Linear habitat

The role of linear features as habitats in their own right has been reviewed by Forman & Baudry (1984), Dowdeswell (1987), Bennett (1990c), Bennett (1991) and Johnson & Beck (1988) (see also Table 3.2). Certain species may be able to survive outside such linear habitats whereas others are restricted to the patches and interlinking linear habitats. Sometimes an artificial feature placed in a large natural expanse (eg a powerline swathe through a forest) may become the habitat for a distinctive set of species (eg Schreiber *et al.* 1976), just as does a natural or semi-natural feature in an artificial landscape.

Maelfait & De Keer (1990) considered that small field-edge 'corridors' are important for invertebrate conservation. They found that such features act as linear habitat and overwintering refuges and may serve as migration routes to more suitable habitats for some species. Field 'margins' or 'boundaries' generally have been of particular interest to ecologists in recent years because of their potential for improving the game holding capacity of a farm and in providing habitat for natural enemies of agricultural pest species (Dennis & Fry 1992; Wratten 1988). Such margins may take the form of hedgerows or the 'edge' habitat between natural habitat and arable fields. Work relating to the dispersal of plants from field margins has been reviewed (Marshall 1988). Wratten (1988) summarised five points with respect to work recently carried out in the UK on the subject of polyphagous predators and field boundaries:

1. Polyphagous predators do appear to have a role in pest suppression.

2. Those species which have the greatest ecological potential for pest suppression have been identified.

3. The importance of field boundaries as overwintering sites for beneficial arthropods has been shown.

4. Certain important features of the overwintering sites have been identified (largely sheltered, dry, microhabitats) although the biological properties are still unknown.

5. It is possible to create overwintering habitats on farmland that favour the development of high populations of arthropod predators. Thomas & Wratten (1988) described the construction of raised banks of earth (0.4 m high x 1.5 m wide x 350 m long) sown with various grass species within fields. Within two years of their establishment (Wratten & Thomas 1990), high-density populations of polyphagous predators were overwintering in the linear 'island' habitats and thus provided a nucleus population from which dispersal into the crop could take place during spring. Spring represents the time when the predators 'biocontrol' potential is at its highest.

Table 3.2 Linear habitats

This list refers to studies in which the role of linear features in providing habitat has been investigated. The list is designed to illustrate a range of corridor types (road verges, riparian, hedgerow, railway, shelterbelt etc) and of different taxonomic groups. Many of them also discuss other possible roles of linear features, such as providing corridors for the movement of species through a landscape.

1. Reference 2. Species 3. Country
4. Linear habitat
5. Summary

Pollard 1973 Plants UK
Hedgerow
Study of single hedge, study of colonisation of hedges planted close to woodlands and a survey of roadside hedges in Huntingdon and Peterborough.

Suominen 1969 Plants Finland
Railway
Plant cover of Finnish railway embankments. The chief vegetation units and their ecology are described.

Webb 1988 Plants Ireland
Hedgerow
Importance of hedgerows as wildlife refuges, especially for woodland flora and fauna.

Cameron *et al.* 1980 Mollusca UK
Hedgerow
Study made on the historical and environmental influences on hedgerow snail faunas.

Desender *et al.* 1987 Carabid beetles Belgium
Road verge
Habitat preferences and synecological aspects of the carabid fauna along a motorway verge. Phenology of the life cycle of certain species in relation to recorded microclimatological conditions.

Desender *et al.* 1989 Carabids/spiders Belgium
Field margins
Comparison made of abundance estimates of predatory arthropods (carabids/spiders) between crop field centres and their edges. Results differ between carabids and spiders according to the type of cultivation.

Rosenberg 1984 *Limenitis weidemeyerii* USA
Riparian/road verge
Structures overhanging sunny, open areas of corridors are defended territorially by a proportion of the male admiral butterfly population. If there are more quality perch sites along a corridor then more males can defend territories. This may result in more matings (as territorial males have the most matings each year) and therefore greater genetic variation.

Samways 1989a Bush crickets France
Road verge/ditch/riparian
Investigation of the role of elements of the landscape (corridors, patches and matrices) in relation to the distribution of bush crickets.

Thomas & Wratten 1988 Arthropod predators UK
Banks
Raised banks sown with various grasses were created in fields. These new habitats provided overwintering refuge sites for many polyphagous predators (Carabidae, Staphylinidae, spiders).

Arnold 1983 Birds UK
Hedgerow
Bird abundance and diversity in farmland was related to hedgerow and ditch structure and area of woodland and garden. The characteristics of hedges and ditches influenced their use by birds.

Gaines 1980 Birds USA
Riparian valley
Censuses made of birds in riparian forest sites in the Sacramento Valley, California. High diversity of bird species present.

Osborne 1984 Birds UK
Hedgerow
Relationships between bird numbers and the characteristics of forty-two hedges on a Dorset farm. Bird-rich hedges were described as having a large basal area, many tree species, some dead timber and being near scrub habitats.

Arnold *et al.* 1991 Kangaroos Australia
Road verge
Linear strips of vegetation were believed to play only a small role in sustaining regular movements between patches. In some instances there were indications that the road verge was used as habitat in association with remnant patches of native vegetation.

Bennett 1988 Mammals Australia
Road verge
Roadside vegetation was studied as habitat for mammals. Remnant forest vegetation occurred along the roadside. At least 18 of the 23 species of mammals (excluding bats) known to occur in forested vegetation in the area were recorded.

Bennett 1990a Small mammals Australia
Road verge
Six native and two introduced species of small mammal were studied on roadside vegetation habitat. The habitat facilitated continuity between otherwise isolated populations and provided habitat in which to reside.

Henderson *et al.* 1985 *Tamias striatus* Canada
Fencerow
Chipmunks were studied in woods separated by farmland and connected by fencerows. Fencerows served as movement corridors and also as habitat for small breeding populations.

