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Linear features: linear habitats and wildlife corridors

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Linear features: linear habitats & wildlife corridors

by

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PREFACE

This report on linear features was prepared for English Nature (EN) during 1990-91 as part of its Commissioned Research Programme at the instigation of George Barker. It is one of a series of inter-related reviews looking at issues connected with habitat fragmentation and how any deleterious consequences for wildlife may be overcome. Further information on EN's Habitat Fragmentation Study Programme can be obtained from:
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SUMMARY

1. Semi-natural vegetation in the British countryside, particularly in the lowland, is patchily distributed in a matrix of intensively managed agricultural land, urban areas and commercial plantations of introduced conifers. Connecting these remnant patches are linear features of different sorts, hedges, streams, road and railway verges.

2. Linear features have a value for conservation both as habitat in their own right and as potential wildlife corridors. In addition these features provide environmental benefits in both rural and urban situations, such as reducing soil erosion and pollution. They have considerable landscape importance and much potential for recreation and education, particularly in urban areas.

3. Habitat destruction and reduction in the size of surviving patches lead to reductions in species richness, the creation of new "edges" with changes to the composition and structure of plant and animal communities and reduced movement of species between patches with consequential potential loss of genetic variation. Maintaining or creating linear features to link habitat patches may help to offset some of these effects but is not a justification for permitting further habitat loss.

4. A wide range of studies have established the importance of linear features as wildlife habitats and their potential to act as corridors for species movement. It is however often difficult to prove that in a particular situation corridors are absolutely necessary for species movement to occur (as opposed to merely facilitating spread). Corridors may permit the spread of undesirable species, diseases and disturbance such as fire. Linear features may also act as barriers to movement, particularly some man-made structures such as roads.

5. Planning and management of linear features must usually take account of their value for recreation, in the landscape, for shelter as well as for wildlife, but there is much scope for combining objectives. Models of good management for different types of feature are illustrated. The emphasis in such models is usually on maintaining a variety of structure and composition in the habitat, taking account of the landscape pattern within which the stream, forest ride or road verge exists.

6. Nature conservation in future will depend on better management and integration of whole landscapes, not just nature reserves and special sites. More research is needed into how linear features function both as habitats and as corridors if we are to make the best use of them in countryside planning.

1. LINEAR FEATURES

Introduction

Human impact on the terrestrial environment has resulted in an uneven, heterogeneous landscape composed of artificial features and remnant patches of natural or semi-natural habitat. For example, rural landscapes have a very familiar and characteristic patchwork appearance, with fields, towns, villages and roads interspersed with plantations, woodland fragments, hedgerows, streams and rivers. Cutting across the landscape are motorways, railway lines and powerlines, which weave their way around towns and other settlements. Urban landscapes can be equally heterogeneous. Houses and roads are interspersed with small blocks of woodland, derelict land, various kinds of recreation grounds such as golf courses, gardens, cemeteries, parks, allotments, roadside verges, hedges, avenues of trees etc.

Semi-natural patches are valuable aesthetic features of the landscape and also provide habitats for a variety of wildlife. For some plants and animals, however, the patchy and fragmented nature of these habitats makes it difficult for them to disperse; some wildlife will be confined to a patch of habitat because the surrounding land-use makes it difficult to move about.

Linear features such as hedgerows, roads and roadside verges, streams and rivers, powerline routes etc, may be prominent and attractive features in both rural and urban landscapes. Some of these features, such as roads, can act as barriers and limit the dispersal of plants and animals. For other species, linear features such as roadside verges provide a permanent habitat or may be used as corridors for dispersing between fragments of habitats. It is however difficult to obtain data that clearly demonstrate the corridor function (Hobbs 1992).

Figure 1.1 Patches and linear features in the landscape

Linear habitats and wildlife corridors

Linear features such as hedges, riverbanks and powerline corridors have collectively been called by several different names, including buffer plantings, linear habitats, wild corridors, wildlife corridors, conservation corridors, wildlife links, travel ways, travel corridors, greenways, greenlinks, strip corridors and line corridors (see Forman (1983) and Forman & Godron (1986) for different classifications of linear features).

In this publication, the term linear habitats is used to refer to those linear features (whatever their origin or composition) in which species live more or less permanently. A wildlife corridor is used to refer to linear features that are used for migration and dispersal or otherwise act to link habitats in ways that reduce the isolation of populations. This definition is similar to that of Soulé (1991). Linear habitats and wildlife corridors may be the incidental result of changes in land-use, for example the strips of remnant vegetation left when surrounding land has been cleared; others are constructed for specific purposes (Table 1.1). Edges of woodland and indeed almost any kind of edge between one type of ecological community and another can act as both a linear habitat and a corridor, so many linear features could also be thought of as long edges.

Table 1.1 Examples of linear habitats and wildlife corridors

Terrestrial:	Aquatic:
Urban green-belts	Ditches
Windbreaks, shelterbelts	Streams, riparian habitats
Hedgerows	Irrigation channels
Railway linesides	Lake shores
Road verges	Coastal habitats
Pylon swathes, transmission line routes	
Strips of urban gardens	
Tunnels, underpasses	
Remnant woodlands	
Fences	
Forest ride verges	
Fire breaks	
Avenues of trees	
Buffer plantations	

Linear features vary tremendously in size, from ditches and channels, through hedgerows and motorway verges to long tracts of the countryside, as for example those left to facilitate the movements of elephants (Cox 1988).

