing use of animals for vegetation management in nature reserves, and improvements, mainly overseas, in the effective use of animals for weed control in forests.

Currently, forest rides are maintained with the help of machines and herbicides. There is a very real possibility that grazing animals can be used to achieve ride management, conservation, or even silvicultural objectives with a saving in costs. The purpose of this review is to draw together some of the experience of grazing in forestry and conservation and to explore the possible means and benefits of grazing in British forests.

The function of herbivores as vegetation modifiers

Defoliation

Herbivorous mammals have a major impact on vegetation. Many of the changes they inflict closely parallel mechanical methods of vegetation removal, and their use can therefore be considered in many areas where machines or chemicals are used. The most conspicuous effect of grazing is the reduction in vegetation height or above ground biomass (Rawes, 1983; Bakker *et al.*, 1983; Bullock and Kinnear, 1988). As a consequence the amount of dead plant material is reduced and the rate of nutrient cycling increased (Barrow, 1961). Under light or moderate grazing, floristic diversity is increased, not simply because light transmission is improved and mean plant size reduced, but because faster growing dominants are removed; and smaller, slower growing but grazing-tolerant species are able to compete. Under heavier grazing, reductions in diversity occur, either because of a reduction in vegetation structure (as in woodlands) or because of plant mortality, trampling and erosion increasing the amount of bare ground (Bakker *et al.*, 1983; Thalen, 1984; Macpherson and Rasmussen, 1989; Putman *et al.*, 1989).

Defoliation has never been demonstrated to improve plant fitness, but many species (grasses in particular) have adaptations, such as low meristems and high root/shoot ratios which enable them to tolerate grazing (Belsky, 1986). Variation in these plant adaptations results in changes in vegetation composition under grazing.

Plants in general are more vulnerable to defoliation before carbohydrates are translocated to storage organs, and differences in the season of grazing can influence vegetation composition and diversity, particularly if dominants are grazed when they are most vulnerable (Macpherson and Rasmussen, 1989).

In woodlands, grazing and browsing can result in vegetation removal up to the reach of the species concerned. Low levels of browsing can result in the selective removal of certain tree species (Zeltner, 1979; Alverson *et al.*, 1989) while higher levels remove all regeneration, creating a park-like effect.

Trampling, dung and ranging behaviour

Apart from foliage removal, herbivores have additional effects which contribute to vegetation diversity. Dung redistributes nutrients, creating microsites for nutrient demanding plants (Bakker *et al.*, 1983). Dung also distributes seeds and can bury and kill plants (Hatton, 1989; Welch, 1985). These effects can be amplified by rabbits, *Oryctolagus cuniculus* L., and horses which deposit dung in aggregations. Hooves, particularly those of cattle which have a high weight/area ratio, can both create seed sites and damage roots and subterranean rhizomes (Harper, 1977; Adams, 1986). Ranging behaviour can also affect vegetation. Animals rarely use an area equally and this can create structural diversity (Thalen, 1984). Sites previously grazed are revisited to eat actively regrowing shoots. Facilitation between herbivore species has also been widely reported (McNaughton, 1979; Gordon, 1988; Holachek *et al.*, 1982).

Diet selection

The most important effect of herbivores is their selectivity. The diet of each species is a function of digestive morphology and metabolic requirements. Sheep and cattle are predominantly grazers and usually consume browse only when herbs and grasses are unpalatable or unavailable (Fitzgerald *et al.*, 1986; Fitter and Jennings, 1975). Deer and goats are browsers and will usually consume trees and shrubs at any time of year although each show marked preferences among the tree species they select (Mitchell *et al.*, 1977). In general, sheep are more selective than cattle which are in turn more selective than horses, and roe deer are more selective than red (Grant *et al.*, 1985; Hinge, 1986). Feeding preferences are sufficiently characteristic that each species could have a very different effect on a vegetation community. Table 10.1 highlights some of the differences between each of the main species of wild and domestic herbivore. The use of animals therefore provides an opportunity to exploit feeding preferences for specific goals in any particular site.

The use of herbivores in conservation and forestry

Recently, considerable interest has developed in the intentional use of animals for both nature reserve and forest management (Gordon and Duncan, 1988; Doescher *et al.*, 1987). Animals have been employed in reserves primarily to suppress vegetational succession and maintain a flora and fauna associated with early successional habitats (Bakker *et al.*, 1983; Bullock and Kinnear, 1988; Gordon and Duncan, 1988; Massey, personal communication). In forests, their use has been primarily to control weeds and other undesirable vegetation that interferes with tree growth (Doescher *et al.*, 1987; Sharrow *et al.*, 1989). Animals have also been used to maintain firebreaks in forests (Green and Newell, 1982) and a number of these studies have investigated the potential for animal production in addition to vegetation control (Adams, 1986; McCarthy, 1985, McKinnel 1975). A summary of these examples appears in Table 10.2.

Grazing and forestry

Not all of these trials or studies have achieved complete success with their chosen objective. Problems have been reported with damage to trees (Adams, 1975; Adams, 1986; Dale and Todd, 1986; Doescher *et al.*, 1987), with reluctance to consume intended vegetation, and among the animals with weight loss, abortion and even mortality (Adam, 1986; Dale and Todd, 1986; McCarthy, 1985). Later experience has revealed answers to many of these problems. The choice of animal is, of course, vital. Goats and deer for example, are more likely to strip bark or browse trees than sheep or cattle. Grazers can therefore be used much more safely at higher stocking rates provided that more palatable vegetation is *always* available (Doescher *et al.*, 1987; Fitzgerald *et al.*, 1986). The timing of the deployment of animals is equally important. Many conifers become more palatable during budbreak and this period should be avoided (Welch *et al.*, 1988). Several authors emphasise the need to monitor

Table 10.1 The vegetation impact of mammalian herbivores.

	Diet	Examples of impact
Cattle	Selective grazer	Creation of shrub-dominated communities under heavy grazing or in nutriet poor sites. Leaves a longer grass sward than sheep. Inflicts most trampling damage. Browse normally avoided.
Horses	Coarse grazer	Removes spp. (e.g. *Juncus, Phragmites* and *Cirsium*) usually avoided by cattle and sheep. Can graze wetter areas and poorer quality forage than cattle.
Sheep	Very selective grazer	Creates mosaic of short and tall pastures. Some spp. (e.g. *Pteridium, Juncus*) conspicuously avoided.
Goats	Browser/grazer	Reduces shrub biomass. Consumes grasses in spring.
Rabbit	Grazer	Maintains short lawns close to burrow systems. Patchy effect.
Red deer	Intermediate browser/grazer	Selective removal of tree species. All tree regeneration prevented at moderate densities.
Roe deer	Selective browser	Suppression of some dicotyledonous spp. (e.g. *Chamaenerion angustifolium).* Alteration to tree species composition. Removal of coppice regrowth.

