ROUTLEDGE
HANDBOOKS

The Routledge Handbook of Urban Ecology

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Landscaped parks and open spaces

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Introduction

Landscaped parks and open spaces in (sub)urban areas vary greatly in structure, extent, functions, history and management. They range from highly formal, carefully managed areas where access by people often is restricted, to parks that are largely sports grounds, or parks that are basically remnants of common land, woodland or open space. The character of urban parks also reflects their history, and thus also the ideas of their planners and designers, some of whom deliberately laid out formal areas or planted exotic species in a formal manner. They usually owe their societal importance to their location, close to densely populated areas. For people, parks and open spaces are oases of green, tranquility, relaxation and pleasure. Their size, which usually is a proxy for their habitat heterogeneity, makes them an essential component of urban green structure. They usually contain a considerable number of trees, but elements such as lawns, pastures, ponds, garden elements and related infrastructure are more dominant, while forest stands are often limited or even absent. So habitat variety often is high. Life forms range from the visually dominant trees to invertebrates and fungi. Plant and animal life are a mixture of naturally occurring and deliberately introduced species; an assemblage that changes in space and time. All this makes parks complex ecosystems that are difficult to comprehend, even more difficult to manage in an optimal way and to treat in a concise way as is the goal of this chapter.

Integrative concepts

Given the complexity of landscaped parks and open spaces, and their multifunctionality, integrative and adaptive concepts and approaches are required (see Gustavsson *et al.* 2004). One example of a highly integrative approach arises from the Ecopolis-concept of Tjallingii (1995), which is based on ecological and sustainability principles. According to the Ecopolis-concept, urban parks (UP) may be regarded as eco-device models with inputs and outputs – just like ecosystems. They may be presented as a triangle in which the three corners refer to areas, flows and actors. Each of these themes is managed according to a certain motto. The motto for the areas could then be the Living Urban Park (LUP) for the flows the Green Triangle UP and for the actors the Participating UP (Figure 23.1). The Living UP takes as its motto biodiversity in the broad

Figure 23.1 The ECOPOLIS concept (Tjallingii 1995) of urban parks.

sense, a complex system of which the number of species increases with the area and may easily run into thousands of species (see further). RUP management regulates flows, e.g. water flow, traffic and visitors, export of products (such as green waste), and this should be achieved in a responsible way. The third theme (Participating UP) refers to all users of the UP. This includes the main management actors, including UP managers and public authorities, visitors and other interest groups. All of these should participate in one way or another in order to meet both the multitude of functions and services and the need for communication of values, preferences and knowledge. In this way a sustainable system may be achieved.

The Ecopolis-concept thus strongly links to sustainability. One key question is therefore, how sustainable are parks? This is particularly important in terms of management, as ultimately the services and functions provided by parks will depend on it. Thus it is important to provide an overview of a possible, more sustainable, management system, before focusing on the nature of parks and thus mainly on LUP.

Developing sustainable management

What is sustainable urban park management?

Until recently, only little attention was given to the sustainable management of UP ecosystems. Of importance in that respect is the fact that management of urban parks has changed considerably since 1900. Higher labour costs, increasing throughout the twentieth century, have led to much more extensive management. Temporary green is used less frequently and variegated collections of plants, so typical for the nineteenth century gardens and park styles, have almost completely disappeared. The decrease in management intensity gave more opportunities for natural developments. Consequently, it is not surprising that the ecological aspects of urban greenspace management received much more attention after 1960.

The concept of sustainable development is usually described as a development that provides for the needs of the current generation without compromising the needs and possibilities of future generations (e.g. WCED 1987). Despite this definition, the implementation of the sustainability concept remains difficult. Translated to urban parks, sustainable management of UP could be described as aimed at long-term management of these complex habitats in order to perform their multiple functions also in the future. But what does that basically mean in practice?