Discontinuous patches of habitat and natural features that enable wildlife to disperse and migrate have sometimes been called ‘stepping stones’. There is a gradation between a series of ‘stepping stones’ and what might be thought of as a wildlife corridor. Indeed, some features may not be physically continuous. Hedges, for example, often have gates in them. Connectivity or the extent to which the linear feature is broken by gaps (Merriam 1984) has important implications, especially if it really is to function as a corridor.

The benefits of linear features

The general benefits of linear features can be grouped as follows:

1. Ecological, eg as habitats and routes for migration and dispersal of wildlife.

2. Environmental, eg effects on climate and as accumulators of pollutants.

3. Amenity, eg used for enjoyment, education and recreation.

The biological function of linear features as corridors has long been proposed, but surprisingly there have been few studies which set about to investigate whether or not plants and animals can and do move along linear habitats. There has been a common assumption that, because many linear features make good wildlife habitats, they are also used as corridors. Nevertheless for some plants and animals, linear features probably do have an important role to play in dispersal. In a world where natural habitats are steadily declining and becoming more and more fragmented and isolated this role may become increasingly important. However, some forms of wildlife are pests of agriculture, forestry and horticulture, and such pests may also inhabit linear features and disperse along them. Research on the role of corridors in conservation is continuing to expand (Mackintosh 1989; Hudson 1991; Saunders & Hobbs 1991).

In both rural and urban environments, linear features can provide valuable windbreaks or shelterbelts. The environmental benefits of linear features in urban environments have only lately been appreciated. Trees and other vegetation help to ameliorate climates and also accumulate dust and heavy metals.

Linear features also have an educational, recreational and aesthetic value. This is particularly so in cities and urban environments where, apart from parks, wildlife is very limited. There appears to be a growing concern for the conservation of wildlife in cities and more and more authorities (see Table 5.1) are beginning to include linear features such as greenways, urban green belts, hedges and riverside walks into their strategic planning.

Aim of the report

The aim of this report has been to review the literature on linear features and give a brief appraisal of their characteristics, particularly in relation to urban environments. The main part of the report begins with a brief summary of the effects of habitat reduction and fragmentation on wildlife. The functions of linear features are then considered from an ecological, environmental and landscape point of view. The last two sections review current management practices and the potential role of linear features in the future. A bibliography is included.

2. HABITAT FRAGMENTATION AND ISOLATION OF WILDLIFE

Losses

The damage to and destruction of natural wildlife communities throughout the world have caused much popular concern, in particular about the rate at which tropical forests have been destroyed (Whitmore & Prance 1987). This publicity is well justified but has perhaps drawn attention away from problems occurring in other natural communities. Losses of temperate woodland, for example, with consequent extinction of species, erosion and damage to watershed forests, have become a serious problem in many countries, including North America, Australia and New Zealand (Myers 1989a, b).

Largely as a result of man's exploitation, natural communities throughout the world are becoming progressively smaller and at the same time more and more fragmented (Repetto & Gillis 1988). This process of reduction, fragmentation and isolation has become known as insularization.

In Britain, reduction and fragmentation of natural forests commenced some 5,000 years ago, and now their much-modified descendants cover only about 1.3% of Britain's land surface and are mostly less than 20 ha in area (Roberts *et al.* 1992; Spencer & Kirby 1992). A typical pattern of fragmentation is shown in Figure 2.1 and has become a common feature of the landscape. The process of reduction, fragmentation and isolation applies equally to many other habitats; the changes for heathland have been particularly well documented (Figure 2.2). Similarly about 95% of natural lowland grassland has been converted to other uses (Ratcliffe 1984).

Figure 2.1 Fragmentation of woodland in Warwickshire (redrawn from Thorpe (1978) in Hawkes 1978)

(a) In prehistoric times the landscape appears to have been predominantly wooded (...) but with some scattered clearance particularly associated with major river valleys.

(b) By c1086 AD the pattern had reversed with a mainly cleared landscape but still with some subtantial blocks of woodland.

(c) By 1960 woodland cover had been reduced to small isolated fragments.