Schreiber *et al.* 1976 Small mammals USA
Powerline
Small mammal distribution and abundance in habitats occurring within and adjacent to powerline right-of-way. Maintained rights-of-way create habitat for two species not present in adjacent pine or hardwood forests.

Sinclair *et al.* 1967 Small mammals USA
Stone walls
The influence of stone walls on the local distribution of small mammals was examined. Stone walls apparently substitute for a forest habitat in non-forested situations. They offer suitable nest sites and cover for small mammals.

Yahner 1983 Small mammals USA
Shelterbelt
Habitat variables characterising vegetative features of shelterbelts were correlated with small mammal abundance and diversity. Species richness was greater in larger shelterbelts with complex vegetative structure.

Arnold *et al.* 1987 Vertebrates/plants Australia
Road verge
Sections of road verge were surveyed. More than 100 plant species were found although all sites were heavily invaded by non-native species. Forty-one species of birds were recorded, and numbers of birds in different groupings of species were influenced by vegetation structure.

Brooker 1983 Animals/plants UK
River/riparian
Survey undertaken of aquatic vegetation, riparian vegetation, aquatic macroinvertebrates, fish, birds and otters of the River Teifi.

Linear features as barriers

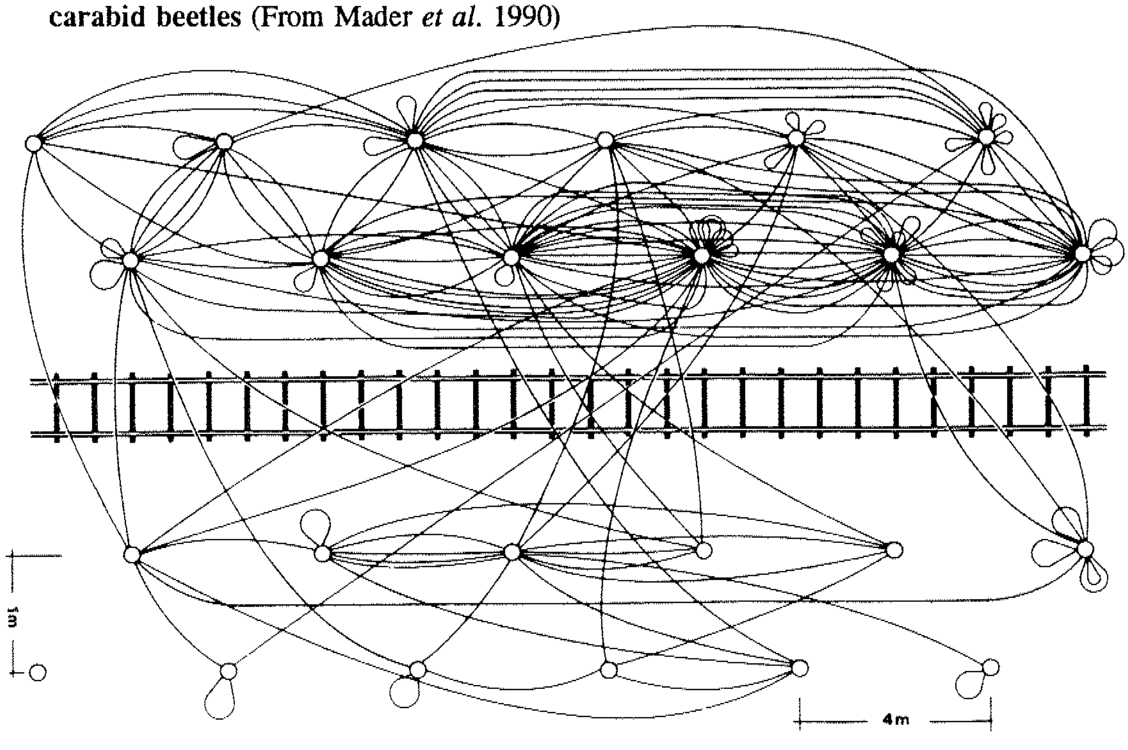
In a study on the tropical-forested Barro Colorado Island, it was found that the poor powers of dispersal of antbirds were particularly detrimental on the small and isolated reserve (Willis 1974). The birds did not cross water gaps, even of a few hundred metres. They were compared to the forest-dwelling birds that Diamond (1973) found did not cross water gaps in New Guinea. In other words, the water gaps were acting as barriers to their dispersal.

The role of such linear features as powerline swathes (Schreiber & Graves 1977), hedgerows (Forman & Baudry 1984) and various types of 'edge' habitat (Yahner 1988) as barriers has been studied, but most of the work investigating this aspect has been on roads (Bennett 1991).

Small forest mammals in Canada have been found not to venture on to road surfaces where the distance between forest margins exceeded 20 m (Oxley *et al.* 1974). However even wider roads were crossed by medium sized mammals such as porcupines *Erethizon dorsatum* and raccoons *Procyon lotor*. Oxley *et al.* considered that a four-lane divided highway may be as effective a barrier to the dispersal of small forest mammals as a body of fresh water twice as wide. In Arizona and Utah, USA, individual mountain lions *Felis concolor* tended to live in areas where hard-surfaced or improved dirt roads were absent or under-represented (Van Dyke *et al.* 1986). Unimproved dirt roads were crossed more frequently than hard-surfaced or improved dirt roads, suggesting that the latter two road types were avoided. Garland & Bradley (1984) found no road mortality of small mammals along a stretch of four-lane highway in the desert area of south Nevada, USA and suggested that such wide roads may act as a barrier.