Adaptation to local conditions

In order to maintain a desired park situation or 'scenery', a particular management is needed. Vegetation succession in a temperate climate leads to closed, forested landscapes in which trees dominate, and thus open habitats will need management if we want to keep them open. Furthermore, a natural forest may be far from the most desired given the multiple functions expected from urban parks and open spaces. In any case, long-term management is best guaranteed when current and future funding is secured. Management with minimal costs assumes that habitats can spontaneously exist and develop without much human help. As a result, the aim could be 'stable' communities where spontaneous processes of establishment of both animals and plants regulate community composition and only need minimal care. In general these communities will be well balanced, adapted to the local environmental conditions. They usually are characterised by a variety of native species that are part of fully developed local food webs. However, many non-native (plant) species can survive and even regenerate without much human help as long as they are adapted to local climate (e.g. frost hardy) and soil conditions. Exceptionally, they can even be the most suitable for urban conditions. Yet their food webs are less developed, as indicated by the lower number of insect species associated with exotic tree species (Kennedy and Southwood 1984). Exotic species may also cause great problems due to strong competitive ability, although this has so far been considered less of a problem in Europe than for instance in North America or New Zealand. But under climate change some of the exotics may become more aggressive and pest, disease and weed incidence may increase (for overview see Bisgrove and Hadley 2002).

The greatest biological diversity of plants, fungi and animals is associated with diverse vegetation which generally reflects a diverse environment. Indeed, particularly along gradual environmental gradients (e.g. light conditions or soil conditions) a variety of species-rich communities develop. Plant species composition then gradually changes and offers great opportunities for a variety of wildlife. This often contrasts strongly with the actual situation with sharp boundaries in UP. The steep banks of lakes and ponds only offer limited space for wildlife. Environmental diversity increases significantly if a gradual gradient from open water to land is created. For the same reasons, gradual transitions from grassland, via shrub to forest also offer a high biological diversity (Bradshaw *et al.* 1986). Furthermore the probability of long term survival of taxa is expected to be much higher when environmental gradients change slowly compared to steep gradients that offer little space and opportunities for biological diversity and adaptation.

Using natural processes and conditions

Ideally management should in a conscious way use the natural processes of spontaneous development of flora and fauna, and eventually take measures to increase the potential through directed, environmental interference. In practice, however, spontaneous development is not always feasible or desirable. For example, it may take decades before natural regeneration of trees will occur and develop in a way attractive to visitors. A high proportion of luck may be required in terms of desirable plants entering the area first (dispersal limitation). Additionally it may be that seed sources, essential to regeneration, are not even present nearby. As a consequence, sowing or planting may be required for regeneration or establishment of species. But native and locally indigenous genetic material should be preferred when possible as this probably offers the best 'fit' to local conditions. If one prefers exotic or non-indigenous species, it is essential to match the choice of species as closely as possible with these local environmental conditions (see Hansen and Stahl 1993). If this is not possible (e.g. with large collections of species on limited space) it

is preferred to adapt environmental conditions, i.e. mainly soil, but also light regimes so that the long term survival of exotic species is possible under minimal management. Those management measures taken to create good starting conditions are grouped under the heading of habitat creation and/or restoration (e.g. Buckley 1989).

Management continuity

Sustainable management also requires *continuity*. If management measures change continuously, the vegetation – mainly composed of perennial plant species – has no time to adapt to the new conditions and it will probably not reach the targets set by management plans, particularly in systems which include living organisms of great longevity (i.e. trees). Only few species adapt to frequent disturbance in combination with stress (Grime *et al.* 1988). Disturbance is considered here as any measure which destroys part of the whole vegetation and thus lowers the biomass. Stress is defined in this concept as any event causing a shortage or suboptimal condition of growth (e.g. shortage of nutrients or light).

In this view, management measures are considered as disturbances in as far as they destroy biomass. Annual ploughing or digging only allows ruderal plant species to persist, such as weeds on arable lands. Under conditions of low disturbance and high nutrients competitive species dominate (e.g. *Urtica dioica*), as in tall herb vegetation on river banks. Annual mowing of grassland with litter removal directs succession to the stress-tolerant and to some extent to the ruderal part of the spectrum. Thus the CSR-theory (Competitive–Stress tolerant– Ruderal) enables us to understand the effect of various management measures as well as the important vegetation processes of dominance and species coexistence (see Grime *et al.* 1988) in parts of urban parks where (semi-)natural communities are aimed at.