Table 10.2 Examples of the use of herbivores for vegetation management

Objective	Animal	No/km² Stocking	Duration and Season	Location	Reference
Birch/willow scrub removal in nature reserve	Goats	3 200	3 months May-July	Fife, Scotland	Bullock and Kinnear (1988)
Firebreak maintenance	Goats	80-500	12 months	California, USA	Green and Newell (1982)
Weed control young Douglas fir plantation	Sheep	13 300	1 month	Oregon, USA	Sharrow *et al.* (1989)
Weed control in Sitka spruce plantation	Sheep	250-600	2-3 months	N. Ireland	Adams (1986)
Bracken control	Sheep	200-800	Until tree damage begins	New Zealand	Breach (1986)
Grass control	Cattle	1 500	1 week	New Zealand	Dale and Todd (1986)
Gorse control	Sheep	2 000	-	New Zealand	Hansen (1986)
Grassland maintenance in nature reserves	Sheep Cattle	80-400 15-100	* *	UK	Massey (1986)
Conversion of acid grassland to heathland	Cattle	100-200	12 months	Holland	Bokdam and Gleichman (1988)
Bramble control in forests	Goats	600	12 months	Victoria, Australia	McCarthy (1985)
Weed control in forests	Sheep	300-500	12 months	W. Australia	McKinnell (1975)

*Varies with grassland type

both vegetation phenology and damage, in order to achieve success (Breach, 1986; Doescher *et al.*, 1987; Sharrow *et al.*, 1989). The choice of season will also depend on the target vegetation species. The maximum damage to plants is usually inflicted during the growing season.

A high stocking rate is usually required where a rapid reduction in vegetation biomass is desired. Ungrazed or lightly grazed vegetation contains considerable amounts of unpalatable material, and in some situations this may be impossible to remove if the tree crop is at a vulnerable height. Damage can also occur if animals congregate in small portions of a stand. This problem may be alleviated either by more effective stock control or the use of attractants, such as salt, water or food supplies, suitably dispersed throughout the area. One example has been reported where damage was reduced by *increasing* stocking, since this forced the cattle to disperse (Doescher *et al.*, 1987).

Several authors have stressed the need either to provide additional good quality forage or to have it available on nearby pastureland (Dale and Todd, 1986; McCarthy, 1985). This is particularly important if animals are forced to eat material which may be low in digestibility or essential nutrients. Horses and some primitive breeds of sheep and cattle are better able to maintain body condition on poor quality forage than modern breeds of sheep or cattle and hence the choice of animal may alleviate this problem.

In spite of many of these problems several authors report successful use of animals in forestry. These include improvements in tree growth after grazing (Doescher *et al.*, 1987; Sharrow *et al.*, 1989), or achievement of weed control in conjunction with animal weight gain, and no damage (McKinnel, 1975) or substantial savings in the cost of herbicide use (Doescher *et al.*, 1987).

Grazing and conservation

The management of ungulates to maximise diversity may require very different methods to those required for vegetation control. Although floristic diversity has often been reported to increase under grazing (Bakker *et al.*, 1983; McNaughton, 1979; Thalen, 1984), diversity of other groups may decline (Moore, 1985). Grazing, particularly if it is heavy, will reduce the food and cover available for small mammals (Birney *et al.*, 1976) and perhaps therefore also their avian or mammalian predators. Grazing in woodlands has been reported to decrease diversity, not just for plants, but for small mammals, and many insect groups as well (Putman *et al.*, 1989). Cattle grazing has also resulted in reductions of bird diversity in riparian habitats (Taylor, 1986). These reductions appeared to be mainly due to loss of the shrub layer vegetation and its dependent fauna. Many authors report a reduction in plant diversity at higher stocking rates (Macpherson and Rasmussen, 1989; Thalen, 1984). Massey (1986) suggests that if grazing is to benefit grassland invertebrate fauna it needs to be light, preferably not during the active growing season and should avoid rapid changes in vegetation structure. It is unlikely that any grazing regime can be found which maximises diversity of all major groups of fauna and flora within a grazed area (Moore, 1985). Grazing should perhaps therefore be used as a tool and applied to small areas, or try to exploit the animals' habitat preferences as much as possible, in order to achieve structural diversity within a forest as a whole (Moore, 1985; Thalen, 1984).

There are therefore clear differences in grazing regimes suggested for weed control (high stocking, short grazing period and effective dispersal) with those recommended to maximise diversity in rides (light stocking, unequal grazing pressures). It is unlikely that a regime could be found that satisfies both objectives together, although direct conflict of objective may sometimes be avoidable.

Requirements for the use of animals in rides

Domestic animals

A number of problems face the forest manager interested in the rational use of animals in forests, the most obvious being the prevention of damage and the control of movement. The possibility of permanently fencing rides is almost entirely out of the question, for reasons of cost alone. A more likely solution would be to either tether (or enclose) a small number on the ride and move them progressively as required, or to allow the animals to range freely throughout the forest. The former method would permit much finer control in stocking, ranging and timing of impact, but would require more intervention. The latter method has considerable attractions if it could be used where the animals may confer some silvicultural benefit, or at least not cause damage, as well as grazing in rides. The experience of other workers reported in the previous section all points to the need for such strict controls on stocking, timing and ranging that it appears that there would be few situations in Britain where this method would be suitable if timber production was an objective. Furthermore, if the forest covers an extensive area, it may be difficult to retrieve animals when they are no longer required.

A well reported example of grazing sheep in a Sitka spruce (*Picea sitchensis* (Bong.) Carr.) plantation in Britain resulted in reduced tree growth (due to suspected root damage) and poor animal performance (Adams, 1986). This example is not encouraging, since it implies that the right balance between stocking rate, damage and husbandry costs may be very difficult to achieve in British upland sites with soft, peaty soil and poor quality forage.

Deer

Deer, even at relatively low density, can selectively remove regenerating trees and shrubs to the point where concern arises for their conservation (Alverson *et al.,* 1988). This problem may go further than just the flora. Many tree species that are known to support both scarce and diverse phytophagous insects (e.g. oak, *Quercus* spp.; poplar, *Populus* spp.; sallow and willow, *Salix* spp.), (Kennedy and Southwood, 1984; Winter, 1983), are also preferentially selected by both red and roe deer (Mitchell *et al.,*1977; Szmidt, 1975). Deer may therefore need to be heavily controlled if these species are to be grown in forests or ride edges. On a limited scale, individual tree guards could be used to protect the trees until they have reached a safe height. A better understanding of how deer affect ride vegetation and their dependent fauna is urgently needed, not least because beneficial interactions may also be found.

Conclusions

Domestic animals are clearly valuable tools for vegetation manipulation and could be applied to ride management, achieving gains in floristic diversity and probable savings in cost. Unless carefully controlled, their impacts on fauna may be negative. There is however a lack of understanding of the complexities of vegetation change under grazing for both wild and domestic herbivores, and virtually no information that applies directly to British commercial forest vegetation. Furthermore, most foresters and rangers would lack the appropriate skills in animal husbandry. Experimental trials should be conducted to try to meet these deficiencies.

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Paper 11

Management of Riparian Edges

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Abstract

Streams and riparian areas are particularly valuable habitats for wildlife for a number of reasons. They are diverse habitats with a large amount of edge and may be important corridors for the movement of wildlife. The loss of wetland habitats through agricultural improvement has further added to their value. Afforestation and forest practices have been cited as being harmful effects on these habitats, and guidelines issued by the Forestry Commission are designed to minimise negative impacts and to manage riparian areas in a creative and sympathetic manner. Management practices are outlined and research priorities put forward which are aimed at improving the management of riparian edges.