Invertebrates are also affected by linear features. In the Montpellier region of southern France roads were not considered as barriers for some species of bush cricket as they had the ability to fly across such structures (Samways 1989a). However, for apterous (wingless) species, the ability to disperse was much reduced. The building of new roads at an airport had resulted in one particular population of the apterous bush cricket *Platycelis fedtschenkoi azami* being divided through the formation of a complete barrier. Mader (1984) illustrated the barrier effects of roads, even hard-surfaced forest roads not open to the public, on populations of forest-dwelling carabid beetles and wood mice *Apodemus flavicollis*. In a similar study (Mader *et al.* 1990), grassy field tracks had no significant effect on the movement pattern of carabid beetles and lycosid spiders, but hard-surfaced and gravel field tracks reduced the rate of crossings. Reduced crossings were also found to occur at a railway track (Figure 3.2).

Figure 3.2 Mobility patterns, illustrating a barrier effect of a railway line on movement of carabid beetles (From Mader *et al.* 1990)



Mader (1984) listed five specific points that might contribute to the barrier effect of roads:

1. The edge of the road marks a break in microclimatic conditions.

2. There is a variety of emissions and disturbance as a result of road traffic, such as noise, car exhaust fumes, dust etc.

3. Road verges are periodically cut and sprayed with chemicals resulting in zones of environmental instability.

4. Animal and plant species composition on road verges will differ from that of more distant habitats. This could result in intensified competition for resources and a broadening of the zone of disturbance.

5. There is a risk of animals being killed on the road by traffic.

A sixth point, not considered by Mader, relates to the frequent reduction of plant cover along intensively managed road verges resulting in their avoidance by animals due to an increased risk of predation.

Although it probably happens, there appear to be no reported cases of linear features acting as complete barriers to species movement, there were always some individuals that get across. However a network of man-made linear structures across a landscape, especially intensively-used structures such as roads, may have serious effects on certain species. Those species with reduced abilities for dispersal are likely to suffer to the greatest degree. A network of barriers may also tend to guide species parallel to them with the result that the average distance they can move is reduced (Mader *et al.* 1990) (Figure 3.3).

The small mammal *Microtus pennsylvanicus* appeared to extend its range southwards in the high intensity agricultural region of central Illinois after continuous corridors of dense vegetation were established along interstate highway verges (Getz *et al.* 1978). It was presumed that it did not disperse into the region earlier as, firstly, mowing regimes along the highway roads (as opposed to the bigger and newer interstate highway roads) were too intensive; secondly the original highways and railways went through small towns along the route, thus resulting in interruptions of the grass verge habitats and a network of barriers. The interstate highway system bypassed towns and therefore provided continuous corridors for dispersal.

Breaks in barriers may reduce detrimental effects by permitting animals to move from one side to the other. Dormice *Muscardinus avellanarius* are thought to be poor colonisers as they have been observed to make extensive arboreal detours to feeding sites rather than cross forest rides (P Bright in Harris & Woollard 1990). Therefore Bright & Morris (1989) have emphasised the importance of maintaining aerial runways to facilitate dispersal. Bridges over and tunnels under roads have been provided for the benefit of several species, for example toads (Morrison 1988) and mule deer (Reed *et al.* 1975). Hunt *et al.* (1987) studied the use of tunnels under railway lines by small native mammals in New South Wales, Australia.

Edge

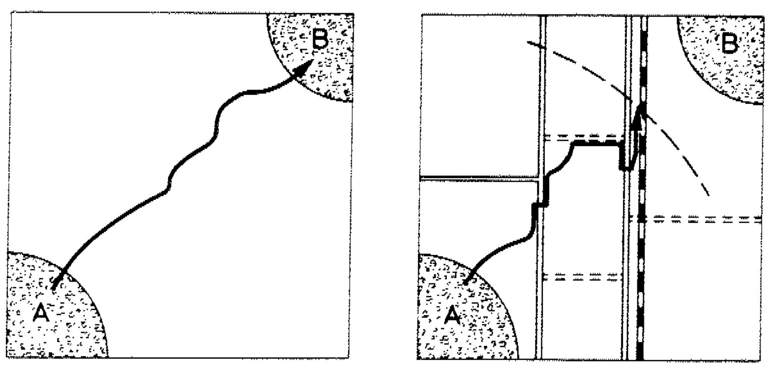
'Edge' can be defined as the place where adjacent plant communities meet or where successional stages or vegetative conditions within plant communities come together (Thomas *et al.* 1979). Yahner (1988) described edges as being either inherent or induced. The former type are long-term features of the landscape, such as the junction between two plant community types, resulting from local differences in physical conditions. An induced edge is usually a short-lived, man-made feature at the junction of distinct land uses or successional stages.

The 'edge effect' can be defined as the tendency for the variety and density of organisms to be greater at the borders (ie edges) between different plant communities than in the interiors of the communities (Odum 1971). Species characteristic of each of the adjacent plant communities may be present plus species that frequently require more than one vegetation type and those that specialise in edge habitat. The principle of edge effect has often been incorporated into wildlife management plans as a means of increasing species diversity. However, the creation of edge (and other treatments to maximise habitat diversity) does not always have beneficial effects (Noss 1983; Yahner 1988).

Linear habitats and corridors are long, narrow landscape features, so edges are an important part of their structure. When designing corridors and linear habitats for wildlife management purposes, the strength of the edge effect on the core of the corridor varies depending on the width. If the purpose of the linear feature is, for example, to connect woodland patches, then woodland interior species may not move along them if they are too narrow. Instead, the feature may be used only by edge species.

Anderson *et al.* (1977) examined bird populations along powerline swathes in deciduous forest. They observed that narrow (12 m) swathes had reduced species diversity whereas intermediate swathes (30.5 m) had high species diversity and density. Wider swathes (61 and 91.5 m) were less diverse but attracted several open-country bird species not characteristic of the surrounding forest. Similarly, much work in Britain has been done on the widths of rides that are needed to maintain particular butterflies (Ferris-Kaan 1991) depending on the height of the adjacent trees.