In order to achieve well-developed vegetation, it is important to maintain a chosen management regime or measure. Addition of species (e.g. bulbous perennials in grasslands, or forested parts) through planting may increase diversity and attractiveness if they manage to maintain viable populations (see e.g. Lloyd 2004). Usually this results in an increase of species diversity and stability of the community, both of which are favourable for achieving a more sustainable ecosystem. The management principle of continuity also assumes an a priori developed long-term vision or strategy for the UP management of a particular site.

Use of chemicals

The use of chemicals in managing vegetation should be avoided as much as possible, as serious objections to it can be brought forward from the perspectives of the environment, public health as well as wildlife. As many chemicals are not selective, they also affect other plants and/or animals than those aimed at. Wildlife (and in particular insects) may also suffer from the loss of food plants. Some specific pesticides may be needed – special situations (e.g. for the management of pavements or ruins), but in general they are not part of sustainable UP management.

Water and recreation management

Public urban parks serve recreational purposes, including walking, sports, and relaxing. Different recreational needs demand different types of infrastructure and may thus be difficult to jointly accommodate (e.g. horse riding, walking, mountain biking).

In order to meet recreational demands, at least minimal recreational facilities should be provided and maintained. The higher the recreational pressure, the more open pavements

can be, as trampling is a primary factor in controlling vegetation development. For a review of the ecological effects of recreation see Liddle (1997). Open or half-open hardening also enables precipitation to percolate. Run-off increases when the soil-surface sealing increases. Management respecting or enhancing water infiltration and retention is important particularly in urban environments. Water management in which infiltration, retention and restrictive water use facilities are sought is another integral part of UP management (cf. Tjallingii 1995; see Dunnett and Clayden 2007). All too often, water problems are 'exported' to neighbouring areas.

Biodiversity

Biodiversity has a multiscale content going from genes, species to habitat and ecosystems; biodiversity also contains structural and functional attributes at these four levels of organisation. Most often however, the biodiversity is approached at the species level. Then it can be measured as species richness or species diversity. The species diversity of urban and suburban habitats, including parks and gardens, can be extremely high (e.g. Loram *et al.* 2008), as is also illustrated convincingly by Owen (1991). Of the total species number for Great Britain (i.e. 1032 species) 21 per cent was observed over a 15 year period in a young 741 m² garden. Given this high biodiversity it is not easy to monitor it.

Papers looking at the biodiversity of urban parks are therefore often restricted to specific species groups, for example bats (Kurta and Teramino 1992), mammals (Chernousova 1996), arthropods (Natuhara *et al.* 1994) or birds (Morneau *et al.* 1999; Fernández-Juricic 2001).

Therefore it is justifiable to examine variation in habitats and habitat diversity in urban parks. This has the advantage, if defined accurately, of being easier to apply. Also habitats perhaps incorporate better some threats to biodiversity, such as fragmentation, habitat loss and habitat change through management (Maddock and Du Plessis 1999).

Habitat units as templates for biodiversity

To determine habitat diversity in an efficient way, a list with all possible habitat units in parks is essential (Table 23.1). Although made for the parks in Flanders, Table 23.1 is useful to other parts of the temperate world. Each unit has to be unambiguously defined leaving no confusion about its delineation in the field. Because each habitat unit is measured differently and it impacts the architectural design of an urban park in a different way, a distinction should be made between punctual, linear and planar elements (Hermy and Cornelis 2000). The planar elements include inter alia different types of woodland, plantings, grassland and gardens, ponds and buildings. Alleys and different types of hedges, verges, rides, watercourses and riverbanks are the most important linear elements. The punctuating elements include single trees, pools, icehouses and some other infrastructure elements.

Geographical Information Systems (GIS) combined with aerial photographs, or even remote sensing, are powerful tools for quantifying the amount (e.g. number, area, length) of these habitat units, to be used in diversity measurements and for displaying purposes such as the distribution of certain habitat units and/or species, eventual overlaying with knowledge system building, management, and planning. In a study of 15 suburban parks in Flanders we found a positive correlations between habitat diversity and the number of plant taxa, breeding birds and amphibian species, but not with butterfly species richness (Figure 23.2a) (Cornelis and Hermy 2004). It also became clear that total park area is not necessary positively correlated with species richness (Figure 23.2b).