Introduction

The high value of streams and their riparian areas as habitats for wildlife is now a familiar theme in ecological literature throughout the world. Among the main reasons for this high value are:

1. a large degree of diversity of habitat is created by the flow processes or erosion and deposition, by weathering of rock, and by the varying depths and substrates;
2. the margins of rivers have a high amount of edge between adjacent, narrow habitat types, which are characterised by varying topography, physical structure, moisture levels and frequencies of flooding, which in turn produces a variety of vegetation types some of which are not found in other habitats;
3. the continuous nature of a river and the flow of water enables colonisation and movement of plants and animals, which may be prevented by variable land use or topography or adjacent land. The riparian 'corridor' too is an important route for movement of wildlife by virtue of its continuity of habitat;
4. the microclimate of riparian zones is usually less variable than that of the surrounding land and the vegetation is usually more lush due to the high local water-table, both of which tend to make riparian areas favourable habitat for many terrestrial animals.

In UK forests an additional factor is the frequent presence of freely draining mineral soils in the riparian areas, especially those with significant slopes, and this may provide sites which are relatively fertile compared with most of the afforested area. In the UK, upland grazing and burning practices have often confined semi-natural vegetation such as tall herbs, shrubs and trees to the steeper, more inaccessible river gulleys, thereby exaggerating the ecological differences between many riversides and adjacent hillsides.

In the UK lowlands, and increasingly in the uplands, agricultural intensification and 'improvement' have restricted formerly widespread habitats and species to riparian areas and other edge habitats. Quite small areas, especially of wetland habitats in riparian areas, are being regarded as increasingly important for nature conservation as a result of their decline elsewhere.

Afforestation and forest practices have also caused reductions in the semi-natural vegetation types of riparian areas and have affected water quality, reducing populations of fish and invertebrate fauna in streams.

In addition to this background, two recent changes in UK forestry policy are highly significant. The first is the higher priority placed upon conservation and enhancement of wildlife throughout the forest estate as a result of the Wildlife and Countryside Act Amendment of 1985, and the second is the recent publication of the *Forests and water guidelines* by the Forestry Commission in 1988.

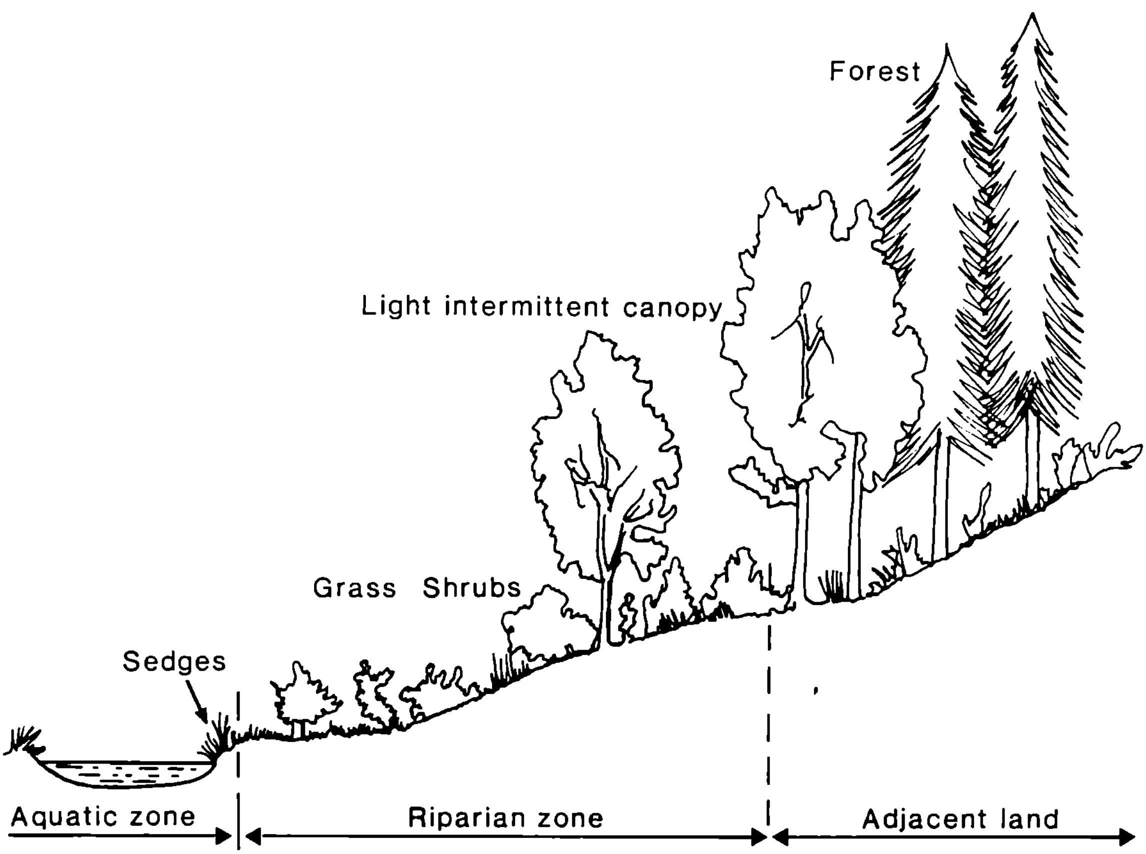
Management practices and guidelines

Forest managers are now being encouraged to apply the *Forests and water guidelines* especially to minimise negative impacts on water quality and fish habitat, but they are also thinking creatively about the management of riparian areas for other aspects of wildlife conservation as one of a number of uses which include landscaping, recreation, deer habitat and culling areas and the establishment of windfirm crop boundaries.

Some of the more important provisions of these guidelines relate to the management of the vegetation in the riparian zone, for example:

1. protective strips of at least 5 m width consisting of 'thriving vegetation' should be established on each bank of small streams;
2. for larger streams these protective strips on each bank should be two or three times the width of the stream bed;
3. at least 50% of the stream surface should be open to sunlight with the remainder under intermittent shade from light-foliaged, mainly native, trees and shrubs.

Figure 11.1 Riparian edges.



These provisions aim to minimise the input to the stream of silt from forest operations and also to achieve a varied vegetation structure in the riparian zone, while allowing sufficient light to reach the stream to promote productivity of algae, higher plants, invertebrate animals and fish. As broad guidelines they appear satisfactory, but they have not yet been fully tested and refined to allow site-specific designs to be devised. The prescriptions, see Figure 11.1, will result in an increase in the amount of 'edge in the riparian zone, as irregular and discontinuous bands of grasses and sedges, shrubs, broadleaved trees and coniferous trees are formed, in addition to any wetland features such as pools or old river channels'.

The interaction of the riparian vegetation with the stream itself is the critical feature which distinguishes riparian edges from terrestrial edge habitats such as rides. Worldwide studies of stream ecology have demonstrated the strong interaction of rivers and their terrestrial setting. For example, the stream is influenced by riparian vegetation in terms of channel morphology (shading can cause loss of vegetation on banks and subsequent bank erosion), and biotic effects such as inputs of plant litter and invertebrate animals as energy sources, and control of the amount of sunlight reaching the water. In turn the stream influences riparian vegetation by means of erosion and deposition processes and by fluctuations in water-table levels. Land use practices are therefore important and can affect the wildlife of the stream quite dramatically. For example fish populations in streams are strongly influenced by stock grazing and forestry practices on the banks, both of which can cause channel modifications and changes in the amount of cover and shelter afforded by bankside vegetation. Two sets of data illustrate this.