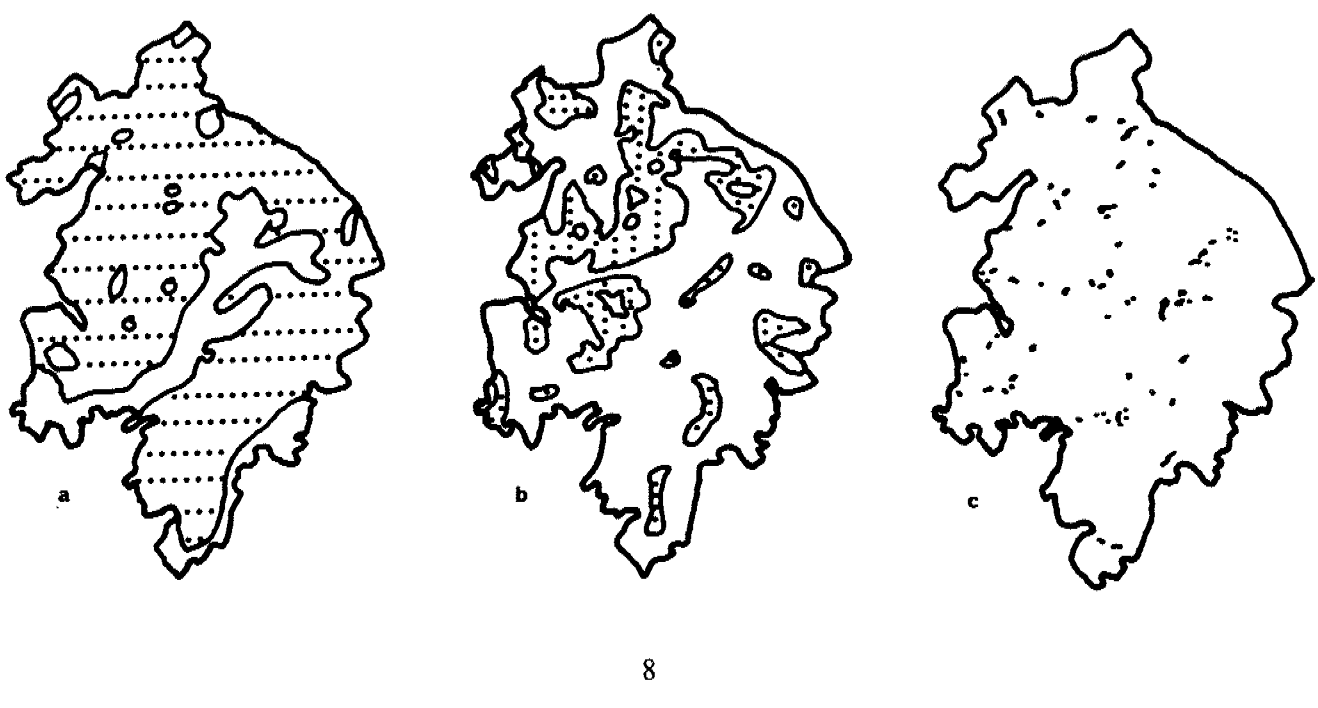
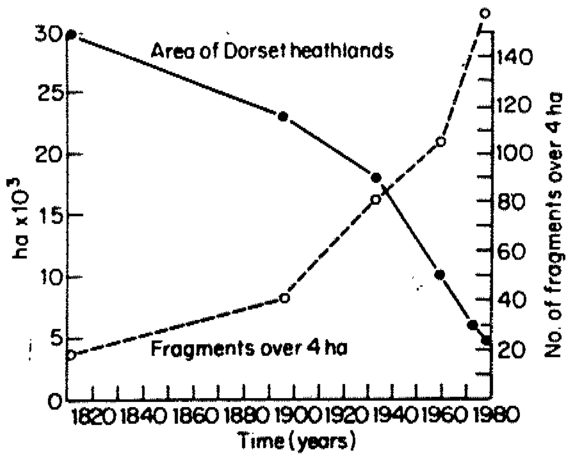


Figure 2.2 **The decline and fragmentation of Dorset heathland** (Based on data from Moore (1962) and Webb & Haskins (1980)



Effects of habitat loss and fragmentation

The effects on wildlife arise from three main causes: the loss in area of habitat, the changes in physical conditions around the edge of the fragmented habitat, and increasing distances between remaining 'island' fragments.

Reduction in habitat area generally results in a decrease in species richness. Smaller populations and fewer species tend to be found in small than in large fragments, as shown for example for plant species of both upland and lowland forests in North America (Dunn & Loehle 1988), butterflies in woodlands in England (Shreeve & Mason 1980), mammals in North American National Parks (Newmark 1986), mammals in Australian forests (Bennett 1987), primates in rainforests of the Amazon (Schwarzkopf & Rylands 1989), and many birds (see for example Diamond 1973; Moore & Hooper 1975; Rafe *et al.* 1985; Ford 1987; Loyn 1987). Some of this work has been on real islands, some on habitat patches surrounded by a different 'hostile' habitat. Attempts to make comparisons between the species richness of pseudo- 'island habitats' and real islands have proved to be of limited use (Spellerberg *et al.* 1991). There is no single straight-forward explanation why more species tend to be found in larger patches than smaller patches, but a major contributing factor is reduced levels of resources in small areas. An additional factor may be the loss of 'key' or 'keystone' species, that is, those plant and animals species that are important in the ecology of many other species. For example, many grassland sites should be grazed to maintain their value, since if they are too small to support a flock of sheep (and other grazers are absent), the grassland will deteriorate. Sheep could thus be considered a key species, albeit in this case a domestic one.

Reduction in area of a habitat, whether as a result of roads, buildings or other changes in land use, creates new edges and causes changes in the temperature, humidity, light and other physical factors on the newly created edge. The new conditions on the edges will be favourable for some plants and animals and there are many species which inhabit edges of communities (see Yahner 1988 for a review). However, newly created edges, such as those caused by a new road, are unfavourable for other plants and animals, particularly those which inhabit the inner regions of the community. As a result of changes in physical conditions, some plants may not survive at the new edge and some animals may move away from it to find more suitable conditions. If the rest of the site is fully occupied already for that species then the population will decline, compared to the earlier state.

Fragments of once larger communities are surrounded by different land uses, and consequently the nature of the surroundings has an effect on the species composition of the 'island' fragment. On heathlands, for example, the species richness of beetles and spiders is affected by the type of surrounding land use such as whether it is used for agriculture, forestry or housing (Webb *et al.* 1984). Species moving in from the surrounding land, especially plants such as bracken and rhododendron, similarly cause considerable problems on the remaining lowland heathlands.

As well as immigration and emigration of plants and animals between habitat patches and the surrounding areas, the fragments of communities are subject to physical and chemical disturbance, depending on the nature of the surrounding land-use. Woodland and heathland fragments adjacent to urban housing developments, for example, are soon affected by many impacts including recreational activities (Anderson & Radford 1992), dumping of garden refuse and the accumulation of excreta from domestic animals. Fires may be more frequent and can result in almost total elimination of some plants and animals in the patch affected.