Figure 3.3 **The possible barrier-effects of linear features such as roads and railways on animal dispersal.** Assuming the animals eventually cross the barriers, there may initially be frequent movements parallel to roads before crossing. Energy resources could be exhausted before reaching a suitable habitat, thus decreasing the effective dispersal range. From Mader *et al.* 1990.



4. THE IMPORTANCE OF LINEAR FEATURES

Ecological

One of the basic theoretical roles of a corridor as discussed in the previous chapter is to facilitate the movement of species between habitat patches. By increasing the rates of immigration into a patch, its isolation is reduced. Reduced isolation could have the result of increasing or maintaining species diversity, increasing population sizes of specific species and reducing the possibility of local extinction, and maintaining genetic variation within populations and preventing inbreeding depression (Noss 1987; Mackintosh 1989) (Table 4.1). Corridors, even if they work, do however have disadvantages. Arguments for and against the use of corridors have been put forward by Simberloff & Cox (1987) and Noss (1987).

Table 4.1 Ecological benefits provided by the presence of linear habitats and corridors

(i) Increase in the rate of immigration into habitat patch.

- Increase and/or maintenance of species diversity.
- Increase of population size for certain species and reduced risk of extinction within a habitat patch. If a local extinction occurs within a habitat patch, then it may be more readily colonised.
- maintenance of genetic variation within populations and the prevention of inbreeding depression.

(ii) Provision of escape routes from habitat patch after large scale disturbance such as fire.

(iii) Provide habitat for many species.

- 'Margins' may be sources of beneficial species such as insect pollinators and polyphagous predators of agricultural pests.
- Can provide networks of habitat for animals with large home ranges or territories in an otherwise degraded environment.
- Provision of cover from predators between patches.

<u>Disruption of existing genetic patterns</u>

Potential disadvantages from corridors include the risk that increased gene flow between habitat patches lowers the fitness of the populations involved, thus reducing their chances of survival. Where local adaptation or coadaptation has occurred, the gene flow between populations that may result after the construction of interconnecting corridors could result in hybrids and lowered fitness ('outbreeding depression', Templeton 1986). However Noss (1987) noted that outbreeding depression has never been observed in populations of patches where natural connectivity has been maintained or restored.

Where inbreeding may pose a threat to the survival of a population in a habitat patch, translocation of specimens between habitat patches has been suggested as an alternative to corridors in some situations (Simberloff & Cox 1987). In this way managers could closely monitor the gene flow between populations and the potential disadvantageous aspects of connectivity could be avoided.

Although this might be considered a satisfactory method in some cases when particular species are a matter of concern, it is certainly impractical to translocate whole communities between patches. The aesthetic and ethical questions of translocation as a substitute for natural movement were also considered by Noss (1987) to warrant discussion.

Simberloff & Cox (1987) made the point that it is not always a good thing to facilitate gene flow between isolated populations. They presented the example of the Seychelles turtledove *Streptopelia picturata rostrata*, a morphologically distinct subspecies which has been replaced or has interbred with the introduced Madagascar subspecies *S. p. picturata* on most of the islands. The latter species was introduced to the Seychelles at least by the mid-nineteenth century. The presence of interconnecting corridors between the islands of the Seychelles would have probably resulted in even faster destruction of the native subspecies. In this situation it is clear that natural isolation has resulted in a distinct local flora and fauna and that such isolation should be maintained as much as possible. The possibility that other long-established isolated systems may be disrupted should still be borne in mind in other circumstances where there is more of a case for corridors.

Spread of undesirable species, disease, fire etc along linear features

An aim of creating interconnecting corridors is to increase dispersal rates of 'desirable' species into patches, but immigration of diseases, pest species, unwanted exotic species and weeds may also be enhanced. In New Zealand and Australia some previously widespread species are now confined to vermin-free offshore islands because they are isolated (Lynch 1987). These island populations were either established through translocation from mainland sites by conservation workers or they represent the natural, remnant populations. In England islands have similarly provided a refuge for red squirrels *Sciurus vulgaris* while on the mainland it has been suggested that large blocks of conifer woodland be maintained which can function as refuges from grey squirrels *Sciurus carolinensis* (Harris & Woollard 1990).

Kolb (1984) and Page (1981), working on foxes in Edinburgh and London respectively, suggested that railway lines affected how far and in what direction a proportion of dog foxes disperse. This could be particularly important information for a control operation in the event of a rabies outbreak as railway lines could be targeted for control operations. However, later work concluded that railway lines appeared to have little effect on the distance or direction of dispersal movements (Trewhella & Harris 1990). In Western Australia, the endangered, near-flightless noisy scrub bird *Atrichornis clamosus* has shown an ability to disperse from the colonies it was once confined to, given suitable corridors (Danks 1991), but there is concern over the potential risk of disease spreading between the sub-populations.

In a Swedish study, the field vole *Microtus agrestis* was found to disperse along narrow grassland links within a forest-dominated landscape (Hansson 1987). However, as the field vole is considered to be an important pest species in Swedish forestry, the aim of forest managers would be to have low connectivity of grassland patches. An example of an exotic species utilising corridors is provided by the spotted grass frog *Limnodynastes tasmaniensis*. Individuals of this species were released by unknown people at a road verge less than 20 m in width in northwestern Australia, 1800 km from their natural distribution in southeastern Australia. Between 1977 and 1978 the range of the frogs had increased 6.7 km along the road verge (Martin & Tyler 1978).