Figure 11.2 Range of trout biomasses recorded in well-buffered upland streams in UK.

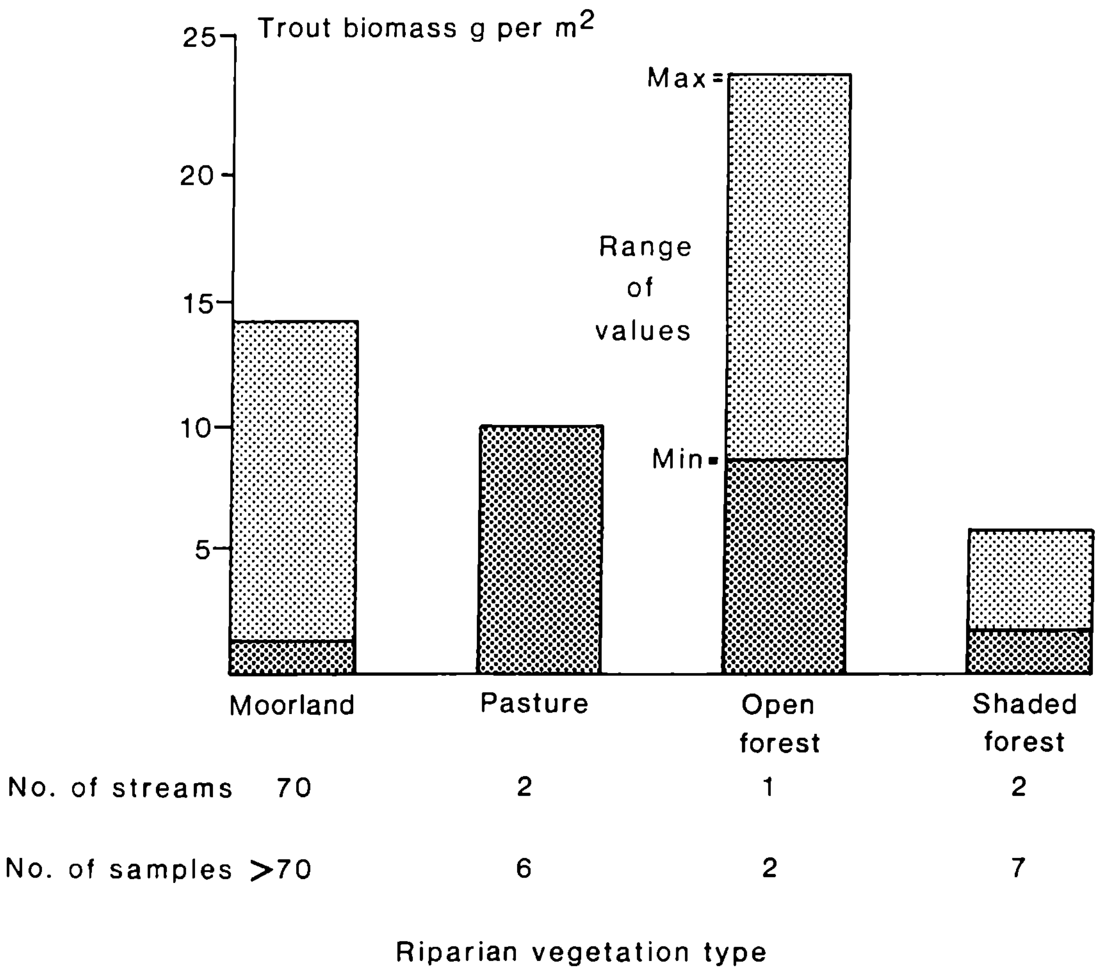
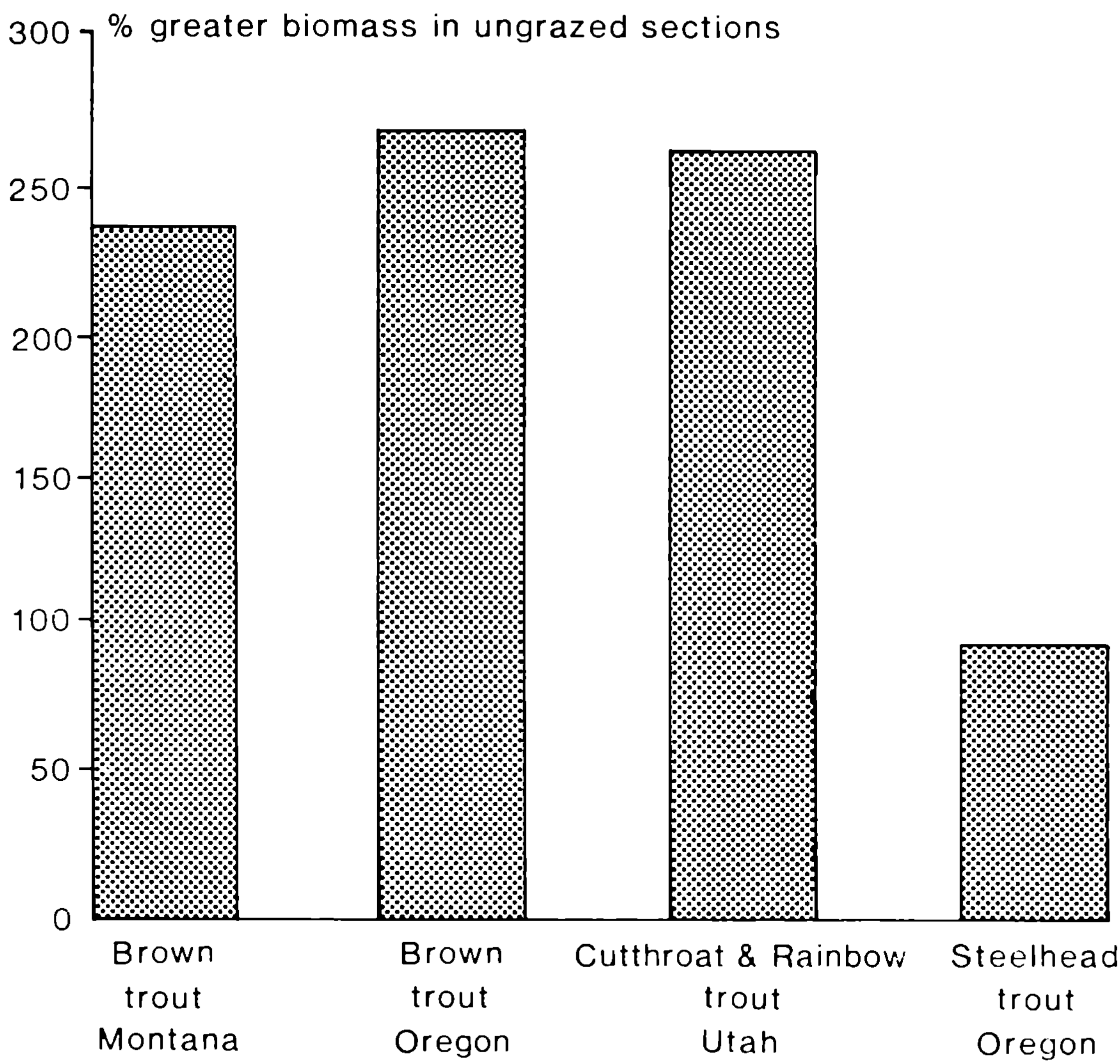


Figure 11.2 shows data on trout populations from different land-uses in well-buffered upland streams in the UK, where acidity is not likely to influence populations. There have been very few studies published for UK forest streams so the data must be interpreted with caution. However, the probable influence of dense tree shade in reducing populations is indicated and it is interesting to note the figures for open forest, which, although derived from only two samples at one stream, do suggest that populations may be at least as high as those of moorland streams (sample size 70 streams).