Table 23.1 List of habitat units distinguished in (sub)urban parks in Flanders; for coding purposes each element has a unique number (in brackets)

1 Planar elements

- 1.1 Forest stand: unit composed of a more or less natural forest vegetation
 - 1.1.1 deciduous wood: forest stand of deciduous trees
 - 1.1.1.1 coppice: forest stand of regularly cutted thickets (1)
 - 1.1.1.2 coppice with standards: forest stand of regularly cutted thickets and upper trees (2)
 - 1.1.1.3 park wood: forest stand of single trees with ligneous undergrowth (3)
 - 1.1.1.4 leafy, regular high forest: forest stand of regular high deciduous trees (4)
 - 1.1.2 coniferous wood: forest stand of conifers (5)
 - 1.1.3 mixed wood: forest stand of deciduous and coniferous trees (6)
- 1.2 Plantation: unit composed of planted trees
 - 1.2.1 orchard: enclosed unit planted with fruit trees (7)
 - 1.2.2 forest grassland: grassland planted with forest trees (8)
 - 1.2.3 tree gallery: linear plantation of trees without undergrowth (9)
 - 1.2.4 arboretum: plantation of different tree species with an educational function (10)
 - 1.2.5 forest plantation: plantation of forest trees (<3 m) (11)
- 1.3 Labyrinth: unit composed of close hedges in labyrinth form (12)
- 1.4 Shrub plantation: unit composed of shrubs (13)
- 1.5 Grassland: unit composed of grass species
 - 1.5.1 lawn: frequently mown grassland (14)
 - 1.5.2 sports field: frequently mown grassland used as sports ground (15)
 - 1.5.3 hay meadow: grassland used to make hay (16)
 - 1.5.4 pasture: grassland grazed by animals (17)
 - 1.5.5 hay-pasture: grassland that is grazed after hay-making (18)
- 1.6 Tall herb vegetation: unit composed of rough herbs, inclusive reed vegetation (19)
- 1.7 Heathland: unit composed of dwarf shrubs (20)
- 1.8 Agricultural area: unit composed of arable crops (21)
- 1.9 Fallow land: temporary unit composed of fallow ground (22)
- 1.10 Garden: enclosed unit composed of vegetables, fruit or ornamental plants
 - 1.10.1 kitchen garden: garden composed of vegetables and fruit (23)
 - 1.10.2 herb garden: garden composed of medicinal herbs (24)
 - 1.10.3 rose garden: garden composed of roses (25)
 - 1.10.4 ornamental garden: garden composed of other ornamental plants (26)
- 1.11 Ornamental plantation: non-enclosed unit composed of ornamental plants (27)
- 1.12 Water feature: unit composed of water
 - 1.12.1 castle-moat: water feature round a historical building (28)
 - 1.12.2 pond: water feature free from each building (29)
- 1.13 Building: unit composed of buildings, inclusive the limited space between the buildings (30)
- 1.14 Car park: unit composed of parking places for vehicles
 - 1.14.1 half-hardened: parking with a hardening that is not completely sealed (31)
 - 1.14.2 not hardened: parking without any hardening (32)

2 Linear elements

- 2.1 Alley: double or four-double row of trees, including the verges (33)
- 2.2 Tree row: row of trees (34)
- 2.3 Hedge: linear woody vegetation
 - 2.3.1 sheared hedge: hedge that is regularly sheared (35)
 - 2.3.2 non-sheared hedge: hedge that is not sheared (36)
 - 2.3.3 woody embankment: hedge on an embankment created by humans (37)
- 2.4 Road verge: non-hardened strip along a road (38)

