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# Towards a monitoring method and a number of multifaceted and hierarchical biodiversity indicators for urban and suburban parks

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**Abstract**

In this paper we develop a method for the general monitoring of the biodiversity in (sub)urban parks. The method works along two lines, that of habitat diversity and that of species diversity. On the habitat level we measure the diversity in so called 'habitat units'. These units are divided in planar, linear and punctual elements. For each category we calculate a Shannon–Wiener diversity index and a saturation index. The latter is the ratio of the diversity index compared to the maximum diversity possible. On the species level we use the species number and diversity index of vascular plants, as measured in random sampling plots of 100 m$^2$ (for trees and shrubs) and 4 m$^2$ (for herbaceous vegetation). In addition, we also use the species number of butterflies, amphibians and breeding birds. These numbers are compared with the total species number in Flanders, resulting in a saturation index per park for butterflies, amphibians and breeding birds. In this way 20 biodiversity indicators are obtained. The proposed method was applied to the municipal park of Loppem (West-Flanders, Belgium), from which the necessary time budget has been calculated. Since it is the first application of a new method and no reference to other parks is available, the proposed bioindicators have been compared with criteria given in the literature on the selection of biodiversity indicators. 

*Keywords:* Monitoring method; Biodiversity indicator; Urban parks

## 1. Introduction

Biodiversity has a multiscale content going from genes, species to habitat and ecosystems (Noss, 1990; Raven, 1992); additionally biodiversity also contains structural and functional attributes at these four levels of organization (Noss, 1997). Most often however, the biodiversity measurement is approached at the species level. Then it can be measured as species richness or species diversity (Magurran, 1988). The species diversity of (sub)urban habitats, including parks and gardens, can be extremely high (cf. Gilbert, 1989), as is illustrated convincingly by Owen (1991) studying a young, 741 m$^2$ garden: 1032 species (21% of the total for Great Britain) were observed within a 15 year period.

Keeping in mind the constraints of cost and knowledge only a small portion of a habitat and of the total species diversity can be measured adequately. There are never the resources or the expertise available to survey the total biodiversity of an area (Pharo et al.,

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1999). Therefore, multiscale and rapid assessments of species diversity (Stohlgren et al., 1997) as well as the extent to which one group of organisms (e.g. plant species) can function as a surrogate for less well-known groups (e.g. bryophytes, invertebrates) (Noss, 1990; Crisp et al., 1998; Pharo et al., 1999) become important.

Despite the ongoing debate on the usefulness of the biodiversity concept (e.g. Jutro, 1993; Haila and Kouki, 1994; Stork and Samways, 1995), there is a growing interest in biodiversity indicators (Noss, 1990; Nelson and Serafin, 1992; McKenney et al., 1994; Angermeier, 1994; Hawksworth, 1996; Noss, 1997; Prendergast, 1997). Because biodiversity is multifaceted and hierarchical, indicators that we select for monitoring should ideally represent all of this complexity (Noss, 1990). This is scientifically a huge and challenging task, but probably an unfeasible one. However, good indicators should at least fulfil a number of criteria (Noss, 1990; Pearson, 1996) and should not be focusing on one hierarchy or facet (McKenney et al., 1994). In that respect habitat diversity may play a prominent role in the determination of species richness, since there is often a positive correlation between habitat diversity and species diversity (cf. Hobbs, 1988; Rosenzweig, 1995; Honnay et al., 1999). So habitat heterogeneity, may be a good starting base for the development of biodiversity indicators. It 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, habitat change through management,... (Maddock and Du Plessis, 1999).

Until now most studies on biodiversity are concerned with forests or other (semi-) natural habitats. No studies seem to be available for urban parks. The causes for this are diverse: (1) biodiversity indicators are a relatively recent issue; (2) (sub-)urban parks are highly complex, with a mosaic of quite different habitats (forest, scrub, hedgerows, wood pasture, pasture, lawns, gardens, ponds, buildings, roads and paths, ...) (Gilbert, 1989); (3) urban parks have a multifunctional goal, of which biological conservation is often only a minor, but a growing, one; (4) following the multifunctional significance, (sub-) urban park managers usually do not have a tradition in managing for nature conservation; recreation, cultural and aesthetic values, often better served with exotic species, are considered far more important; (5) conservation has focused on native plant and animal species or biological integrity (Noss, 1990) and exotic species often have considerable importance in parks.