Figure 11.3 shows some data from the USA (Hall and Baker, 1982) and shows much larger trout biomasses in ungrazed compared with heavily grazed sections of rangeland streamsides. Such differences may not be so great in the UK where the concentration of cattle upon the river may be less pronounced due to our wetter summers, but it is likely that trout populations will benefit from the cessation of grazing on land which has previously been heavily grazed. An American study by Hubert *et al.* (1985) demonstrated the habitat changes

Figure 11.3 Effects of grazing upon trout populations (from Hall and Baker, 1982).



which resulted from excluding grazing animals by fencing. A rapid increase in vegetative growth occurred, which resulted in narrower, deeper channels with greater amount of overhanging vegetation and shaded channel area. Channel changes occurred in 4 years and the trout populations took slightly longer to respond to them. There is, surprisingly, no published study which investigates this process in the UK, where afforestation following the *Forests and water guidelines* may be expected to produce similar benefits to fish habitat, at least on land which was formerly heavily grazed.

Grazing at moderate levels may often be desirable to conserve floral and faunal diversity in river valleys and streamsides which are retained unplanted. Therefore it is desirable to know the effects of grazing at different intensities upon the aquatic and terrestrial habitats so that managers may select an appropriate regime to meet their local objectives.

The future management of the complex of edge habitats that comprise streams and their riparian zones will need to be based upon an evaluation of the current status and the potential of the habitats present, with clearly stated objectives. Although for any given site a local assessment would be required, some broad priorities and guidelines may be suggested from existing knowledge and from general conservation principles.

These would indicate that relatively undisturbed river corridors, with a more natural vegetation and a channel morphology that is not radically altered or degraded by past management, will have higher conservation value. Almost all forest streams are relatively undisturbed compared with engineered channels in arable lowland farmland, but nevertheless the heavily shaded streams in plantations have been reduced in wildlife value compared with more open streamsides. Broadly speaking then, the emphasis for unshaded first rotation streams should be to conserve, while in previously shaded streams, rehabilitation and habitat improvement should be the main aim.

The potential wildlife resource depends upon the type of stream. Generally the larger streams in flat flood plains have the largest influence upon the surrounding land and the greater variety of features peculiar to streamsides. They therefore have potentially the greatest wildlife value. However the actual wildlife value may be low due to past management and indeed, because of their inaccessibility, deeply gullied stream corridors often have been less modified by past management both agricultural and silvicultural, and have greater current wildlife interest than the low-gradient sections downstream.

Table 11.1 is an attempt to allocate priorities to a range of possible management objectives for various stream types and for shaded and unshaded situations.

Research priorities for managing riparian edges

As always, many topics can be identified where more knowledge is desirable. I have confined myself to listing some of the ones which I believe are most important. These are as follows:

1. Basic ecological research

   The influence of light and shade and temperature upon all trophic levels in streams, especially primary producers.

2. Applied ecological research

   a. Long-term changes in the vegetation of unplanted riparian areas in relation to width and management, especially grazing regime.

   b. Fish populations in relation to riparian vegetation type in well-buffered streams and the response of fish populations to felling shaded streamsides.

   c. Development of riparian and aquatic vegetation after felling a shaded streamside.

Table 11.1 The importance (ranked A, B, C) of various objectives for wildlife in relation to stream type

Type of management objective	*Planted shaded streamsides	*Open unshaded streamsides	Boggy headwater stream	Gullied high gradient upland streams	Low-gradient stream meandering/ braided
Evaluation of habitats and selection of boundaries of riparian management zone	C	A	B	B	A
Conservation/enhancement of non-woody semi-natural vegetation and associated fauna	C	A	B	A	A
Planting trees and shrubs in the riparian management zone	A	B	C	B	A
Ensuring a long-term supply of large logs in riparian areas and channels	B	B	C	B	A
Restoration or improvement of physical habitat on banks and riparian management areas	A	C	B	B	A
Restoration or creation of desirable plant assemblages	A	C	C	B	A
Manage stream channel to improve fish and other wildlife habitats	B	C	NIL	C	B

*'Planted' means plantations established close to banks eliminating most ground vegetation
'Open' means managed approximately in accordance with current Forestry Commission guidelines

3. Methodology

   a. Classification and evaluation of site types and vegetation.

   b. Simple monitoring techniques which can be applied by forest managers.

4. Physical processes

   a. Assess changes in channel morphology through the canopy closure, clear felling and restocking phases.

   b. Model of stream temperature and sunlit period using vegetation and site variables.

Of slightly lower importance or dependent upon the answers to the research listed above would be basic research such as:

c. The habitat preference of aquatic invertebrates, riparian invertebrates, bats, birds, small mammals:
    i. specialists;
    ii. species partly dependent on riparian and aquatic habitats.

d. The dynamics and influences of large woody debris in streams and flood plains.

e. Evaluation of management techniques to manipulate riparian and stream habitats, for example:
    i. experiments to test methods of streambank stabilisation and restoration (willow/*Carex*/ planting, etc);
    ii. experiments to restore semi-natural vegetation to felled riparian areas.

f. Manipulation of stream channels to increase habitat diversity for fish and invertebrate fauna. For example, construction of log weirs to create pools.

Conclusion

In the last two decades the high ecological value and integral nature of streams and their riparian zones have been increasingly realised and studied by ecologists and wildlife managers worldwide. A high concentration of 'edge' occurs naturally and this permits a wide range of plants and animals to thrive.

The management of streams and their adjacent land for wildlife conservation and other objectives as well as wood production is now being actively pursued by forest managers in the UK. At present this management is based largely on empirical guidelines, and these now need to be tested and refined to enable more specific guidance, which has been validated by research, to be given to managers.

A number of issues are priorities for research, including basic and applied ecological research, modelling of physical processes and the development of techniques of inventory evaluation and monitoring which can be used by forest managers.

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Paper 12
Some Economic Factors in the Long-Term Maintenance of Edges

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Abstract

A survey of ride management practices and costs within east England was carried out in 1988. This revealed high costs and a number of shortcomings in current management regimes. The survey showed that ride mowing regimes were not always suitable to meet particular conservation objectives and highlighted the need for research into optimum timings and mowing frequencies. Shrub edge cutting was also found to be unsuitable in some cases, and longer cutting cycles are suggested as a solution. Inadequacies of currently available cutting machinery were noted. The costs of ride management, and the backlog of shaded rides requiring widening, confirms the need for more research and establishment of model regimes.

Results

In an attempt to stimulate discussion on the research and development of both cost-effective and conservation-effective ride management practice and machinery, an estimate of current ride management costs and quantities with the Forestry Commission's East England Conservancy was gained by means of a questionnaire survey of Forest Districts in late 1988.