- 2.5 **Bank**: strip of land on each side of a water feature or a watercourse
 - 2.4.1 **bank of a water feature**: bank of a castle-moat or pond
 - 2.4.1.1 **natural**: bank not consolidated by humans (39)
 - 2.4.1.2 **semi-natural**: bank consolidated by humans where vegetation is still possible (40)
 - 2.4.2 **bank of a watercourse**: bank of a ditch, brook or river
 - 2.4.2.1 **natural**: bank not consolidated by humans (41)
 - 2.4.2.2 **semi-natural**: bank consolidated by humans where vegetation is still possible (42)
- 2.6 **Watercourse**: linear element used for the discharge of water
 - 2.6.1 **ditch**: watercourse with a width of max. 1 m that may contain water (43)
 - 2.6.2 **brook**: watercourse with a width of max. 3 m that always contains water (44)
 - 2.6.3 **river**: watercourse with a width of more than 3 m (45)
- 2.7 **Road infrastructure**: strip used and prepared for pedestrians and service traffic
 - 2.7.1 **road**: road infrastructure with a width of more than 2 m
 - 2.7.1.1 **half-hardened**: road with a hardening that is not completely sealed (46)
 - 2.7.1.2 **not hardened**: road without any hardening (47)
 - 2.7.2 **sunken road**: sunken road infrastructure, including the verges (48)
 - 2.7.3 **path**: road infrastructure with a width of less than 2 m
 - 2.7.3.1 **half-hardened**: path with a hardening that is not completely sealed (49)
 - 2.7.3.2 **not hardened**: path without any hardening (50)
- 2.8 **Wall**: linear masonry used as enclosing (51)

3 Punctual elements

- 3.1 **Single tree or shrub**: tree or shrub not surrounded by other trees or shrubs (52)
- 3.2 **Pool**: small, shallow, stagnant water $\leq 100\text{m}^2$ (53)
- 3.3 **Icehouse**: house where ice was kept (54)
- 3.4 **Tumulus**: burial mound (55)
- 3.5 **Infrastructure element**: human construction (well, fountain, kiosk, chapel, monument, statue, bridge, aviary...) (56)

Source: Hermý and Cornelis 2000.

Species diversity

As species diversity may be great even in urban habitats (see Table 23.2), monitoring needs to be restricted to some groups. Many possibilities are open here. Yet all will probably include (vascular) plant species as the latter determines the architecture and structural variation in urban parks, they are usually also well known and they offer a variety of ecological niches to animal species and services to people. Additionally urban parks traditionally have high botanical and/or horticultural values. Lists should therefore preferably include indigenous, naturalised and exotic species, including intraspecific taxa and varieties. But most plants have relative long generation times and therefore often possess a time lag in responding to environmental changes. The latter makes them less suitable for monitoring purposes.

As water plays an important landscape role in parks and attracts wildlife, water ponds should be included e.g. by studying amphibians or invertebrate populations. Through their amphibian lifestyle many of these animals both incorporate terrestrial and aquatic habitat qualities of the park. Amphibians are very sensitive to environmental stress factors. As invertebrates easily take up more than 50 per cent of the total species richness on earth some groups should be included for monitoring purposes. They usually have short life cycles and high habitat specificity, which makes them potentially sensitive for monitoring changes. Butterflies are such a group. They quickly respond to changes in the structure, configuration and botanical composition of habitats, their taxonomy is well known and they can be monitored relatively easily. As with all more

Figure 23.2 Diversity relationships in 15 (sub)urban parks in Flanders (Belgium). (a) the relationship between habitat diversity (number of habitat units, cf. Table 23.1) and number of species in vascular plant species ($y = 5.6238x$, with x number of habitat units; $R^2 = 0.40$), breeding bird species ($y = 1.0837x$; $R^2 = 0.25$), number of amphibian species ($y = 0.2053x - 2.0331$; $R^2 = 0.40$) and number of butterfly species (not sign. correlation); (b) the relationships between park area and species richness in various taxa (equation for plant species = $y = 41.194\ln(x) + 12.265$; $R^2 = 0.76$).

Table 23.2 Park area and biodiversity characteristics for 15 (sub)urban parks in Flanders (calculated from Cornelis and Hermly 2004)

Characteristic	Average (SD)	Cumulative total	Saturation % ¹
Park area (ha)	27.9 (±24.12)	418	–
Number of plant taxa	136.7 (±35.12)	497 ²	29.9 ³
Number of butterfly species	14.8 (±2.65)	82	48.5
Number of amphibian species	3.1 (±1.84)	28	38.9
Number of breeding bird species	26.2 (±9.91)	8	61.5

Notes

1 ratio between total observed number over all parks and the total number known from Flanders, multiplied by 100.