Habitat fragments have become more and more isolated from other patches of the same habitats, and for some species this makes it more and more difficult to move from one fragment to another. Overall, therefore, these species experience not only reductions in population size but also various degrees of isolation from other populations of the same species. Where the isolated populations are small they may be subject to genetic drift and inbreeding, which diminish genetic variability. They may become less able to adapt to changing environmental conditions. For example, some small cheetah and rhinoceros populations now show very little genetic variation indeed (Boecklen & Bell 1987; O'Brian *et al.* 1985). It is not clear how significant this problem is in practice for British species, compared with other threats associated with small populations, but it should not be ignored completely.

In summary, reduction in area and fragmentation and isolation may result in the following:

Reduced populations
Species extinctions
Immigration of species favoured by newly created edges
Invasion of habitat fragments by species from surrounding areas
Changes in community composition
Changes in number of species (species richness)
Isolation of some plants and animals
Reduced genetic diversity within species
Exposure to pollution and physical disturbance

Overcoming the problems of habitat loss and fragmentation

Habitat loss and fragmentation are the major problems resulting in losses of wildlife throughout the world. Those losses have been estimated to be in the order of several species a day (Prance 1991). Species extinctions occur not only in tropical regions but also in temperate regions. In Britain it is estimated that at least one plant species is lost from Britain each year (RSNC 1987), mainly as a result of habitat loss and fragmentation. This is despite considerable efforts to reduce the rate at which natural or semi-natural communities are reduced in area. As the remaining fragments become smaller, more and more species may be at risk.

Linear features such as hedgerows and streams may act as corridors for the dispersal of wildlife between habitat fragments, or as a series of stepping stones between one habitat and another. The potential usefulness of wildlife corridors for minimising the effects of fragmentation and isolation does not mean that further fragmentation of wildlife communities can or should be justified. There is still much uncertainty about where and what types of linear features are effective corridors (Hobbs 1992). Thus they should be seen as something that should be conserved together with patches, not as a justification for creating more and more smaller patches.

3. THE ECOLOGY OF LINEAR FEATURES

Classification of linear features

Linear features are a conspicuous part of the human-dominated landscape. Most are the result of man's direct or indirect actions, for purposes such as transport, boundary marking, shelters and barriers. Rivers and streams tend to be the only linear features in a natural landscape and even these are often modified for human purposes.

Forman (1983) and Forman & Godron (1986) classified linear features in two ways. The first system was based on the origins of the linear features.

1. Environmental resource corridors. These are naturally occurring linear features, for example stream corridors.

2. Remnant corridors. These result from disturbance in the surrounding matrix. Good examples of these are the extensive road verges of Australia which are often the only remaining native vegetation in the agriculturally-dominated landscape (Bennett 1988; Saunders & Hobbs 1989).

3. Disturbance corridors. Such corridors arise where there has been some form of disturbance along a linear strip, such as railways and powerline swathes through forests.

4. Planted corridors. Human planting of vegetation in strips has resulted in the formation of hedgerows and shelterbelts (and more recently in Britain of herb-rich grassland strips by roads and field margins).

5. Regenerated corridors. These result from the regrowth of a strip in a disturbed area and examples include hedgerows that have grown up along fences ('fencerows') and some urban green belts.

The second system of classification used by Forman & Godron (1986) was based on the structure of the corridor. Three major types were identified:

1. Line corridors
2. Strip corridors
3. Riparian/stream corridors

Line corridors are very much affected by the environmental conditions of the adjacent habitat, and experimental studies suggest that no species is completely restricted to line corridors. In many cases there may also be a great deal of disturbance to wildlife from within the line corridor itself, for example in the case of roads and railways. In general line corridors have no distinct interior environment and are therefore dominated by edge species.

Strip corridors are wider landscape features, and although there may be an edge effect on either side of the corridor, there is also an interior environment in the core. Examples of strip corridors could include wide woodland strips, wide powerline swathes and wide urban green belts.

Although strip and line corridors are categorised on the basis of their width, the effect of corridor width can vary according to which organism is under consideration. What is wide for a snail may be narrow to a fox.

Stream corridors or riparian corridors were described by Forman & Godron (1986) as bordering water courses and varying in width. Thus riparian corridors may also be considered as line corridors or strip corridors, depending on their width. In human-dominated landscapes, riparian corridors are often very narrow and sometimes totally absent. They are important in controlling water and mineral runoff and also tend to be rich in wildlife. The streams themselves are important corridors for aquatic and semi-aquatic wildlife.

The structural variation found across some different types of linear feature is illustrated in Figures 5.1-5.3.

Common types of linear feature

Hedgerows

These are narrow bands of woody vegetation and associated organisms that separate fields (Forman & Baudry 1984). A 'hedgerow network' or 'bocage' results from many hedgerows interconnecting. Such networks are a characteristic part of the landscape in many parts of western Europe. The ecology of hedgerows has also been reviewed by Pollard *et al.* (1974) and Dowdeswell (1987).

Hedgerows are often the result of planting but they may also be remnants of woodland or created by regeneration (Forman & Godron 1986). European hedgerows are largely planted, and documentary evidence has allowed some hedges in the UK to be traced back as far as 900-1,100 years. The composition of hedges is affected by certain local variations in soil, climate, landscape history and planting methods, but older hedges tend to be richer in species; this can be partly attributed to colonisation (Hooper 1970; Cameron 1984). Pollard (1973) has argued that remnant hedgerows are also generally richer in species, because such hedgerows were initially rich in woodland species and retain much of that diversity, although the original woodland has long since disappeared.