Conservancy estimates of quantities and costs, excluding the New Forest District, revealed that ride length totalled 4 650 km, of which 860 km (19%) was of designated or high conservation value. The management survey showed that 1 800 km (39%) of the total ride length was mown annually. The cost of this mowing in 1988 was estimated to be £28,400, or £15.6/km. Of the 'conservation' ride length, 450 km (52%) was mown annually. However, on none of this was the cut material removed. The estimated total shrub edge length was 1 300 km. Annual flailing was undertaken on 315 km (24%), at a cost of £16,000 or £50/km. It was estimated that there was in excess of 350 km of 'closed' ride length requiring initial widening. It was found that only 50 km of ride length was widened annually, where edge trees were removed or scallops created.

Almost all current ride mowing, including that of 'conservation' rides (19% of the total), takes place between September and November. It is difficult to see what benefits this practice would have for floristic values, particularly as very little, if any, cut material is removed. Dominant grasses and bracken, *Pteridium aquilinum,* are likely to be encouraged by such practice, due to nutrient enrichment, even more than no mowing at all. The general view, endorsed by comments made during the survey, suggests declining conservation values over the last decade or so. During the 1950s and 1960s, resources for mowing appear to have been far greater, with the result that rides were mown more frequently during the year. Mowing was carried out at least twice, including a summer cut, often for hay. Such practice is more akin to traditional hay-meadow management, where maximum biomass is removed during July, as this is more conducive to maintaining low nutrient status and floristic diversity.

Approximately 50% of 'conservation' rides are mown annually. This would suggest that most are cut, at the least, every 2-3 years. This may be detrimental to the ride flora, particularly if no cut material is being removed, but the interval may also be too frequent for woodland-edge butterflies, and these are usually an equally important management objective. Important butterfly food plants such as violets, vetches and peas etc. require either semi-shade or 3-4 years in which to develop and flower. Exceptions to this are the blue butterflies, which generally require very short vegetation and high ground temperatures that encourage associated ant species.

The results from this survey relating to shrub cutting on ride margins indicate a 3-5 year cutting cycle. This may be ideal for certain plant and invertebrate species, and for tractor-driven machinery, but may not be suitable for certain key bird species. Recent research has indicated that dense coppice growth of 6-8 years' age is ideal for nightingales, *Luscinia megarhynchos,* and probably also for *Sylvia* warblers, such as the blackcap, *S. atricapilla,* and the garden warbler, *S. borin.* This cutting frequency may also be too short for butterflies dependent on violets, which thrive in semi-shade. However, so far as birds are concerned, forest boundary edges are probably of more value than internal ride edges, possibly because they tend to be wider and of more diverse age structure and provide nest sites for species that forage on adjoining farmland.

Remarks made in questionnaire returns highlight inadequacies of current flail machinery, particularly with regard to its reach. Numerous management recommendations have suggested that shrub edges should be taken back to the crop side of rideside ditches. However, this can only be contemplated if either there are pre-existing shrubs present, or if crop edges are removed first of all (usually at least two rows for the creation of scallops) and shrubs established thereafter. Many diverse shrub edges have not responded after cutting due to crop shading and have consequently been lost. Growth rates of this linear shrub belt will, of course, vary with site conditions, and coppiced edges may additionally need protection from deer browsing.

The survey revealed that 'closed' shaded rides were being opened up at a rate of 50 km/yr. With estimates of the extent of these overgrown rides indicating a total of 350 km, a backlog of 6 years work is suggested. With recruitment of further rides during this period, this would appear to be an ongoing task. In most forests, widening can be done at first thinning, but if this is delayed, or if the crop species grows particularly well laterally and casts heavy shade (i.e. beech, *Fagus sylvatica*), this needs to be done earlier as a separate operation.

Recommendations

A number of recommendations can be made in the light of these findings. Firstly, on conservation rides, resources should be redirected to more timely and less frequent mowing, and with removal of the cut material. For example, a May cut might be essential for maintaining plant species richness. Optimum cutting regimes need to be worked out for particular rides and conservation management objectives. In the absence of such prescriptions, particular ride sections should be cut in rotation on a 3-4 year cycle and the cut material removed, if necessary by hand raking. There is also a need for research to examine the potential of cultivation and turf stripping, to see if such techniques have a role to play in maintaining diversity or restoring valuable flora. The wider use of machinery such a forage harvesters that are capable of cutting and removing or collecting material in one pass should be investigated.

Shrub edges should be cut in sections on a 6-8 year cycle, except for sites with particular management objectives that would be better met by alternative regimes. The current, usual practice of flail-cutting shrub edges on a 3-5 year cycle is determined more by machine capability rather than conservation requirements. Clearly, a 6-8 year cycle would require heavier machinery, which could also operate off the ride within widened edges and scallops. If there is insufficient shrub width, removal of crop edges is a prerequisite of attempting to relocate the shrub edge, cropside of the rideside ditch. A depth of about 5 metres in width is required to prevent detrimental shading, although this varies according to the crop species involved. In east England, plantations of beech are particularly damaging to rideside shrubs.

The ideal time for ride widening and scallop creation to take place is at first thinning, provided that this occurs at due time. If delayed thinning of young crops is anticipated, then ride widening and scalloping should be done as a separate operation as soon as saleable material is evident. In any case, this should not be carried out later than normal first-thinning time if windblow problems and detriment to conservation values, are to be avoided. When widening is undertaken, it should be bold enough to alleviate any need for subsequent widening through the remainder of the rotation. This normally means an average ride width of 20 metres, or wider where edges are taken back to stable elements or to expose features of value.

Ride management prescriptions which are given at present are based partly on research and partly on intuition and experience. These should be refined in due course, and model regimes for different soil and site types should be provided. There is currently no consensus regarding the optimum timing of ride mowing, or the effects of removing cut vegetation for particular site types, and urgent guidance is required. In general, more attention needs to be given towards ride management activities, as large costs can be involved.

Discussion

P.R. Ratcliffe: There are two main issues to be addressed in the course of this discussion session; namely, management recommendations, and the direction of future research. Despite some concern on the part of many speakers, we do have a lot of information available. Although some of this is not based on research, much is based on sound ecological principles, and there is a generally held view that the implementation of these ideas will be of benefit and not detrimental. In terms of why we are managing edges, this is now fairly clear. Edges are either managed to enhance structural diversity or variety, or secondly to encourage taxa, groups, or even single species. I believe that we can put together some form of package which is a general treatment, which can be overlain with the particular requirements of rare or sensitive species, where this is necessary. Although Forest Managers are very good at implementing management recommendations, they are often less good at monitoring the impact of what they have done. I think this is essential, and how to do it needs addressing.

C.I. Carter: Should Forest Managers put aside money within their budgets for monitoring the effects of ride management, instead of spending money on operations themselves?

F.A. Currie: Ride widening and scallop creation is now an accepted part of the first-thinning operation, and it is not a cost to the conservation budget. It is only on important sites that are in danger of being shaded out that it is necessary to undertake widening at an earlier stage.

P.R. Ratcliffe: It is sensible not to deal with the enormous backlog of shaded rides, and simply concentrate instead on the best sites, these east west rides and so on. Having done that, we must build into the cost of management something for the monitoring.

T. Yates (ITE Monks Wood): For monitoring, something that is very cheap, very quick and very easy to do is fixed-point photography. I use the technique myself when monitoring the butterfies in Monks Wood, taking photographs in April and July. In the 13 years over which this has been done, big changes on rides have shown up, including the vegetation itself.