2 including introduced species; native and naturalised spp. = 393.

3 only for native and naturalised spp.

mobile species groups, they may not only respond to changes within urban habitats, but also to changes beyond these habitats. Birds integrate a number of features of urban parks (tranquillity, structure, age of trees, management, habitat heterogeneity). This group also contains a number of top-of-the-food-chain species (e.g. owls) and migratory songbirds.

Ecologically sound management measures

Urban woodland, tree-rich parts of parks, and shrub areas

Sustainable management should focus on maintaining a variety of functions, from timber production to nature conservation and not in the least recreation. Creating and maintaining an attractive and diverse woodland image for recreational purposes will mostly be the main goal. It should be kept in mind that with spontaneous forest development investment and cost are at their lowest. But amenity values may be lower as well, at least during part of the forest development cycle. Moreover, in case of arboreta, and also for many parks, spontaneous development is not possible or desirable. Yet even here, more nature-like forms of woodland management will keep costs at a minimum.

Apart from non-intervention, woodlands and wooded elements may be managed in a variety of ways. It has to be remembered, however, that radical changes in woodland management usually have large consequences, as many of the typical woodland species are typical for steady-state communities. Changes in woodland management practices therefore can only be implemented over longer periods of time, and consequently also here management continuity is an important principle. It also means, however, that traditionally managed parts, such as coppice or coppice-with-standards (Buckley 1994) or high forest should be maintained or only gradually changed. This is particularly true where these traditional forms of management have resulted in valuable plant communities, often indicated by abundant carpets of spring flowers (e.g. *Scilla non-scripta*, *Anemone nemorosa*). Coppice cycles usually are in the order of 10–20 years, while shorter and longer cycles are possible. Cut lots can be distributed in time and space over the forested area. This will generate a variety of regeneration stages, each of which will be associated with typical wildlife, and which is motivated by aesthetic reasons as well. Cycles for standards are usually longer than 100 years. For an overview we refer to Buckley (1994).

When aesthetical, social or ecological values of coppice or coppice-with-standard systems are low, it is better to convert these woodlands to some form of high forest that requires less cost and is closer to nature. Most sustainable forest management mimics nature.

Urban parks usually have no production function, although the value of timber may contribute to compensating management costs. Yet old and dead trees support a wide variety of wildlife; heavy wood debris in particular is highly valuable for many animal species and fungi, and old trees serve bird species and even bats. Old trees thus should be maintained as long as possible if the safety of visitors allows this.

Water and bank vegetation

Many urban woodlands and parks contain bodies of water. These serve a variety of functions, including water and fish production and providing amenity values. Sustainable management should aim to develop a gradual transition from water to land, thus creating smooth gradients from inundated and wet to drier conditions (see above). Large fish or waterfowl populations do not match large populations of hydrophytes. Management of the terrestrial part of the water 'ecotone' may involve an annual or biannual mowing regime. Moss (2010) has provided an overview of fresh water ecology. Even if hard edges cannot be removed, some form of mitigation is usually possible, for example through stepping stones from the water or shallow water.

If reed marshes are present, management will usually involve a winter or autumn mowing regime with litter removal. This will usually result in vital reed marshes with considerable plant species richness. Autumn mowing can also be combined with bird conservation, as it yields shelter through reed re-growth in spring. Mowing from the ice during winter – where winter freezing occurs – may be the only easy way of working; fortunately reed needs not to be managed every year. Wet meadows (e.g. with *Caltha palustris*) or tall herb communities (e.g. *Filipendula ulmaria*, *Epilobium hirsutum*) usually are best mown every 2–5 years, in late summer or early autumn. During this time of year the ground water table is usually at its lowest. If not managed these areas will develop into willow shrub and/or ultimately into some form of black alder (*Alnus glutinosa*) forest.