The purpose of this paper is therefore to develop a scientifically sound but practical method for the monitoring of (part of) the biodiversity in (sub-)urban parks, that takes into account the multiscale and complex habitats that parks usually are, with respect for the multifunctional nature of parks. A two-stage approach is followed: one focusing on species diversity and the other starting from habitat diversity. To assess the feasibility of the method, it was applied to a pilot project, namely the municipal park of Loppem (West-Flanders, Belgium). Since it concerns the first application of a new method, the time needed for the survey was monitored in detail. We aim at a scientifically sound monitoring method that is capable of assessing changes in the structure and species composition of parks caused by management or other environmental influences. It should also yield detailed distribution maps of species and habitats and thus be able to serve as a good starting point for management plans using modern tools like GIS.

## 2. Methods

### 2.1. General approach

The method focuses on two lines, that of species diversity and that of habitat diversity. A complete inventory of all species is impossible and the definition of habitat types is not simple, since it depends on the comparison of species lists and/or on the selection of otherwise important ecological variables. Both, species and habitat should be clearly defined and measurable in a clear, feasible way. They also should reflect the values and functions the society attaches to (sub)-urban parks (what are important elements in it?). To us this means that other than strictly natural elements should be incorporated in the development of a biodiversity indicator for (sub)urban parks, at least in so far as they affect biodiversity. The value of an (sub)urban park is influenced both by indigenous and exotic species (including their cultural varieties). The value of cultivated species and species which are economically important is recognized at least indirectly in the Convention on biological diversity (Art. 7 & annex I). Therefore, the exotic species and their varieties were included in the species diversity measurement.

## 2.2. Habitat unit diversity

To determine habitat unit diversity in an efficient way, we composed a list with all possible units that can be found in (sub)urban parks. This list (Table 1) is the outcome of a discussion with the Forest and Green Spaces Division of the Ministry of Flanders. It is meant for parks in Belgium, although it will also be useful for other parts of Europe. 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, we distinguished between punctual, linear and planar elements. Planar elements are expressed in area

Table 1
List of habitat units distinguished in (sub)urban parks in Flanders

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 dwarfshrubs (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)

Table 1 (*Continued*)

| |
|---|
| 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 wooden 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. *wooden 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 |
| 2.5.1. *bank of a water feature*: bank of a castle-moat or pond |
| 2.5.1.1. *natural*: bank not consolidated by humans (39) |
| 2.5.1.2. *semi-natural*: bank consolidated by humans where vegetation is still possible (40) |
| 2.5.2. *bank of a watercourse*: bank of a ditch, brook or river |
| 2.5.2.1. *natural*: bank not consolidated by humans (41) |
| 2.5.2.2. *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 >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 >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 <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 $\leq 100$ m$^2$ (53) |
| 3.3. *Icehouse*: house were 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) |

(m$^2$), linear elements in length (m) and punctual elements in a number. The area of planar elements and the length of linear elements have been computed from a digitized map, using a Geographic Information System (we applied Arc/Info and ArcView for this). GIS gives the additional advantage of being very appropriate for displaying certain aspects, e.g. the distribution of certain habitat units and/or species, eventual overlaying, knowledge system building, management, planning, etc.

When making a list with habitat units, we only took those elements into account that may be important for the biological diversity. Infrastructure elements like artificial banks, furniture, roads (carriageway) or car parks with a closed asphalt pavement do not contribute to the biodiversity of an urban park. Therefore, these elements were omitted from the list. But the method does not alter fundamentally when including them. Buildings are listed because they may be important for spontaneous wall vegetation or façade covering. Since only the area of their base is measured, their effect remains relatively restricted compared to the other planar elements (e.g. lawns, forested islands, and scrub). The same reasoning is valid for the punctual elements: single trees and shrubs are much more found and have therefore a much higher proportion than the distinguished structural elements.

The composed list contains 56 habitat units: 32 planar; 19 linear; and 5 punctual park elements (Table 1). 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. Since the latter also have a certain width, they strictly spoken, also belong to the planar elements. Therefore, an element is said to be linear when its ratio length/width is more than 10. The punctual elements include single trees, pools, icehouses and some other infrastructure elements. Here also, these punctual elements have an area. However, we arbitrarily limited the maximum area of punctual elements to 100 m$^2$, above which they were considered as planar elements.

Using field information and/or detailed aerial photographs, the delineation of planar, linear and punctual elements was determined. After digitising, we computed their area, length and number. From these data the proportion (%) of the total area, length or number of habitat units in the urban park was calculated. With these proportions the habitat unit diversity was computed (in Excel 7.0) using the Shannon–Wiener diversity index ($H$), one of the most popular diversity indices (Begon et al., 1996).

$$H = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where $i$ is $i$th habitat unit, $s$ the number of habitat units, $n_i$ the area, length or number of the $i$th habitat unit, $N$ the total area, length or number in the park.