Abiotic disturbance can also pass along corridors ('contagious catastrophes', Noss 1987). Gorse *Ulex* spp. for example is seen as a problem on road verges in Britain due to the potential fire hazard it represents. Roadside vegetation in southeastern Australia is perceived as an unacceptable fire hazard by some parts of the local community (Bennett 1990a). However, although the spread of biotic or abiotic disturbances is a potential disadvantage of corridors, they are only relatively narrow strips of terrain which land managers may be able to cut off, thus controlling the spread of the disturbance.

Also, if there is a large scale disturbance such as a fire in a habitat patch, a corridor could represent an escape route for animals.

Corridors may increase the risk of exposure to predators, humans (poaching) and domestic animals (Noss 1987; Simberloff & Cox 1987). Cats *Felis catus* and foxes *Vulpes vulpes* were more numerous in road verge forest habitats than in forest patches in an Australian study (Bennett 1990a). Predation on small mammals was potentially higher on the road verges than the patches.

Environmental

Hedgerows affect the microclimate of fields by acting as windbreaks, thus providing shelter for livestock and increasing crop yields to various extents (Dowdeswell 1987) (Table 4.2). On hilly terrain they can inhibit soil erosion and protect soil nutrients in the fields (Forman & Baudry 1984) and provide sources of beneficial insects such as pollinators and polyphagous predators (see 'margins'). Farmers often consider hedgerows to be sources of weeds, pests and diseases, but whether these represent serious problems is a matter for further research (Dowdeswell 1987; Marshall & Smith 1987). Hedgerows also shade the edges of crops, require management and occupy potentially cultivable land.

Road verges require a certain degree of management but can also be sources of crop pollinators or invertebrate predators of agricultural pests (Free *et al.* 1975). Riparian corridors and other linear habitats help to control water and mineral nutrient flows. When there are wide riparian corridors which extend to the upland areas, water runoff and soil erosion are reduced and flooding minimised (Forman & Godron 1986).

Table 4.2 Environmental benefits provided by the presence of linear habitats and corridors

(i) Microclimate.

- Hedges can act as windbreaks and affect crop yields.
- Temperatures in urban environments may be moderated by the presence of wooded areas.

(ii) Reduction in soil erosion.

- Windbreaks.
- Water runoff moderated (eg wide riparian corridors).

(iii) Reduction in pollution, especially in urban environments. Examples include:

- Noise pollution.
- Light pollution (car headlamp glare etc).
- Dust.
- Heavy metals.

In urban areas linear habitats and other types of green space can play important roles in factors relating to climate, pollution and water run-off ('buffer plantings' in McPherson 1988). As part of the Man and the Biosphere (UNESCO) urban programme, the Dayton Climate Project was initiated to study the city of Dayton's (Ohio, USA) vegetative ecosystem. Particular emphasis has been placed on how the 'urban forest' affects the built environment, local climate and quality of life (Spooner 1986; UNESCO 1989). The existing tree canopy lowers the city's temperature by approximately 20% from what it would be without trees. Similarly the landscape park of Tiergarten in the inner city of West

Berlin was found to be up to 7°C cooler than neighbouring urban areas (Horbert *et al.* 1982). The ability of tree-planted areas to moderate microclimates and to reduce the energy to heat and cool buildings persuaded the authorities of Stuttgart to cancel a plan to clear much of its city forest in favour of more building (Baines 1990).

Vegetation can be used to act as a buffer to noise pollution, especially that created by industrial operations and high-speed traffic. Rome has one of the highest noise levels recorded in a European city but plans are being made to develop suitable acoustic barriers of trees and other vegetation along busy roads (Spooner 1986). Light from street lamps, car headlights and illuminated road signs can also act as a pollutant, causing discomfort to residents and being potentially hazardous to drivers in some situations. Vegetation can be planted to reduce glare and stray reflections by acting as a screen. Trees can be important in acting as biological sinks for heavy metal pollutants (eg Greszta 1982). They can function in filtering the air of particulate pollutants, and have been calculated to reduce dustfall by up to 38% (Dochinger 1980).

The Dayton Climate Project has also identified the importance of vegetation in reducing water runoff (Spooner 1986). After a severe storm, the tree crowns in the city lowered runoff volumes by at least 7% from what it would have been if the trees had not been present. This reduces the risk of flooding and lessens the pressure on sewerage works. Storage of precipitation in the tree canopies results in increased ground-water recharge potential and reduced overland flow (eg Brechtel 1982).

Soil erosion is as great a problem in the urban environment as it is in the agricultural environment. The Dayton Climate Project worked out that almost 12,000 tons of soil is removed from just under 500 acres of exposed soil in the city each year. The soil, as well as the vegetation, acts as a sink for pollutants, so erosion should be avoided if it is at all possible. Vegetation could be used to do this.

Amenity

There are also good aesthetic reasons for maintaining corridors and linear habitats. The hedgerow 'patchwork' is a characteristic part of the British countryside and generally accepted to present a more picturesque landscape than the hedgeless, prairie-type fields dominant over much of East Anglia. In an urban environment, green spaces (or 'green ways') are particularly important to people for recreation and general aesthetic reasons. There now appears to be a greater interest in creating green spaces with a more natural appearance as opposed to the formal, intensively managed parks. The responses of people to vegetation and landscape have been reviewed by Ulrich (1986) and there appears to be a relatively consistent trend of preferences towards natural landscapes in general and trees and green, park-like or pastoral landscapes in particular (Schauman *et al.* 1987).

Table 4.3 Educational and recreational benefits of linear features

(i) Recreation.

(ii) Education.

(iii) Aesthetic appearance.

(iv) Limit to urban sprawl ('green belt').