About 500-600 vascular plant species have been recorded in English hedgerows, which is an indication of their importance to wildlife (Pollard *et al.* 1974). In Ireland where only 5% of the land area is covered by forest and only 0.5% broadleaved high forest, hedgerows are estimated to cover 1.5% of the country (Webb 1988). Almost two thirds of Ireland's bird species nest in hedges. Other work includes studies of birds (Arnold 1983; Osborne 1984; Lack 1988), small mammals (Eldridge 1971; Boone & Tinklin 1988), and invertebrates (Cameron *et al.* 1980; Burel 1989) in hedgerows plus papers from the 1992 British Ecological Society symposium.

The hedgerows of the Great Plains in North America are almost all planted, but on the eastern side of the USA and in southern Canada, most are naturally regenerated and termed 'fencerows'. Fencerows are hedgerows that have formed where a fence is or was once present. Dispersal of plants along such fencerows is aided by birds. Work on the ecology of small mammal populations in the mosaic landscape of woodland patches and interconnecting fencerows of an area south of Ottawa, Canada, has been undertaken by Wegner & Merriam (1979, 1990), Middleton & Merriam (1981), Fahrig & Merriam (1985) and Henderson *et al.* (1985). They have established the importance of fencerows for movement by and as habitat for small breeding mammal populations. Johnson & Adkisson (1985) and Wegner & Merriam (1979) have also observed that certain bird species tend to fly along fencerows.

'Shelterbelts' are generally composed of several planted rows of woody plants. They tend to be isolated and protect farm buildings and livestock from wind and drifting snow. During a study in Minnesota, USA, Yahner (1983) found that small mammal species richness was greater in larger shelterbelts with complex vegetative structure. The importance of shelterbelts to wildlife management has been comprehensively reviewed by Johnson & Beck (1988).

Roads

Bennett (1991) identified the total 'road reserve' as consisting of the actual 'road' surface along which vehicles travel and the adjacent 'road verges' (or 'roadside'). Although the road surface is an alien and unsuitable environment for animal and plant species and therefore can act as a barrier to their movement and/or dispersal, road verges do have potential as habitat.

Road verges are constructed with the primary intention of providing such things as visibility for drivers at corners, areas for emergency parking, drains and soakways and structural support for the road surface (Dowdeswell 1987). They also have a role in the aesthetic appearance of the road. Their value may be particularly important to wildlife conservation in human-dominated landscapes (eg intensively-managed agricultural areas or cities), where they may represent a significant proportion of the available remnant or regenerated habitat. Interest in the wildlife value of road verges has resulted in a number of ecological studies concentrating on their value as areas of habitat (Way 1973, 1977; Free *et al.* 1975; Kelcey 1975; Reeve 1977; Arnold *et al.* 1987; Drake & Kirchner 1987) or as possible corridors (Getz *et al.* 1978; Haeck *et al.* 1980; Bennett 1990a; Arnold *et al.* 1991). Motorway embankments can be particularly important travel corridors as they tend to have fewer breaks or discontinuities (eg junctions, passages through towns) per unit length than normal roads do (eg Getz *et al.* 1978).

Railways

The ballasted road bed on which a railway track is laid is called the 'permanent way'. It is likely to act as a barrier to certain species, just as road surfaces do (eg Mader *et al.* 1990). However, railway embankments may provide valuable habitat (Table 5.2) (eg Suominen 1969; Way 1977; McNab & Pryce 1985) and possibly travel corridors for species such as roe deer (Chapman 1977). The importance of railways in providing dog foxes with corridors for dispersal in some cities (Page 1981; Kolb 1984) was thought by Trewhella & Harris (1990) to be less than originally suggested.

Powerlines

The effects of powerline (or 'transmission' or 'pylon line') swathes on wildlife have been examined by Schreiber *et al.* (1976), Schreiber & Graves (1977) and Anderson *et al.* (1977).

Other linear features such as dikes, ditches, canals, banks, stone walls etc are considered by Sinclair *et al.* (1967), Nip-Van der Voort *et al.* (1979), Healing (1980) and Arnold (1983).

Ecology of linear features

The main functional characteristics of a linear feature in a landscape, in an ecological context, can be listed as follows (after Forman & Baudry 1984):

1. corridor for species movement
2. linear habitat and/or refugia
3. barrier to species movement
4. edge influences

In the following sections these points will be examined and a summary of relevant research provided.

Corridor for species movement

Direct observations have been made of animal movement along a linear feature such as a hedgerow or road verge (eg Dover 1990; Johnson & Adkisson 1985; Middleton 1980) and studies involving radiotracking or mark/recapture techniques have provided other evidence for such movement (eg Eldridge 1971; Wegner & Merriam 1979). Table 3.1 includes other references to work where movement along some form of linear feature was thought to occur, although it was not the main aim of many of the studies to examine species' movement along corridors.

Animals, when travelling along linear features, may be either moving within a home range of territory (performing normal activities such as food gathering and caring for young) or using it for dispersal. Dispersal can be defined in a number of ways. Macdonald & Smith (1990) described dispersal for animals and plants as 'any movement (excluding the short-term excursions undertaken by some animals) of individuals that takes them away from the sites they or their parents previously occupied (or in the case of some animals, away from their former home ranges)'. The short-term excursions excluded from Macdonald & Smith's definition of dispersal were categorised as a third type of movement observed in small mammals on road verges by Bennett (1990a) and were described as 'forays'.