In this way, we obtained a diversity index for each habitat type category (punctual, linear and planar). The value of the diversity index depends on both the number of habitat units found in the park and the evenness (equitability) with which habitat units are distributed over the park. Because a Shannon–Wiener diversity index for only one park is not very meaningful, we made the ratio between the calculated diversity indices and the maximum potential diversity. The latter is reached when all concerned habitat units (Table 1) are present in the park and each with the same area, length or number. The total number of distinguished habitat units is needed to calculate the maximum Shannon diversity index:

$$H_{\max} = -\ln \frac{1}{s_{\max}} = \ln s_{\max}$$

where $s_{\max}$ is the total number of distinguished habitat units.

Table 2
Maximum potential Shannon–Wiener diversity ($H_{\max}$) for three categories of habitat units in (sub)urban parks in Flanders

| | Maximum number ($s$) (see Table 1) | $H_{\max}$=ln $s$ |
|---|---|---|
| Planar elements | 32 | 3.47 |
| Linear elements | 19 | 2.94 |
| Punctual elements | 5 | 1.61 |

The ratio $H/H_{\max}\times 100$ gives the percentage of the maximum diversity for planar, linear or punctual elements. Since we are using the total number of all possible habitat units for all parks in a region (e.g. Flanders), we interpreted this ratio as a '*saturation index*'. $H_{\max}$ remains the same for all parks in Flanders. The respective values of $H_{\max}$ for planar, linear and punctual elements are given in Table 2. The saturation index is an easy way to express the diversity as a percentage of a maximum.

The total saturation index ($S_t$) for all habitat units together is calculated as the weighted average of the three separate indices. Weighting is done using the number of recorded units in the park:

$$S_t = \frac{S_{pl} n_{pl} + S_{li} n_{li} + S_{pu} n_{pu}}{n_t}$$

where $S_{pl}$ is saturation index of planar elements, $n_{pl}$ the number of planar elements, $S_{li}$ the saturation index of linear elements, $n_{li}$ the number of linear elements, $S_{pu}$ the saturation index of punctual elements, $n_{pu}$ the number of punctual elements and $n_t$ the total number of habitat units.

### 2.3. Species diversity

#### 2.3.1. Selecting the species groups

We propose four different species groups as an indicator for the biodiversity in parks. Besides vascular plant species (indigenous, naturalised as well as exotic species, including intra-specific taxa and varieties), we also used butterflies, breeding birds and amphibians. To some extent the choice is arbitrary, but arguments are briefly summarized here. All selected groups are relatively well known to the public and to policy makers.

The main points for including plants is that they make the architecture of urban parks, they are usually well known and they offer a variety of ecological niches to animal species. Additionally urban parks traditionally have high botanical and/or horticultural values. But most plants are relatively long-lived, have relative long generation times and therefore often possess a time lag in responding to environmental changes.

Butterflies were included because they quickly respond to changes in the structure and botanical composition of habitats. They are usually short-lived, have short generation times and comparatively high habitat specificity. Their taxonomy is well known and they can be monitored relatively easily (see, Ref. Wynhoff et al., 1992). Also, there is a contemporary trend to use insect species as indicators in stead of vertebrates (Pearson, 1996).

As water plays an important architectural role in parks and attracts wildlife, water ponds were included here by studying amphibians as a third group. Through their amphibian life style these animals both incorporate terrestrial and aquatic habitat qualities of the park (Blab, 1986). Like butterflies, amphibians are very sensitive to environmental stress factors (Noss et al., 1992).

Breeding birds integrate a number of features of urban parks (tranquillity, structure, age of trees, management, habitat heterogeneity). Furthermore, they usually are well known and do not pose identification problems (Boer, 1993). This group contains a number of top-of -the-food-chain species (e.g. owls), migratory songbirds, etc.

### *2.3.2. Plant species*

To determine the plant diversity in parks, a stratified random sampling scheme of the planar and linear habitat units was adopted. For herbaceous vegetation we used plots of 4 $m^2$ and for trees and shrubs (>1.30 m) we used plots of 100 $m^2$. Within each plot, we listed all vascular plant species that were present and the cover (%) was estimated using the decimal scale of Londo (1976). Eventually cover (%) may be substituted by presence/absence observations. To describe any wall vegetation or façade greening, the cover of those plants is expressed as the covered (%) of a vertical plane, which is the wall or the facade.