P.R. Ratcliffe: Do we actually require more information than that; for example, is it necessary to monitor invertebrate density?

K.J Kirby (Nature Conservancy Council): You suggest that some form of more intensive monitoring is needed. However, even if all ride management was accompanied by a photograph before and after the work was done, and even if not from precisely the same point, it would still give a very useful overview of what was occurring. It only requires a camera in the tractor cab when mowing or cutting is taking place. The NCC use fixed-point photography quite a lot, and everyone is encouraged to take general habitat shots during any operations on site.

P.R. Ratcliffe: If we consider that monitoring is vital, then photography is a most cost-effective method.

M.A. Anderson: The FC Micheldever plots have been photographed using a form of standard position, with marker stakes fixed in the corners of the viewfinder, but I am not convinced that the technique works. It is relatively easy to get repeatable photographs, but very difficult to interpret them in a way which could be published.

M.S. Warren: There are still a number of unanswered questions. In terms of the frequency of ride cutting and the timing, there are no experiments being set up anywhere , as far as I know, which involve a replicated trial of different types of cutting. Different options need to be tried within the same area. It would be useful for ecologists to go and look at the effects of a particular treatment, perhaps 5 or 10 years after being carried out. Monks Wood is quite a good case study because ride-widening was undertaken some time ago, specifically for conservation. Initially, the effect was very beneficial for the few species that were monitored. Butterflies responded well in the first few years. Not much management has been done since this initial widening, although the rides are still cut in the autumn and raked. In the past few years butterfly diversity has actually been declining and species are being lost. This is worrying because this is a National Nature Reserve where some ride management is being deliberately undertaken, based on the best information available, and quite clearly it is not working for many species.

G.P. Buckley: There is a need for long-term research. It must be especially difficult for the entomologists due to big seasonal variations, which mean that any levelling-out would only be observed over a long period of time. There is a similar problem when studying seed banks, and long-term monitoring will be required in order to see any trend through the seasonal variation.

P.R. Ratcliffe: We can set up research studies, and then continue low-cost monitoring every 3-4 years, but there is no guarantee of continuity. We need a long-term strategy which is more watertight.

D.S. Prigmore (University of East Anglia): Much research that is done is not reaching the managers and there is limited research on grasslands. Many plantations are not on woodland sites but are on grassland, heathland or former agricultural land. Sometimes it might be necessary to extrapolate from work done on other habitat types, e.g. grazing. A lot of grazing research is being carried out, especially in the Netherlands. It may be possible to extrapolate, provided that the communities are similar and dominated by the same rank grassland. The difference may be in the seed bank composition, and incoming propagules, and the resultant vegetation.

D.A. Greig (Forestry Commission): If we are interested in structural diversity, is there a better way of achieving this than by working with internal edges? All suggestions made today have either been complicated, or rather unattractive in terms of the internal landscape of the forest. Should we not be looking at restructuring the forest to obtain structural diversity? Perhaps researchers should be promoting change of forest structure by more radical work, because the reason edge management does not get done is that managers find it difficult to implement a complicated plan. It might make sense in an NRR or an SSSI but in most forests a different set of requirements have been arrived at. If we are seeking to achieve structural diversity to benefit wildlife, is it better to achieve that by working on the edges of rides and roads, or by more fundamental work inside the forest, making it more exciting and diverse?

P.R. Ratcliffe: If a ride layout already exists then there are benefits from managing those rides rather than others elsewhere. If we are faced with something that has been created from new then maybe we have been too constrained by what is already there. Perhaps we should be cutting one-hectare chunks out of our beech plantations.

R.J. Fuller: From an ornithological point of view, ride edges have only a limited role to play in enhancing bird diversity in the context of the whole forest. There is a big research topic that deserves exploration, ornithologically, in terms of stand treatment, such as manipulation of thinning regimes and harvesting processes that could maximise benefit to bird populations. Forest design, in terms of the development of certain types of compartment, internal edges between stands of different ages, would be worthy of research. These stand manipulations might well do more to enhance bird diversity in the long term than focussing attention on what is a very small proportion of the forest area.

K.J. Kirby: It may be necessary for conservationists to change their attitudes. One reason why most of the best butterfly sites now are commercially managed plantations is because conservationists were not perhaps brave enough, or did not have the resources, to manage semi-natural woodland as hard as it should have been in the fifties and sixties and perhaps even today. There are likely to be some sites where it is better to take risks and make large changes, in the hope of success. It will probably be successful for many species and groups but may not work for everything.

P.R. Ratcliffe: Is it possible to establish guidelines from the old examples which have been successful?

M.S. Warren: It is complicated and many factors are involved. In general, the prime sites in commercial forestry plantations which are good for butterflies and, we suspect, for other invertebrate groups, tend to be large forests of uneven age and are often managed for pheasants. Equally, there are other commercial forests which have lost 20-30 butterfly species over the post-war period. What characterises these sites is also unclear. On the whole, they tend to be even-aged, and none of them appears to have any ride management regimes. The better sites have good butterfly populations by virtue of their history, largely because they have had a sequence of holes knocked in them to make new plantations. What is worrying is that this phase has now ended and any future clearings will be on ex-conifer sites rather than ex-broadleaved sites. That is where the edges are likely to become crucial, because a clearing made in a conifer plantation will have very different effects on the flora and fauna from those made in the broadleaved plantation.

M.A. Anderson: Until today, I was rather of the view that it was not possible to formulate general recipes for ride management. For example, of the distances across rides that have been recommended today, all but two of the seven have been close to 20-25 metres. There are generalisations coming out and we are near enough to undertake the fine tuning now needed.

P.R. Ratcliffe: I hope that managers can see that there are trends appearing which have a body of opinion behind them. We can tell the manager sensible things based on the information that we already have. In the past we have looked only for opportunities where managers have already been doing things and tried to superimpose some experimental design on top of this, and that is not the best way to lay down experiments. We ought now to be thinking more widely.

R. Ferris-Kaan: Whether or not we prefer the idea of managing forest interiors more than edges, it is true that managers, particularly in the southern lowlands, are enthusiastic about edge management. It would be wrong of us at this stage to suggest that it is no longer the thing to do. We need to tackle the problems and answer the questions that they are putting to us.

G.S. Patterson: Since most of us have talked about general prescriptions with regard to structural diversity, particularly of the shrub layer, the first thing we need to do is to attempt to measure the effect of a few different combinations of structure. This should concentrate on the shrub layer: the quantity and density and their impact on a reasonable range of taxa.

P.R. Ratcliffe: An important question and one that is likely to worry the manager is how to cope with the more invasive species. We have seen a number of examples of early seral stages doing great things for a number of taxa and then the whole value declining badly. How do we deal with invasive species such as *Deschampsia cespitosa,* bramble, and bracken, and how do these plant communities change over time? When these flushes of bracken, or nettles, or thistles occur, perhaps 2-3 years after rides have been opened up, are they likely to be transient? Are we becoming too alarmed or will they simply disappear again?

K.J. Kirby: I hope that in many cases they will disappear, that they are transient phases. The problem is that we are trying to maintain artificially what would usually only survive in the first 2-3 years on one site, rather than deciding simply to recreate that set of conditions somewhere else to keep the cycle going. These changes over time are important and edge management only becomes worthwhile if it is done over a large enough area. If you try to concentrate on too small an area then you become a gardener.