Research involving in-depth discussion groups with local people in London has been undertaken to assess their attachment to open land and the role that it plays in their daily lives (Burgess *et al.* 1988). People expressed criticism of barren landscapes of closely-mown grass as it precluded close contact with the 'sensuous' qualities of landscape. They wanted children to encounter wild open spaces but on the doorstep where the parents could keep a watchful eye on them. Burgess *et al.* (1988) suggested the incorporation of natural areas and wildlife corridors into the communal greens of housing estates and suburban developments. It was felt that when such areas were close to home they would be more readily policed by local people. Feelings of insecurity and vulnerability in open spaces, and dissatisfaction with untidy, messy and overgrown appearances are however examples of negative views that have been expressed with regards to natural open spaces (Burgess *et al.* 1988; Harrison & Burgess in Gilbert 1989).

The potential educational benefits of natural areas within urban areas, especially when they are in close proximity to schools, are obvious. Environmental education is included in the new national curriculum in the UK and the availability of sites where students can undertake fieldwork would prove invaluable for this. The educational benefits of such sites are included in the draft nature conservation strategy produced by Bristol City Council (1990).

Thus green spaces in urban environments enhance the scenery, provide areas for recreation and education, and can improve the general quality of life for residents. They may also play a role in limiting urban sprawl ('green belts'), provided that their protection is also seen as important.

Opportunity costs of maintaining/creating corridors

Money spent on the acquisition and management of linear features as corridors could alternatively be spent on obtaining new nature reserves. Unless it is clear that there really are advantages in creating new wildlife corridors in terms of effects on species richness (ie the presence of corridors results in maintaining or increasing species richness of connected habitat patches), careful thought has to be given to the use of existing conservation resources on this rather than other projects. However the recent increase of public awareness in environmental matters could result in more money being available from local and national authorities and industry to pay for the incorporation of corridors and linear habitats into planning schemes. There are also the other environmental and landscaping advantages (some with potentially important economic consequences) in the incorporation of corridors and linear habitats into management and planning strategies.

Any decisions should be considered on a case-by-case basis, but the general principle with corridors is to recreate or maintain connectivity in a landscape that was once naturally interconnected before the impact of intensive human activity, and not to increase connectivity between naturally isolated habitats.

5. MANAGEMENT AND PLANNING OF LINEAR HABITATS AND WILDLIFE CORRIDORS

A basis for planning corridors

Linear features offer habitats for wildlife and corridors for movement and migration of some plants and animals; they also have a wide range of other environmental and recreational benefits. In North America and elsewhere corridors and wildlife reserves have been maintained because of a perceived human, ecological, environmental and scientific value (Adams & Dove 1989). Other corridors, sometimes on a grand scale, have been proposed or established (but not necessarily shown to function), for example the Rio Grande Wildlife Corridor (300 miles long and linking dozens of refuges and protected areas (Harris & Scheck 1991)); the linking of national parks in northern Italy and Switzerland to protect the annual migration corridor of red deer *Cervus elaphus* (Harris & Scheck 1991); and the development of a regional series of linked protected areas in north Florida and south Georgia (Noss & Harris 1986). In Britain, English Nature is also exploring the possibilities for this type of approach in parts of the country with a concentration of protected sites of different types, so-called "high biodiversity areas".

Local authority plans

Several local authorities have recognised the value of linear features and have included networks of them (often referred to as greenways) in urban areas, for both wildlife and recreation (Table 5.1). Strategic plans for conservation of urban wildlife including greenways should include the following (Barker 1984):

- Surveys to identify the main reservoirs of wildlife.
- Identification of the main potential linear habitats permeating the built up area.
- Identification of the key linear habitats between reservoirs.
- Protection and management of the reservoirs and linear habitats.
- Identification of the main areas where semi-natural habitats are not open for access.
- Development of policies to improve areas.
- Development of policies to ensure that the public can enjoy wildlife areas.
- Insistence on design standards for building developments which make the most of the opportunities to add to wildlife habitats and which cause the least possible damage to existing wildlife habitats.
- Development of policies to encourage initiatives for all of the above.

Table 5.1 Examples of local authorities in Britain who have adopted linear habitats/wildlife corridors in strategic planning

Area or local authority	Reference
Greater Bristol	Bristol City Council 1990
Southampton City	Ball 1989
Billingham Beck Valley	Cleveland County Council 1990
Dudley Metropolitan	Dudley Metropolitan Council 1989
Manchester	Greater Manchester Council 1986
London	Greater London Council 1984
Milton Keynes	Kelcey 1975
Leeds	Leeds City Council 1990
Lewisham	London Borough of Lewisham 1989
Leicester City	Leicester City Council 1990
West Midlands	West Midlands County Council 1984
Tyne & Wear	Nature Conservancy Council 1988b

Hedges and similar linear habitats

Structure, width and species composition of the trees and shrubs are important attributes to consider if a linear habitat such as a hedge or boundary fence is to be managed mainly for wildlife. Bird-rich hedges tend to have a large basal area, many tree species and some dead timber and are close to scrub habitats (Osborne 1984). Furthermore, if the linear habitat is to serve as a potential corridor for movement of wildlife between habitats, then obviously connectivity is also important, that is, there should be as few breaks and gaps as possible. Hedgerow evaluation schemes based on these ideas have been developed (Clements & Tofts 1992).

For terrestrial habitats, vegetation structure is closely related to species richness and generally speaking structurally complex habitats support higher levels of species richness. In hedges, for example, structurally diverse vegetation is important at both ground level for ground dwelling animals and at the canopy level for various bird species and some mammals such as dormice (Bright & Morris 1989) - not that species richness should always be the ultimate goal, because there may be circumstances in which a particular species is conserved in a relatively species-poor environment. Also, some ecosystems such as heathlands are naturally plant species-poor, and increased species-richness suggests degradation.