Since species richness and diversity usually increase with the area, the number of samples taken is proportional to the total park area. For trees and shrubs we investigated 1% of the total park area. That means that for a park of 25 ha 2500 $m^2$ must be surveyed or 25 samples of 100 $m^2$. For the herbaceous vegetation we arbitrary sampled 0.2% of the total area. For a park of 25 ha that means 500 $m^2$ or 125 samples of 4 $m^2$. We arbitrary proposed to assign 2/5 of these samples to the linear elements and 3/5 to the planar elements. Relatively many samples are assigned to the linear elements because these elements (banks, verges, . . .) often contain a high species diversity in response to rapidly changing ecological conditions over a small area. The number of samples is equally divided in relation to the proportion of the different planar or linear elements. Within each habitat unit, the samples were chosen at random. Plot form changed in relation to the type of element.

Since many herbaceous species are only flowering during a short period, the inventory of herbaceous plants was performed twice, once in spring and once in summer. The highest value for each species in the two sampling periods was used. From the estimated dominance-abundance of the plant species, the Shannon–Wiener diversity index was computed. For each species we used the average cover (%) of all plots. The diversity index of all plant species ($H_p$) can then be calculated as the weighted average of the index for trees and shrubs and the index for herbaceous plants:

$$H_p = \frac{H_{tr}n_{tr} + H_{he}n_{he}}{n_{tot}}$$

where $H_{tr}$ is diversity index for trees and shrubs, $n_{tr}$ the number of plots in woody vegetation, $H_{he}$ the diversity index for herbaceous plants, $n_{he}$ the number of plots in herbaceous vegetation, and $n_{tot}$ the total number of plots.

The number of indigenous and naturalized plant species in Flanders is 1279 (Cosijns et al., 1994). The number of exotic plants is not known, but is extremely high, as is suggested by, e.g., the RHS Plant Finder 1999–2000, which enumerates more than 70,000 species and cultural varieties. Due to the unknown number of exotic taxa, we did not calculate a saturation index.

### *2.3.3. Animal species*

Since censusing the importance (e.g. population size) of animal species is more time consuming (Sutherland, 1996) than for plant species, we only took the species richness for these animal groups as a biodiversity indicator. The method however does not fundamentally alter when using the abundance of the animals.

The species number of butterflies was determined in two ways. Firstly, all species that were seen during the field survey of the plants, were recorded. Secondly, we searched during one extra day per 12.5 ha for additional species. This happened on a sunny and warm day, because butterflies do not fly when it rains or when the temperature decreases under 20°C (Wynhoff et al., 1992). The butterflies are identified as much as possible on sight, so they do not have to be captured.

To determine the species number of breeding birds, we used existing data and complemented this by data of local ornithologists or local nature organizations. If not available, a variety of methods is possible to determine the species number (e.g. territory mapping) (see, Ref. Gibbons et al., 1996).

In the same way, we determined the species richness of the amphibians. Standard sampling procedures include trapping and netting (Halliday, 1996). Usually they have been monitored well in Flanders (Bauwens and Claus, 1997).

If we compare each of the observed species numbers with the total number of species in Flanders, we again computed a regional saturation index. In Flanders, there are at the moment 80 species of butterflies, of which 49 are indigenous (Maes and Van Dyck, 1996) and 13 species of amphibians (Bauwens and Claus, 1997). There are 169 different species of breeding birds, of which seven are exotic (K. Devos, personal communication). However, not all species found in Flanders, will be found in (sub)urban parks. If species lists for a high number of parks would be available, then these saturation indices could be calculated based on the total number of species observed in parks. Since no population sizes were recorded, we did not calculate the Shannon–Wiener diversity index for the animal species.

### *2.4. Pilot project*

We applied the proposed method to the municipal park of Loppem. This is an important and diverse historical neo-gothic castle park of 25 ha, situated ca. 10 km to the south of Bruges (West Flanders). Soils consist of a complex of sandy silt, clay and sandy soils with winter ground water table within 2 m of soil surface. In the previous century (1863) it was laid out for the largest part in the English landscape style (Barbier, 1986).

## 3. Results

The habitat unit survey yielded 31 habitat units out of the 56 possible units (Table 3, Fig. 1a). Taking into account the respective proportions of each unit, we calculated an average diversity index of 1.78. The linear elements have a high saturation index (73% of the maximum diversity), while the index of planar and punctual elements is only moderately high (50 and 42% respectively).

Table 3
Biodiversity indicators in the municipal park of Loppem

| Habitat units | Number of categories | Diversity index | Saturation index (compared to the maximum diversity in parks) |
|---|---|---|---|
| Planar elements (max=32) | 14 | 1.75 | 50.4% |
| Linear elements (max=19) | 13 | 2.15 | 73.0% |
| Punctual elements (max=5) | 4 | 0.68 | 42.0% |
| Total (max =56) | 31 | 1.78[a] | 58.8%[a] |
| Species groups | Species number | Diversity index | Saturation index (compared to the species number in Flanders) |
| Vascular plants | 134 | 3.23 | – |
| Butterflies (max=80) | 9 | – | 11.2% |
| Amphibians (max.=13) | 3 | – | 23.1% |
| Breeding birds (max=169) | 36 | – | 21.3% |

[a] Weighted average.