In a study in Victoria, Australia, individual animals (an adult male long-nosed potoroo *Potorus tridactylus*, and a sub-adult male bush rat *Rattus fuscipes*) were recorded moving 1.1 km between two forest patches along a road verge (Bennett 1990a). It was also presumed that southern brown bandicoots and long-nosed bandicoots *Isoodon obesulus* and *Perameles nasuta* dispersed between forest patches in a similar way. Some species were resident within the corridor and dispersal movements between it and the forest patch were recorded. Other animals occupied home ranges that appeared to encompass portions of road verge and adjacent forest patches. Swamp rats *Rattus lutreolus* and male bush rats made 'forays' mainly during the breeding season, when they ranged widely from a home range occupied over the previous winter months.

None of the species that Bennett (1990a) studied were observed in the surrounding closely-grazed farmland fields. However other studies have found that fields may be used for movement. Dispersing foxes *Vulpes vulpes* for example tend to move in straight lines and may cross open fields rather than follow linear features such as hedgerows, whereas foraging or territorial foxes closely follow linear features (Harris & Woollard 1990).

Dispersal of plants may also result from the movement of animals along linear features. Much of the vegetation which has developed around fencerow-type hedgerows was initially a result of birds using the original fence for perch sites and thereby dispersing seed through their faeces. Blue jays *Cyanocitta cristata* were observed to routinely follow wooded fencerows when dispersing beech nuts *Fagus grandifolia* to their autumn caching site during a study in the USA (Johnson & Adkisson 1985). This behaviour was suggested to be a form of predator avoidance adaptation. The jays only selected the best nuts and dispersal distances ranged up to 4 km.

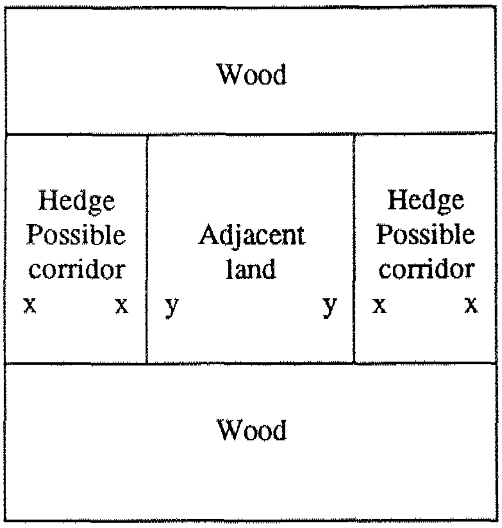
It has been difficult to show whether or not plants migrate along corridors. Indirect evidence based on the spatial distribution of species has been used to support the role of corridors but such variation may be attributable to environmental factors (such as soil and microclimate) rather than as a result of linear migration (Verkaar 1990). The conclusions from three studies undertaken on road verge plants along newly reclaimed polders in Holland (van der Toorn *et al.* 1969; Nip-van dr Voort *et al.* 1979; Haek *et al.* 1980), summarised by Verkaar (1990) are consistent with migration in that old road verges have more species than young ones; lower species richness was found for road verges more distant from the mainland; and some species appeared to benefit from traffic intensity.

Helliwell (1975) however concluded that 'woodland' plants do not readily spread along hedgerows, and this view was supported by Forman (1983). It was calculated that dog's mercury *Mercurialis perennis* spread vegetatively along hedges as slowly as 0.1-0.3 m/yr (Pollard *et al.* 1974).

Burel & Baudry (1990) hypothesized that if hedgerows were used by forest species as corridors to move into farmland then the frequency of the forest species would be related to their distance from the forest source. Preliminary results (Baudry 1984, 1988a, b) suggest that the number of forest species found in hedgerows is a function of hedgerow width and of distance from the forest source. However even these studies do not show that 'corridors' are <u>necessary</u> for or even that they facilitate movement of plants, only that it can occur within them.

Figure 3.1 Problems of identifying the level of movement along linear features

For species (a) the hedge acts as a corridor and is essential for movement; for (b) the hedge also acts as a corridor and there are conservation benefits from its existence as a connecting link although it is not essential for movement. For species (c) the feature does not function as a corridor - movement is as easy through/over the adjacent land. For (d) no movement occurs through either habitat. No conclusions about the value of the feature as a corridor can be drawn by sampling only in the corridor at x-x because movement will be recorded for all three species. Comparative data must be available for y-y to separate which species benefit from the existence of the linear features.



(a)

Corridor Adjacent land Corridor

x↓↓↓↓x y y x↓↓↓↓x

All movement in corridors

(b) (c) (d)

x↓↓↓↓x y↓↓y x↓↓↓↓x x↓↓x y↓↓y x↓↓x x xy yx x

Most movement in corridor | No difference in movement between corridor and adjacent land | No movement at all

↓ = species movement

By way of contrast, the transport of aquatic or riparian plant seeds along river corridors is very likely to be an important form of dispersal for plants. For example, the transport of seeds by water is apparent by the occurrence of arctic-alpine species growing by rivers far downstream from their typical rock ledge or flush communities (eg starry saxifrage *Saxifraga stellaris* and mountain sorrel *Oxyria digyna* (Welch 1990)).

Theoretically, movement along corridors is a mechanism by which the isolation of habitat patches could be reduced, but there is little evidence available for actual effects on species diversity (eg MacClintock *et al.* 1977) and on the populations of connected and unconnected habitat patches (eg Middleton & Merriam 1981; Fahrig & Merriam 1985). The number of variables (eg patch area, distance of habitat patch to other habitat patches, vegetation community of habitat patch, corridor width etc) which may affect species richness make it difficult to isolate any effects that a corridor may be having. During a study by Maclintock *et al.* (1977), the presence of a corridor connecting a 35 acre woodland patch to a 400 acre habitat patch, which in turn was connected to a 10,000 acre forest by several corridors, was judged to be a prime factor in the high bird species richness observed in the 35 acre woodland patch. However it is not possible to determine whether it was the presence of corridors which affected the observed species richness in this study (Simberloff & Cox 1987; Nicholls & Margules 1991; Dawson 1994).