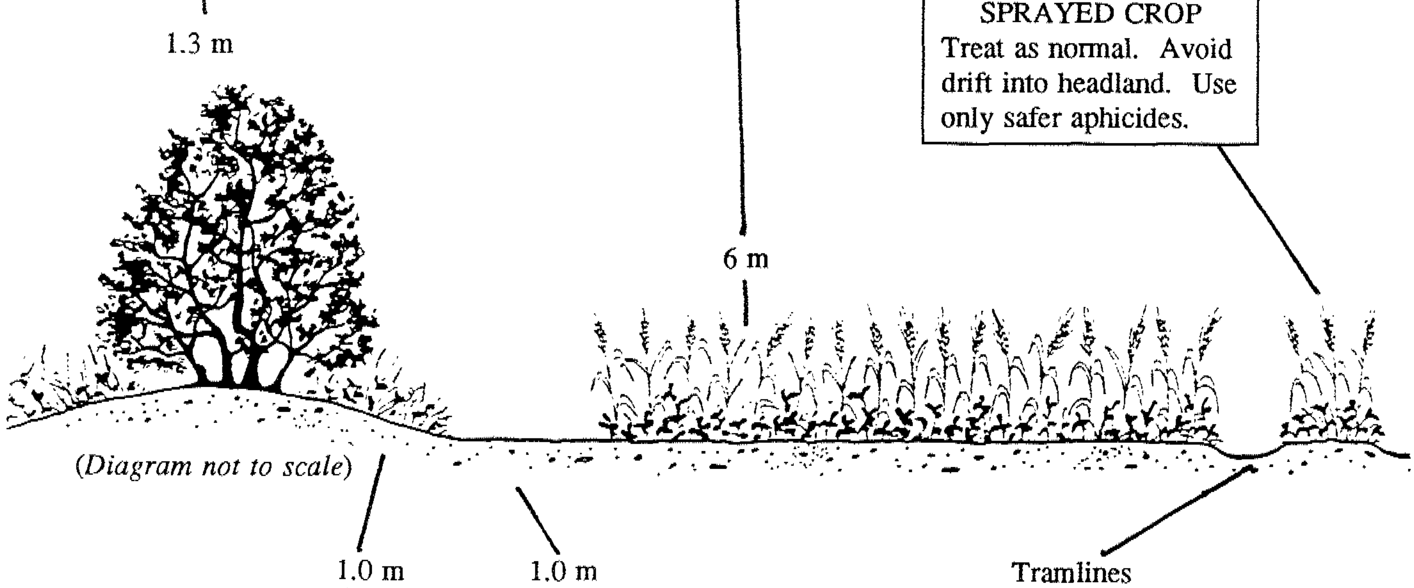
The value of a hedgerow for wildlife is influenced strongly by the treatment of the strip of land next to it. With this in mind, the Game Conservancy has investigated the effects of creating conservation headlands (Figure 5.1). The effects in just a short time have been quite dramatic, with increases in populations of many forms of wildlife. Conservation headlands may not only improve the hedgerow habitat but also improve the chances of wildlife using hedgerows as corridors. Other work on the effects of different ways of treating sown and unsown headland is reported by Smith *et al.* (1992/3).

Figure 5.1 Field margins and "conservation headlands" as developed by the Game Conservancy

HEDGE
Trim hedges every other year and keep to a maximum height of 2 m. Do not allow hedge to overgrow adjacent grassy strip which is the vital area for nesting.

CONSERVATION HEADLANDS
The area between the crop edge and the first tramline (usually 6 m wide according to boom width). This is an area of crop treated with selective pesticides (see guidelines) to control grass weeds, cleavers and diseases whilst allowing most broad-leaved weeds and beneficial insects to survive. Ploughing of headlands is recommended especially on heavy soils or where grass weeds are a problem. Avoid turning furrow onto grassy strip as this area can create ideal conditions for annual weeds. Choose headlands next to good nesting cover. Avoid headlands infested with difficult weeds (especially barren brome and cleavers).

SPRAYED CROP
Treat as normal. Avoid drift into headland. Use only safer aphicides.