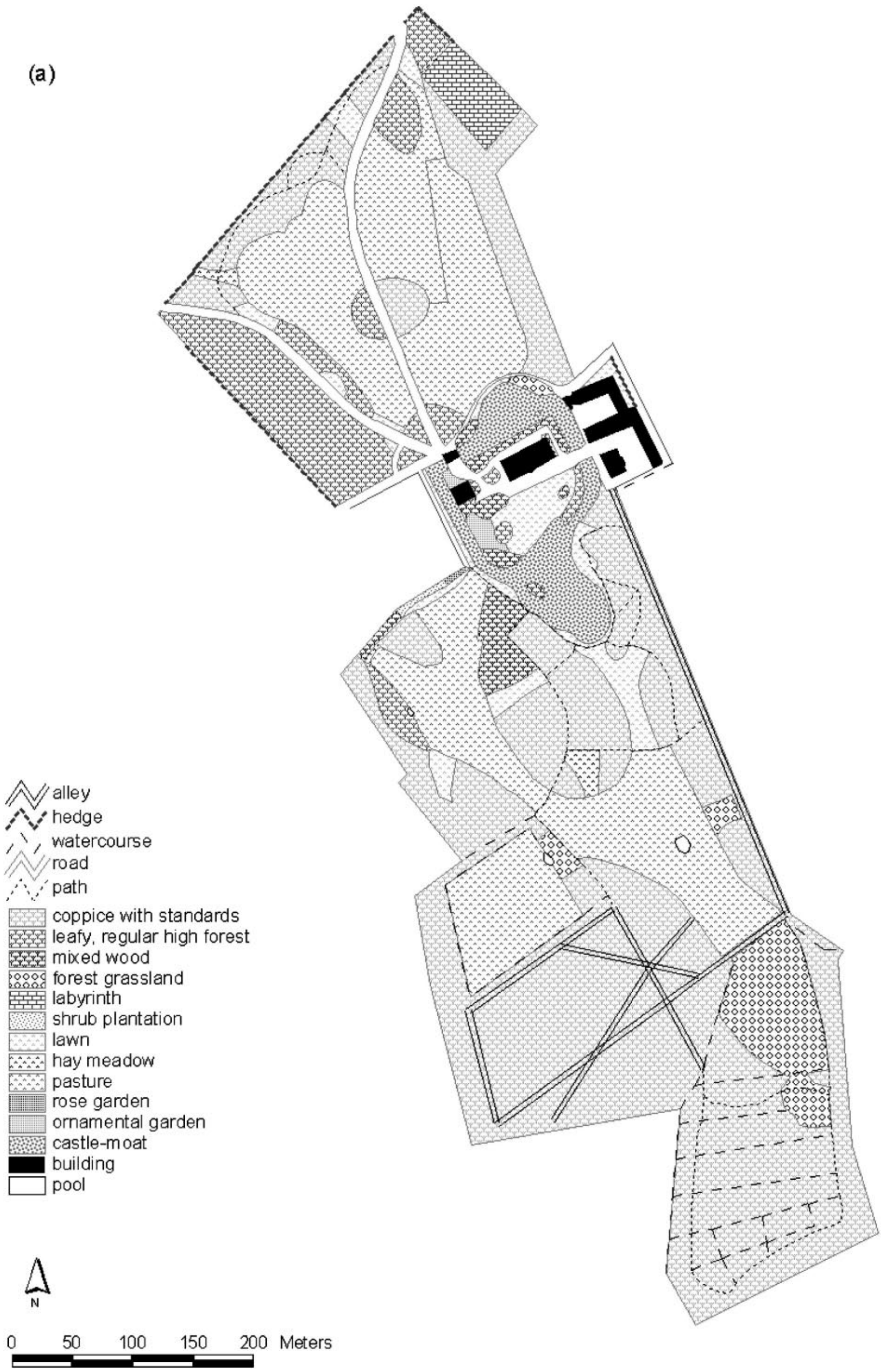


Fig. 1. The municipal park of Loppem with the surveyed habitat units (a) and the localisation of the plots for the inventory of trees and scrubs (large squares) and the herbaceous field layer (small squares) (b).