Table 3.1 Movement along corridors

The following references provide evidence which the authors of the articles suggest indicates that certain species may use linear features as corridors for movement. The following details are given:

1.	Reference	2.	Species	3.	Country
4.	Corridor type	5.	Methods		
6.	Summary				

INVERTEBRATES

Burel 1989 — Carabid beetles — France
Hedgerow — Trapping
(and in Baudry 1988a, b). Species of forest carabids were found several kilometres away from the forest in tracks bordered by two hedgerows and in connected hedgerows with a dense canopy.

Dover 1990 — Butterflies — UK
Field edge — Direct observation
Observations were made of butterflies in and around a field of spring barley. Almost all butterflies (98%) were seen along linear features (hedgerow, crop edge, conservation headland). Individually marked butterflies were observed to fly along the edges of fields or woodland copse but rarely across the expanse of an open field.

REPTILES AND AMPHIBIANS

Prestt 1971 — *Vipera berus* — UK
Ditch/hedgerow — Observation
Seasonal migration of adders from hibernation areas to summer areas occurred along linear features such as ditches, banks and hedgerows.

Martin & Tyler 1978 — *Limnodynastes tasmaniensis* — Australia
Road verge
(In Bennett 1991). A founder population of spotted grass frogs translocated to a road verge area less than 20 m in width, increased its range 6.7 km along the verge between 1977 and 1978.

BIRDS

Danks 1991 — *Atrichornis clamosus* — Australia
Over the previous ten years, the noisy scrub bird population has colonised several areas away from the Mt Gardner headland to which it was once confined. Small numbers have also dispersed from a small colony established by translocation. This has demonstrated that the species has the ability to disperse given suitable corridors.

Date, Ford & Recher 1991 — *Ptilinopus magnificus* — Australia
Rainforest
Wompoo fruit-doves rarely fly long distances outside the rainforest canopy, apparently requiring the shelter of corridors to move between remnants.

Middleton 1980 — *Melithreptus lunatus* — Australia
Road verge — Direct observations
Flocks of up to 60 white-naped honeyeaters were observed using the corridor for migratory movements through cleared farmland.

Newbey & Newbey 1987 | Birds | Australia
Road verge
Nine species of bird were considered to use a 2 km length of road reserve as a corridor for nomadic and dispersal movements.

Saunders & Hobbs 1989 | *Calyptorhynchus funereus* | Australia
Road verge | Observation
Observations of Carnaby's cockatoo revealed that they tended to follow road verges out from breeding areas, feeding along them if they were lined with native vegetation. If the verge led them to another patch, they exploited that. If the verge vegetation petered out, the birds had to search a large area to find another patch.

Harper | Ant birds | Brazil
Rainforest
(In Simberloff & Cox 1987). A rainforest island was surveyed before a connecting 300 m length of corridor was destroyed. Three species of ant birds (*Formicariidae*) disappeared within four weeks. After a year of second growth in the corridor, one of the three ant bird species is beginning to recolonise.

Wegner & Merriam 1979 | Birds | Canada
Fencerow | Direct observation
White-footed mice *Peromyscus leucopus* and chipmunks *Tamias striatus* moved between a wood and connecting fencerows four times as often as they moved between traplines within the wood. Birds seldom flew directly across open fields between woods. Birds moved along well-vegetated fencerows and then foraged from them into the fields.

van Dorp & Opdam 1987 | Birds | Netherlands
Wooded banks/tree rows | Observation
The avifauna of small woodlots was examined. It was not possible to show for any single species that a high connectivity meant a high frequency of occurrence but the number of forest-interior species was significantly affected by the density of connecting elements.

Gehrken 1975 | *Meleagris gallopavo silvestris* | USA
Mature forest | Population monitoring
Travel corridors to provide eastern wild turkeys easy access to suitable habitats were incorporated into a management plan for a pine plantation. The turkey population increased from 276 birds in 1959 to 410 birds in 1973.

Johnson & Adkisson 1985 | *Cyanocitta cristata* | USA
Fencerow | Observation of tagged specimens
Observations were made of blue jays dispersing beech nuts *Fagus grandifolia* from a woodlot to their former breeding territories where the nuts were cached. During dispersal, jays routinely followed wooded fencerows (91% of flights) through the agricultural mosaic.

MAMMALS

Suckling 1982 | *Petaurus breviceps* | Australia
Road verge | Various
Majority of dispersal movements was of young sugar gliders, all of which involved some travel along the roadside strip. The maximum dispersal distance was 1.9 km. Four other arboreal species were recorded in the corridor and were thought to utilise it as a pathway for dispersal.

Prevett 1991 | *Phascolarctos cinereus* | Australia
Forest | Radio-tracking
Where forest is highly fragmented by farmland, translocated koalas are extremely mobile and make use of vegetation remnants and corridors available to them.

Bennett 1990a | Mammals | Australia
Road verge | Trapping
Six native and two introduced species of small terrestrial mammal (< 2 kg) were studied. Corridors were found to facilitate continuity between otherwise isolated populations of small mammals by providing a pathway for the dispersal of single animals between patches and, secondly, by enabling gene flow through populations resident within corridors.

Wegner & Merriam 1979 | Small mammals | Canada
Fencerow | Trapping
White-footed mice *Peromyscus leucopus* and chipmunks *Tamias striatus* moved between a wood and connecting fencerows four times as often as they moved between traplines within the wood. Birds seldom flew directly across open fields between woods. Birds moved along well-vegetated fencerows and then foraged from them in to the fields.