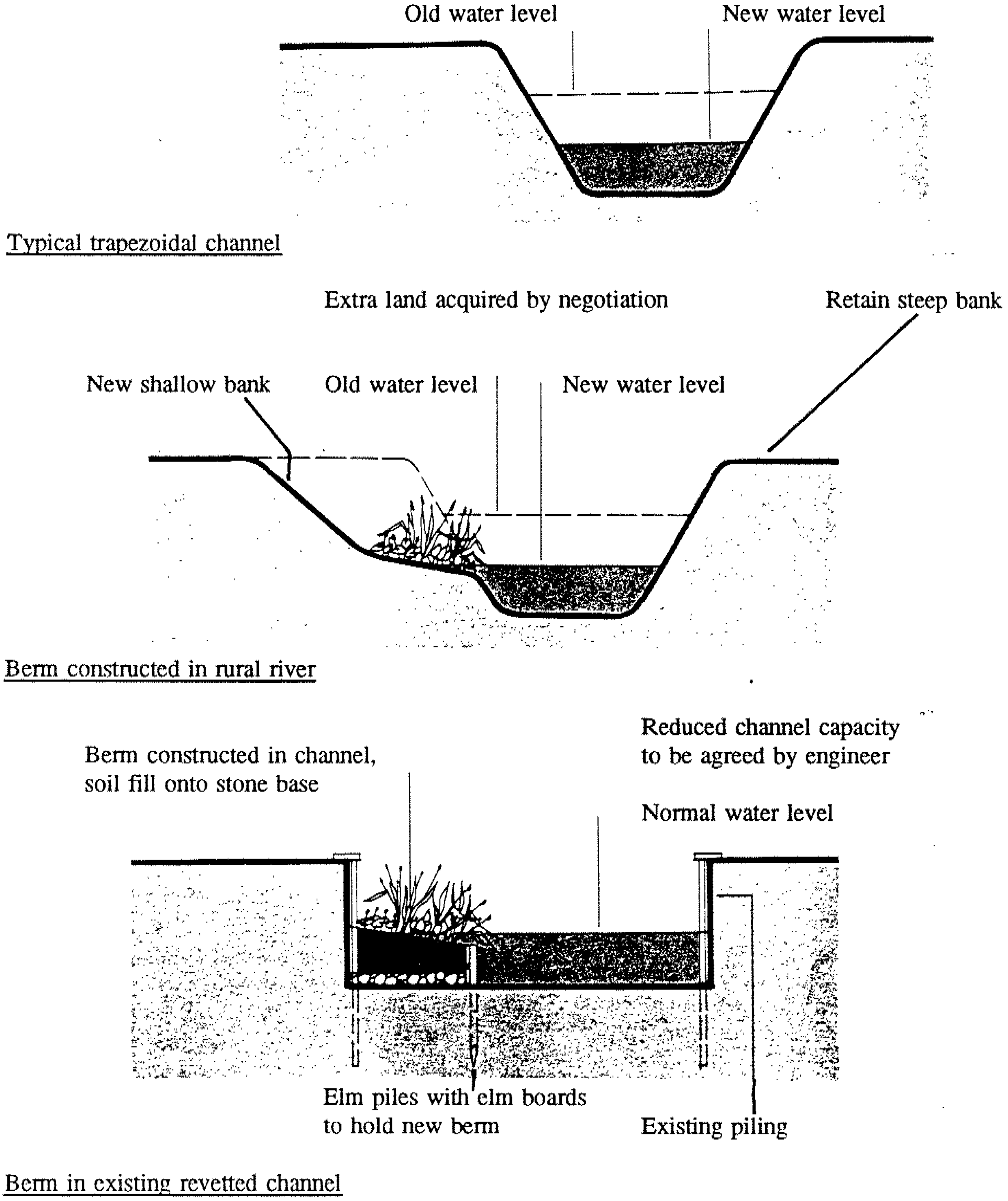
GRASSY BANK/NESTING STRIP
The area used for nest sites by gamebirds and for overwintering by beneficial insects. At least 1 m wide and preferably sited on a bank. Should be composed of perennial grasses and other non-weedy herbaceous species. Avoid spray and fertiliser drift into this area. Allow build up of dead grass material essential for successful nesting, but top the vegetation every 2-3 years to avoid scrub encroachment.

BOUNDARY OR STERILE STRIP
Purpose is to prevent invasion of crop by cleavers and barren brome where they have become abundant. Should be at least 1 m wide. Maintain by rotovation or herbicides (eg atrazine) in February/early March. Do not spray out grassy bank. Drill crop further out into the field to leave area of bare cultivated ground for the sterile strip. Avoid spray drift by shielding nozzle down to ground level. Not essential for conservation purposes, purely intended for weed management.

Wetlands and waterways

Wetlands and waterways (streams, canals, irrigation ditches) can be managed very effectively as linear habitats and wildlife corridors, as well as providing especially attractive facilities for recreation and education (Newbold *et al.* 1983). Where possible, natural waterways with the associated riparian habitats are to be encouraged. The structure of riparian habitats can be improved by ensuring that there is a succession of plants from the submerged level to the top of the bank. This may require restoration or creation of berms along some parts of the channel or stream (Figure 5.2).

Figure 5.2 **Creation of berms along river corridors.** From Newbold *et al.* (1983).



Budd *et al.* (1987) in North America felt that practical determinations of stream corridor widths could be made using a simple field survey of selected variables such as soil characteristics, vegetation, physiography and land-use characteristics. For example a 15 m corridor either side of a stream was adequate for a variety of wildlife whether or not the surrounding vegetation enclosed the stream. In Britain, in circumstances where plantations have been established around riparian habitats, there has been strong support for no planting of conifers close to stream edges. Ormerod *et al.* (1990), for example, found that for dragonfly habitats in plantations, bankside clearance of existing conifers along forest streams was not effective and broadleaved buffer strips were more useful. Consequently guidelines for the treatment of riparian zones have become a standard part of forestry prescriptions (Table 5.1) (Forestry Commission 1991).

Table 5.1 The treatment of stream sides in commercial plantations

- Establish broadleaved trees near watercourses.
- Maintain about half of the stream in full sunlight, the rest in dappled shade.
- Stop plough furrows well short of watercourses.
- Do not plough unnecessarily; consider scarifying or mounding.
- Maintain protective unplanted strips not less than 5 m wide on each bank.
- Keep branches and tops out of the stream.
- Design streamside edges in harmony with the landscape.

No general recommendation can be made about the width of the linear habitat created or maintained along a stream or river because it depends on the surrounding landscape and the role that the strip is to play. The more 'hostile' or distinct the adjacent land use, the wider the riparian strip should be if it is to function either as habitat or as a corridor. On a countrywide basis, however, riparian habitats along the many stretches of streams and rivers provide a whole network of linear features of importance to nature conservation as well as recreation and education.

Forest ride edges (verges)

Structure and width are two important features of ride verges in forest plantations, especially if the ride verges are to act as corridors as well as habitats for wildlife. For small animals, such as lizards, a mean width of 5.6 m between the ride edge and the plantation trees has been found to be optimal, but smaller widths are suitable if the ride verge vegetation is structurally complex (Dent & Spellerberg 1988). These conditions provide optimum amounts of sunshine throughout the summer for these reptiles. Considerable work has also gone into the design and management of ride edges for invertebrates, particularly for butterflies (Ferris-Kaan 1991; Greatorex-Davis *et al.* 1992; Warren & Fuller 1990) (Figure 5.3).