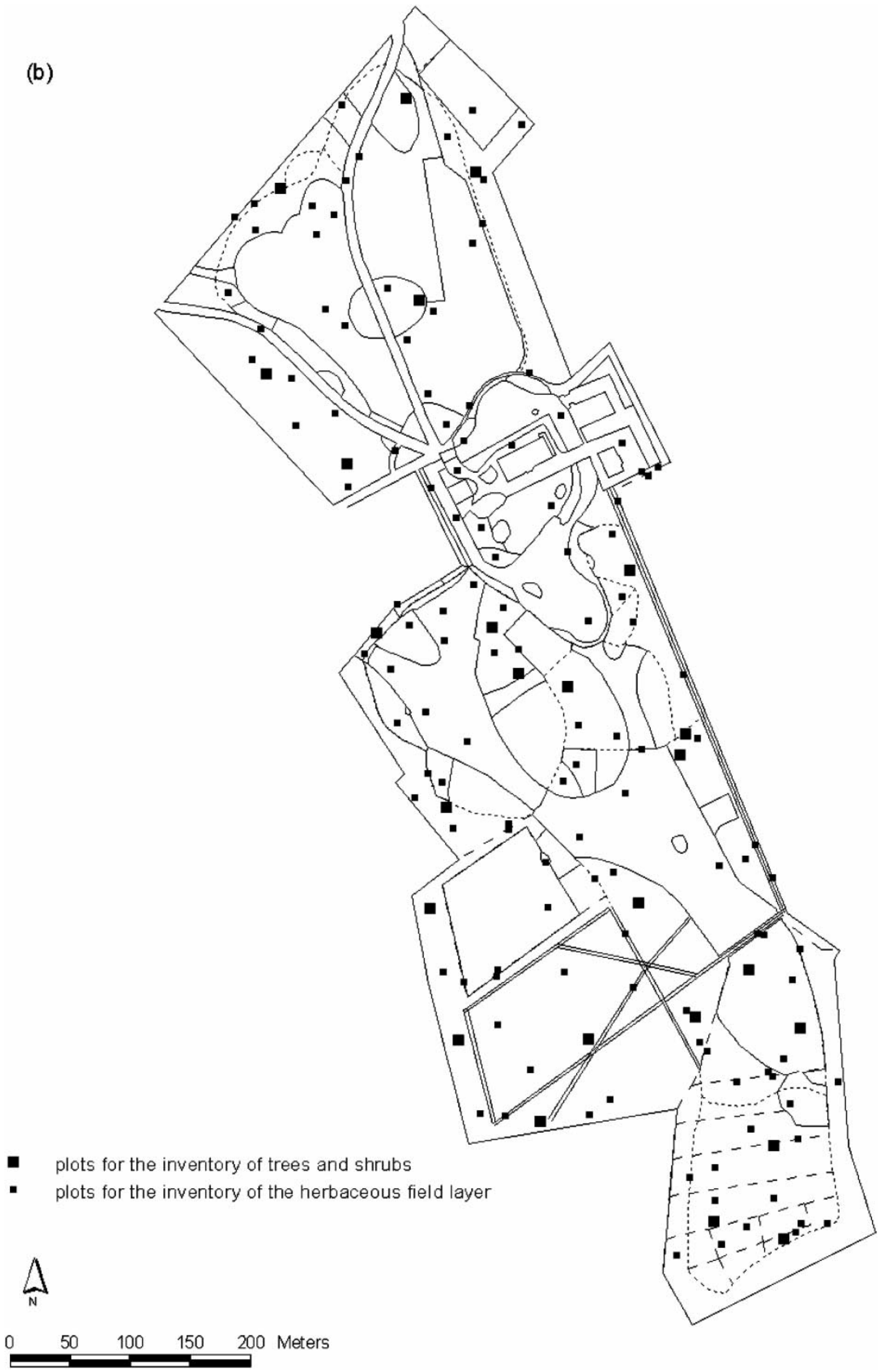


Fig. 1. (*Continued*).

Twenty-five plots of 100 $m^2$ in planar elements were used to survey the woody vegetation layer in the park (Fig. 1b). They range from forest stands, plantations of trees to plantation of shrubs (category 1.1, 1.2 and 1.4 in Table 1). The last type was not sampled with vegetation plots, since it was too small compared with the other units (<1/50 of the total area of forest stands, plantations of trees and plantations of shrubs). In total 36 tree species, two cultivars and one variety have been recorded. *Castanea sativa* (13.6%), *Acer pseudoplatanus* (12.5%) and *Quercus robur* (11.0%) have an average cover of more than 10%. The Shannon–Wiener diversity index ($H_{tr}$) is 2.70.