Sinclair *et al.* 1967 | *Peromyscus leucopus* | USA
Stone wall | Trapping/snow tracks
Most white-footed mice residing in walls seldom ventured more than 1-2 m away from the wall. Stone walls may in certain cases be used as corridors from one forested area to another but many individuals were more or less permanently established in walls in non-forested situations.

Middleton & Merriam 1981 | *Peromyscus leucopus* | Canada
Fencerow | Trapping
A local extinction of white-footed mice in an isolated wood was artificially undertaken. The wood was readily recolonised in a farmland mosaic with fencerow corridors.

Fahrig & Merriam 1985 | *Peromyscus leucopus* | Canada
Fencerow | Trapping
Field data supported model prediction that populations of white-footed mice in isolated woodlots have lower growth rates and thus are more prone to extinction than those in connected woodlots.

Henderson *et al.* 1985 | *Tamias striatus* | Canada
Fencerow | Trapping
Chipmunks were studied in woods separated by farmland and connected by fencerows. Local extinctions (performed by removing all chipmunks) from individual woods were readily recolonised by animals from other patches. Fencerows formed critical connections among woods.

Merriam & Lanoue (1990) | *Peromyscus leucopus* | Canada
Fencerow | Radio-tracking
White-footed mice were found to prefer moving in fencerows rather than in more open landscape elements and to favour fencerows with structurally-complex vegetation.

Gurnell 1985 | *Microtus agrestis* | UK
Grass ride | Trapping
Capture of field voles tended to be associated with a small grass ride which traversed the trapping grid. Specimens sometimes appeared in mature woodland area and therefore the grass rides may act as donor areas for colonisation of other habitats.

Hansson 1987 *Microtus agrestis* Sweden
Meadow strip Trapping
Narrow grassland links provided distinct dispersal routes for field voles (and at the same time permitted dispersal by bank voles *Clethrionomys glareolus* across the grassland links between separate parts of forest). (*Apodemus* and *Sorex* species moved through various habitats.)

Getz *et al.* 1978 *Microtus pennsylvanicus* USA
Road verge Trapping/historical records
The range of the small mammal species was extended southward in the high intensity agricultural region in central Illinois only after continuous avenues of dense vegetation were established along interstate highways.

Szacki 1987 *Clethrionomys glareolus* Poland
Alder thicket Trapping
Bank vole population of isolated woodlot compared with connected woodlot. Population density was higher in the isolated patch than in the connected patch. The corridor had a marked effect on the frequency of movements. (No such effects on yellow-necked mouse *Apodemus flavicollis*.)

Yalden 1980 *Apodemus sylvaticus* UK
Railway Trapping/casual records
Survey suggested that wood mice penetrate deep into the city of Manchester along the corridors of semi-natural vegetation.

Boone & Tinklin 1988 Small mammals UK
Hedgerow Trapping
Neither wood mice *Apodemus sylvaticus* nor bank voles *Clethrionomys glareolus* moved into or out of hedgerows from adjacent coppice or pasture habitats. Hedgerows may act as corridors for dispersal but only for animals inhabiting the hedgerows. Movements up to 60 m were not uncommon.

Eldridge 1971 Small mammals UK
Hedgerow Trapping
Mice and voles were found to move freely along a hedgerow, with a maximum recorded distance of 60 m.

Gurnell 1987 *Sciurus carolinensis* UK
Road verge/riparian
More than 30% of grey squirrels captured in a 10 ha oak wood were regular visitors to neighbouring woods. Linear habitats, such as trees along the edges of road verges or river banks, are used by squirrels to move between larger blocks of trees.

Page 1981 *Vulpes vulpes* UK
Railway Observation
Foxes frequently moved along the edge of railway tracks leading into and out of London.

Kolb 1984 *Vulpes vulpes* UK
Railway Radio-tracking
The presence of railway tracks determined how far and in what direction a proportion of dog foxes moved in Edinburgh.

Trewhella & Harris 1990 *Vulpes vulpes* UK
Railway Various survey
Railway lines may influence the movement of individual foxes within their home ranges but they appear to have little effect on the distance or direction of dispersal movements.

Broekhuizen *et al.* 1986 *Meles meles* German
Hedgerow
Hedgerows are followed by dispersing badgers.

Jefferies *et al.* 1986 *Lutra lutra* UK
River
Main rivers used by otters.

Chapman 1977 *Muntiacus reevesi* UK
Railway Observations/reports
Several records of muntjac suddenly appearing in urban areas. Possibly these animals travelled along corridors of vegetation such as those alongside railway lines. The presence of single animals recorded at Chelmsford, Chingford, Enfield and West Ham may be explained in this way.

Harris 1984 *Capreolus capreolus* UK
Riparian/railway Observations/reports
Observations in Bristol suggested that most roe deer entering the city did so along wooded banks of a river and the main railway line. The presence of a quiet, wooded gorge on south-east of city allowed the penetration of roe deer into a heavily urbanised area.

Goszczynski 1979 Various mammals Poland
Riparian Snow track counting
River bank sectors corresponding to different city zones in Warsaw were usually richer in mammal species. The river banks not faced with concrete thus formed a natural channel penetrated by wild species within city limits.

Forman & Baudry 1984 Deer/raccoons USA
Hedgerow Casual observations of snow tracks
Observations suggested that hedgerow boundaries were used for movement across an agricultural landscape more frequently than any other route, except a road or stream corridor (including by people).