Hydrophytes such as *Nymphaea alba* and *Nuphar lutea* may generate impressive 'pictures' greatly enjoyed by people. But apart from these flagship species many other smaller species may be present as well. Water plants will only thrive when they obtain sufficient light, so shade-covered ponds are usually poor in wildlife. Managers of urban woodlands and parks should also take all necessary measures to ensure the best water quality possible. This may involve the creation of helophyte water purification systems. As time passes all water bodies – and particularly shallow ones – will gradually turn into land. Succession will ultimately result in willow and alder marshes. With this in mind water bodies need cleaning from time to time. This will reverse succession into the open water phase.

Grasslands

Grasslands, including lawns, are often an important part of urban parks and woodlands, and therefore they need specific attention. However, lawns that are not frequently used, apart from the edges along paths, are best replaced by meadows. These are mown once or – in case of heavily fertilised soils – twice a year during early summer and a second time late summer or early autumn. A properly managed meadow flowers, apart from a short period after mowing, almost continuously from spring to autumn (Ash *et al.* 1992). As hay or freshly cut grass is removed, the regeneration niche and ultimately the coexistence of many plant species is assured (cf. Grime *et al.* 1988). To reach greater amenity values naturalised – originally non-native – plant species may be introduced (often geophytes e.g. *Narcissus* spp., *Camassia* spp., *Crocus* spp.). Most of the spring flowering species are found on richer soils, so for a sustainable result selection should follow local

environmental conditions. Hill *et al.* (1999) and Hansen and Stahl (1993) provide comprehensive reviews of the habitat requirements of plant species. Excellent examples include the meadows of Great Dixter in Sussex, England (Lloyd 2004). In order to replace species-poor grassland on nutrient-rich soils litter should always be removed and no fertilising allowed. Through mowing with litter removal the number of more stress-tolerant species increases gradually, allowing for greater coexistence of a large number of plant species (Grime *et al.* 1988). Hay-making is preferred to the immediate removal of the litter as it enables larger seed dissemination, although direct removal of litter may be less expensive. The application of this mowing regime will also considerably reduce the annual biomass production and thus will reduce the cost.

Particularly around the edges of forested parts it can be essential to mow the grassland only once every 2–5 years. This will allow for the development of specific woodland edge vegetation, creating valuable habitats for plants but also for butterflies and other invertebrates. Structurally this allows for a more gradual transition towards forest habitats and thus creating a gradual environmental gradient, where light intensity but also air humidity and other factors slowly change.

In this concept lawns are limited to gardens, to the edge of paths or to places frequently used by visitors for activities such as picnicking and playing. Along paths lawns make gradients of height more gradual. But even on lawns spontaneous processes of germination and establishment may occur. If lawns are mown regularly, litter is removed each time and no fertilisation is applied, gradually more species and particularly more herbs such as *Bellis perennis*, *Veronica filiformis*, *Trifolium repens*, and *Hypochaeris radicata* will establish.

More competitive species occur along the edges of forests, in the transition from grassland to woodland, on open, not frequently managed areas, along ditches, rivers and ponds. Often vegetation with large herbaceous plant species is flower-rich (e.g. *Hypericum perforatum* and *Teucrium scorodonia* on nutrient-poor and dryer sites). Through their structure, these species are highly significant for wildlife: as nectar or food source for many insect species, as refuge for small animals, hibernation sites for invertebrates, as food sources for singing birds, and so forth. Unwanted species may be of great importance for invertebrates. *Urtica dioica* is an important food plant for butterfly species such as *Vanessa atalanta*, *Inachis io*, *Araschnia levana*, *Polygona c-album* and *Aglais urticae*. To maintain tall herb vegetation, mowing is required once every 2–5 years. Mowing intensity is lowest on poor soils. Most of the tall herb species – all related to the competitive plant strategy – are not well adapted to annual mowing regimes, at least during summer. When they are mown annually with removal of litter, grasses and other smaller plant species will take over (cf. Grime *et al.* 1988) and plant species diversity will increase. Mowing within urban parks is best distributed in time and space. This will yield seasonal peaks and an outdrawn flowering season to enjoy, through various phases of re-growth, and thus also shelter and food for a variety of wildlife.

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