For the herbaceous field layer 125 plots of 4 $m^2$ have been used: 50 in linear and 75 in planar elements. Per habitat unit plots have been taken at random by drawing numbers of a grid with cells of 4 $m^2$ (Fig. 1). Hundred and sixteen species have been found. *Lolium perenne* (9.9%), *Anemone nemorosa* (4.7%), *Hedera helix* (4.1%), *Poa pratensis* (4.1%), *Holcus mollis* (3.4%), and *Rubus fructicosus coll.* (2.8%) reach the highest average cover in the park. The Shannon–Wiener diversity index ($H_{he}$) is 3.34.

In total, we recorded 134 vascular plant species (including intra-specific taxa) in the random samples. The weighted Shannon–Wiener diversity index ($H_p$) for the plant species is 3.23.

We have observed nine species of butterflies during the plant inventories and the two extra days, which is 11.2% of all species in Flanders. Three species of amphibians and 36 species of breeding birds can be found in the park. That is, respectively, 23.1 and 21.3% of all species of amphibians and breeding birds in Flanders.

The application of the developed method thus yields 20 biodiversity indicators for the park of Loppem (see Table 3).

## 4. Discussion

The tendency to manage urban and suburban parks for nature conservation raises questions concerning the biodiversity of these parks. The proposed method for measuring the biodiversity of parks works along two lines: habitat units and species diversity.

The first level was chosen because it is an inherent component of the biodiversity definition and secondly because it generally may be considered an important umbrella for species diversity (cf. Hobbs, 1988; Rosenzweig, 1995; Honnay et al., 1999). The method described here summarizes the park's biodiversity in an objective, standardized and repeatable way by means of biodiversity indicators. It may be used as a basis for monitoring parks over time and it yields an inventory of taxa and habitats. It may be a good basis for assessing the effects of management changes or to compare the habitat and species diversity of various parks and to tackle conservation problems. Taxa and habitats may differ in their objectives and therefore also in the priority of the criteria applied to potential indicator taxa (Pearson, 1996). For monitoring studies the priority is generally placed on sensitivity to environmental changes. The selected taxa all meet this criterion to some extent and any changes in area of the habitat units will be signalled immediately. The time needed to measure the population sizes of the animal species was considered too high an effort. So it was omitted, although it could easily — given more time — be incorporated in the diversity indices. The Shannon–Wiener diversity index was selected because it is widely known (Begon et al., 1996). If felt not appropriate other diversity indices may be chosen (see, Ref. Magurran, 1988).

Inventory studies record the distributional patterns of taxa or habitat units over geographical space. Georeferenced data are in this respect important for future monitoring. Although not directly visible, high priority for potential indicators was placed on rare, endangered species and habitats. About 40% of the involved species belong to Red data lists in Flanders. It is clear that our method has through the use of GIS tools the potential of yielding in an easy way distributional patterns of both taxa and habitats.

Sensitivity to changes in the park environment is only one criterion for a potential indicator taxon. Pearson (1996) suggested seven criteria to test objectively the indicator value of a taxon: (1) well known and a stable taxonomy; (2) well known biology and natural history; (3) readily surveyed and manipulated; (4) higher taxa broadly distributed geographically and over a diversity of habitat types; (5) lower taxa (e.g. species) specialised and sensitive to habitat changes; (6) patterns of biodiversity reflected in other taxa; (7) potential economic importance.

The taxonomy, the biology and life history of all selected taxa are well known and well-understood (criterion 1&2). Furthermore the recording of the involved taxa does not pose difficulties, nor is it difficult to learn (3). Yet the method is relatively time-consuming. The most laborious part of the whole procedure is the quantitative assessment of the plant species diversity. Based on the experiences in the park of Loppem, we are able to give a detailed summary of the time needed for the application of such a biodiversity measurement. Since the time budget of some activities depends on the park's area, we give an assessment in function of the area (Table 4). This estimate does not take into account the time needed for permanent marking or exact geopositioning of the plots. The park of Loppem is a relatively complex, but traditional 19th century castle park with a high diversity of habitat elements, so it is largely representative for many European parks. Criterion 4 and 5 are also met and the selected taxa include both generalists and specialists of various habitats. The 6th criterion is more difficult to judge. In general, we think that the selected taxa respond in a fairly similar way as other not recorded taxa to factors such as pollution, habitat degradation or management. In particular many animal taxa depend on the plant structure and plant species composition. Yet each taxon has an unique set of biophysical requirements and responses. The direct and indirect economic importance is clear (7). Many parks partly contain forested habitats, which may be important for forestry. All parks have an increasing recreational function of which the economic value may be estimated by the travel cost method (Adamowicz, 1991; Condon and White, 1994). Also they often contain collections of (exotic) plants and may incorporate gardens, which may have economic importance. More and more biodiversity is considered the issue where ecology and economy blend and there is now a well-established classification of the major categories of value from biodiversity with clearly defined use and non-use values (Edwards and Abivardi, 1998).