M.S. Warren: One of the problems of invasive species is that if the management of a piece of woodland is changed then invasive species will inevitably occur as part of the succession. What is interesting on rides, albeit theoretical, is are we looking at a plagioclimax which is, or will become, stable? Alternatively, are we really interested in creating a whole sequence of seral successions in the edges? It may be necessary to set up experiments whereby different cutting regimes are examined. May cutting that has been proposed may result in *Deschampsia* not being a problem. Many of the problems that we are seeing are because the same thing has been done in so many places.

P.R. Ratcliffe: Much depends on objectives: what are we managing for? If we are managing for a butterfly that depends on violets then we have to maintain the violets and would probably go to great lengths to do so. If we are managing more generally in terms of diversity, the sort of recipes given in the RSPB's *Birds and broadleaves* book, where the management of perhaps 10% of the ride system per year is proposed, are more appropriate. This would result in different seral stages over this 10-year period.

M.S. Warren: There are probably species that are adapted to the seral succession but also species that are adapted to the plagioclimax. We need both approaches. Woodland grassland could be described as the plagioclimax in many cases and a number of species are associated with it.

R. Ferris-Kaan: This is not always the case and herbicides may be necessary as an alternative to cuting regimes under some circumstances. Their use should complement cutting. Perhaps management regimes could comprise an autumn cut followed by a spring application of an appropriate herbicide. Growth regulators could be used to suppress rank vegetation, to allow smaller herbs to get a foothold.

K.J. Kirby: Bracken could be permanent and is a species for which the use of herbicides might be appropriate. But, we do not yet know enough about how herbicides might affect other members of the community to use them more widely.

M.A. Anderson: Bracken and bramble may not be invasive at all and may have been present all along. The problem is that there may be one species that grows rapidly in the spring or early summer and then smothers anything else. It is for this that the herbicide should be used, not the invasive effect per se.

D.S. Prigmore: We ought also to consider disturbance such as ploughing or rotavation.

C.I. Carter: There are some very practical operations in the forest that are already producing disturbance. Disturbance caused by thinning racks, stacking areas and the scarification on ditchbanks, will achieve the same ends. New seed beds will be created, more open areas will result and regeneration in these areas could be monitored as well as, or instead of, setting up new experiments.

R.C. Welch (ITE Monks Wood): It does happen that, on visiting a wood with a forester to discuss past management, there are no proper records. We need to keep records of what we do, however insignificant they appear at the time.

P.R. Ratcliffe: It depends very much on the individual forester and it is up to us to tell them what sort of records they ought to keep. We do have a function within research to give advice on the sort of information that should be collected and how this should be done.

R.C. Welch: A particular type of monitoring will often only continue as long as there is an interested member of staff, but as soon as they leave it lapses. Someone may think of it later if they are able to find the plots, let alone anything else.

M.O. Hill (ITE Monks Wood): One of the things that we have skirted around is the question of objectives. As a research topic we want to be able to say what comprises a good edge or a bad edge? Where are we failing and where have we succeeded? It is necesary to make this type of evaluation in order to give accurate prescriptions.

M.S. Warren: I usually work to clearly-defined objectives such as the conservation of a particular rare species on a site.

R. Ferris-Kaan: It is harder when a manager asks for a definition of a good site for a number of species, especially where these are from different taxonomic groups. It can be done in general terms, but when we are comparing sites of widely differing characteristics we need to know more about land-use history, soil types, and various physical factors.

R.J. Fuller: There are not really all that many groups of plants or animals associated with, or critically dependent upon, rides that we would regard as being national rarities, apart from some butterflies and other invertebrates. If we were trying to adopt an experimental approach shouldn't we focus on those species with the greatest national conservation need? We could couple this with autecological work, so that we can look at the ecological requirements and establish what features of a ride are important.

K.J. Kirby: The chances are that these rare species will not occur on the vast majority of sites. What the managers are looking for are the general prescriptions to implement. If we have a rare species site then obviously more help will be needed but what can we do in more general situations?

G.S. Patterson: From an upland perspective, we have perhaps become too concerned with a particular species or very small-scale manipulation. In the uplands there is generally less potential for species diversity and we ought to be more concerned about structural diversity on a broad scale, for scale is important. Are we really able to do something significantly useful on a 20-25 metre wide edge? Ought we not to concentrate on large, more generous and perhaps fewer, permanent edges along streamsides and wide ridesides, where there might be a chance of a developing assemblage within a larger mosaic? The species may not be particularly attractive in themselves but their occurrence in a mosaic will provide this structural diversity.

D.A. Greig: The general prescription is interesting but we will need to keep it simple for people to implement it. It may be possible to base prescriptions on management which is done for very different reasons. Another aspect is to look at the opportunities when a manager needs to intervene in a forest. There are three of these: at planting/restocking; at the time of first thinning — which may be the only opportunity in a 25-year period; and at clearfelling. We should focus on these points of action and give suitable prescriptions. For specific sites and important species, more detailed research and advice is needed.

E.A. Simmons (Wye College): There are a broad range of plantations which are coming up to first thinning. Are we missing an opportunity if we do not take advantage of the availability of often extensive ride systems on which to do some of this range of treatments?

G.P. Buckley: This idea of having a set-piece management regime is fine, but there are many places where, for example, there is a large population of roe deer and the outcome is affected by their presence in the wood. Trying to give a general management prescription will be different with or without deer and we will be constrained like this on every side. These need to be set aside before any general management prescriptions can be given.

P.R. Ratcliffe: We could give the general prescription first and then restrict it by saying that if roe deer are present then the changes will go in this or that direction. Generally, grazing can have high impact, even at very low densities. For particular plant species which are sensitive to roe deer pressure, such as *Salix*, then almost certainly fencing will be necessary.

R.M.A. Gill: There are some food plants of deer which are almost invariably taken, such as bramble and rosebay-willowherb. Everywhere they will be affected by roe deer browsing, but there are many other species which may be very important to certain insects but about which we know very little as to how they are affected by deer, and exclosure experiments would help elucidate this.

M.A. Anderson: What about machinery? For example, cutting machinery for different regimes requires a different research effort. It is not always possible for machinery to cross the road or rideside ditch. How is the development of machinery taking place?

P.R. Ratcliffe: Another crucial problem is what to do with the litter. As ecologists we quite simply say that this litter must be removed but this advice to the manager is a problem because cutting is cheap, but removing the cuttings is very expensive. Therefore, we do need to get involved in operational research.

M.A. Anderson: Is there a machine that will do both jobs at once; cutting a small space and then removing the cuttings?

F.A. Currie: Yes, a standard forage harvester, but we may need to develop specialised ride-mowing machinery. Coupled with machinery, a secondary consideration is that of markets for the cut, low-diameter and mulch material. It is all really linked with restoring old coppicing regimes.

R. Ferris-Kaan: One point which seems clear is the need for a study of ride cutting regimes, by way of a replicated trial rather than the piecemeal work underway at the moment. It is tempting to use existing opportunities simply to cut costs, but that may not always provide the most useful information.

P.R. Ratcliffe: The objectives of the meeting were to bring together a body of information, ask questions about what research ought to be done and examine whether we have enough information to make recommendations to managers. I believe we have achieved those objectives and today has been a very useful communication exercise. We now know who is doing what, and opportunities of collaboration in research are brighter; the need for more research is self-evident.