Although the selected species taxa largely fulfil the biodiversity indicator criteria of Pearson (1996), it is clear that other criteria (see, Refs. McKenney et al., 1994; Stork and Samways, 1995) are only partly met. As an example, non-vascular plant species (e.g. fungi) are not included. Their ephemeral character and the resulting time needed for recording full species lists argued their exclusion. Measures of stress in populations of species, toxic compounds in wildlife species, below ground species diversity, lichens were also not considered because of the time implications involved in monitoring them. In some studies the diversity in plant species was significantly correlated with that of bryophytes or lichens (Fensham and Streimann, 1997), but in others not (Pharo et al., 1999). The extent to which one group of organisms can function as a surrogate for less well-known groups remains a controversial issue. This is an important reason for not selecting one biodiversity indicator. Yet a pragmatic and feasible selection should be used. Also, one could criticize the classification of habitat units as adopted here. Yet these habitats are common

Table 4
Time budget for measuring the biodiversity in parks based on the experience in the municipal park of Loppem

| Activity | Time needed |
|---|---|
| Digitising the base map (=topographical map and/or orthophoto) | 1 day |
| Distinction of habitat units on the base map by means of field observations | 1 day/15 ha |
| Digitising habitat units; calculation of area or length of each unit; calculation of habitat unit diversity and saturation index | 1 day/30 ha |
| Division of samples | 1 day/50 ha |
| Inventorying trees and shrubs | 1 day/15 ha |
| Inventorying herbaceous vegetation (2×1 day/3 ha) | 1 day/1.5 ha |
| Inventorying extra species of butterflies | 1 day/15 ha |
| Determining species number of breeding birds and amphibians | 2 days |
| Composing species list; calculation of diversity and saturation indices | 2 days |
| Reporting the results | 5 days |
| Total | 33 days/25 ha |

structural elements of parks. The calculated habitat unit diversity is sensitive for both changes in the areas and the number of units. But other criteria, such as measures of water quality and flow regimes, energy consumption levels in ecosystems, levels of pollutant loadings within habitats (see, Ref. McKenney et al., 1994) are not measured here. It is hoped that changes in these criteria are reflected in taxon diversity of the habitats.

The used indicators are easy to determine or to calculate. Although the inventories are time-consuming, no other high costs are involved. The monitoring starts from a sound experimental design. It causes only minimal disturbance and involves both the species and the habitat level.

Butterflies, breeding birds, amphibians and higher plants are very attractive and can count on the interest of the public.

One of the benefits of the described method is that a relatively limited survey results in a set of different biodiversity indicators on various organisational levels of the park. It is an objective method that can be repeated and applied consequently to all urban and suburban parks. The method will gain in value if it is applied to different parks and comparisons are made. Data for different parks will allow us also to look at the relation between habitat unit diversity and species diversity.

A possible drawback is that the species number of butterflies will be positively influenced if the park contains a butterfly garden. Amphibians are related to the presence and quality of water bodies and the presence of hole-nesting birds and birds of prey depend, especially in smaller parks, on the landscape matrix that contains the park. These elements should be taken into account when interpreting the results.

Since the species (including infraspecific variation) and the habitats are the foundations for any ecological evaluation (Spellerberg, 1994), the proposed biodiversity assessment forms a good basis for ecological evaluation if information is added on the rarity, vulnerability of species and habitats. For the species this information is available (Cosijns et al., 1994), but for habitats this is more difficult. The evaluation can provide a basis for priority ranking of parks, species and their habitats in terms of park management. Since management directly effects the structure of the park's vegetation, the proposed method should allow to monitor the changes. Plot data have been proven to be effective in monitoring management effects in nature reserves (Bakker, 1989).

In conclusion, a scientifically sound method for the monitoring of (part of) the biodiversity of (sub-)urban parks is proposed working along two lines, that of habitat diversity and species diversity. Species diversity measurement is based plant species, butterflies, amphibians and bird species. Habitat diversity is based on a predefined list of habitat units. Although the selection of both species groups and habitat units is argued, other groups may be equally important, but the selected groups have the advantage of being rather well known both to scientists and the general public. The proposed method yields a number of biodiversity indicators. In combination with GIS it should enable the assessment of changes in the parks due to management and other influences. We feel that the proposed method is a balanced compromise between feasibility and accuracy for tackling a difficult issue such as biodiversity in (sub-)urban parks.

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