

The Importance of Temporal and Spatial Vegetation Structure Information in Biotope Mapping Schemes: A Case Study in Helsingborg, Sweden

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Abstract Temporal and spatial vegetation structure has impact on biodiversity qualities. Yet, current schemes of biotope mapping do only to a limited extent incorporate these factors in the mapping. The purpose of this study is to evaluate the application of a modified biotope mapping scheme that includes temporal and spatial vegetation structure. A refined scheme was developed based on a biotope classification, and applied to a green structure system in Helsingborg city in southern Sweden. It includes four parameters of vegetation structure: continuity of forest cover, age of dominant trees, horizontal structure, and vertical structure. The major green structure sites were determined by interpretation of panchromatic aerial photographs assisted with a field survey. A set of biotope maps was constructed on the basis of each level of modified classification. An evaluation of the scheme included two aspects in particular: comparison of species richness between long-continuity and short-continuity forests based on identification of woodland continuity using ancient woodland indicators (AWI) species and related historical documents, and spatial distribution of animals in the green space in relation to vegetation structure. The results indicate that (1) the relationship between forest continuity: according to verification of historical documents, the richness of AWI species was higher in long-continuity forests; Simpson's

diversity was significantly different between long- and short-continuity forests; the total species richness and Shannon's diversity were much higher in long-continuity forests shown a very significant difference. (2) The spatial vegetation structure and age of stands influence the richness and abundance of the avian fauna and rabbits, and distance to the nearest tree and shrub was a strong determinant of presence for these animal groups. It is concluded that continuity of forest cover, age of dominant trees, horizontal and vertical structures of vegetation should now be included in urban biotope classifications.

Keywords Biotope mapping · Vegetation structure · Ancient woodland indicator species · Forest continuity · Biodiversity

Introduction

Rapid economic growth and large urban population expansion can lead to the conversion of farmlands, grasslands, forests etc. into new urbanized areas. Rapid urbanization is usually accompanied by undesirable environmental problems, such as a drastic reduction of green spaces and environment deterioration. In some Swedish cities studies have shown that biodiversity has decreased over the last 50 years and many valuable biotopes have continuously deteriorated (Attwel and others 2002). Many Swedish municipalities have established comprehensive plans for long-term preservation and development of land and water in the urban and rural environment according to the Swedish Planning and Building Act (Summary-öp 2002). In addition, people in general appreciate urban wildlife, so that there are strong incentives to maintain and enhance urban green structures, for the benefit of flora and fauna as well as for human visitors

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(Penland 1987; Johnson and Beck 1988; Gustavsson and Ingelög 1994; Wirén 1995).

Urban biotope mapping is an efficient method offering precise information about the quality and distribution of biotopes and landscape units and how they relate to each other (Reumer and Epe 1999; Löfvenhaft and others 2002; Hong and others 2005; Jarvis and Young 2005). Most urban biotope mapping schemes classify biotopes by land use and habitat type, as habitats typically associated with urban land use, e.g., parks, school grounds (Sukopp and Weiler 1988; Cousins and Ihse 1998; Löfvenhaft and others 2002; Freeman and Buck 2003). Urban land use types are classified according to a series of factors (e.g. substrate, size of land use patch, duration of land use, location within the city, maintenance intensity, neighboring uses) (Sukopp and others 1980; Sukopp and Weiler 1988). Classification of urban vegetation habitats are mainly based on vegetation physiognomy and phytosociology including plant communities, their composition and development, and the relationship between species within them (Freeman and Buck 2003). Other parameters, such as vegetation type and succession, the gradient of humidity and land management, are also taken into account in classifying ecological qualities of biotope (Cousins and Ihse 1998; Löfvenhaft and others 2002). However, the comprehensive concept of vegetation structure is usually not described in biotope mapping classifications, especially when investigating biodiversity and recreational values. The definition of vegetation structure varies under different circumstances. In this article, we focus on the temporal and spatial aspects, which are as follows:

- “Temporal” usually means phenological or seasonal aspects and aspects of disturbance such as mowing or grazing, but not of long-term successional processes (Zehm and others 2003). A temporal concept here is defined into two aspects: (1) the continuity of vegetation cover. This means a presence over a long period (many generations) of vegetation cover such as shrub and tree cover (woodland continuity), grass cover (grassland continuity) etc. (Nilsson and Baranowski 1993; Nilsson and others 1995). In this study, we focus on the continuity of woodlands. (2) The approximate mean age of dominant tree-layer individuals.
- The spatial aspects of the vegetation structure have a horizontal and a vertical dimension. (1) Horizontal structure means the distribution of vegetation elements in a plan view; the vegetation patterns are seen in a vertical projection on the ground, and the types of vegetation pattern are determined by canopy cover of trees and shrubs. (2) The vertical structure means the vegetation elements in a side view; here it refers to plants’ vertical stratification including canopy layer (>10 m), understory (4–10 m), shrub layer (1–4 m)

and field layer (<1 m) (Zehm and others 2003; Gustavsson 2004).

Some studies have demonstrated that long-continuity woodland sites provide the sole habitat for many species of animals and plants. Woodland of long continuity is a factor positively influencing species diversity (Segestrom and others 1994; Selva 1994), facilitating the dispersion of birds and other organisms (Sanchez-Lafuente and others 2001) and allowing gene flow between populations (McDonald and others 1999). Many studies have also shown a close relationship between spatial vegetation structure and biodiversity (Karr and Roth 1971; Wirén 1994; Young and Jarvis 2003; Sallabanks and others 2006; Tarsitano 2006; Atallah and others 2007).

The aim of this study is to evaluate the functionality of a modified urban biotope mapping scheme that takes temporal and spatial vegetation structure into consideration. Our hypothesis is that biotope mapping could be more useful as a landscape planning and management tool to collect more detailed information about biodiversity values, if structural parameters are added to the scheme.

Material and Method

Study Area

The study area is within the city of Helsingborg in southern Sweden. A defined part of the city, from the centre to the outskirts, was selected, because there are relatively detailed historical documents. The study area comprises a variety of biotopes and is subject to an investigation of a new green wedge for biodiversity and recreational use (Fig. 1).

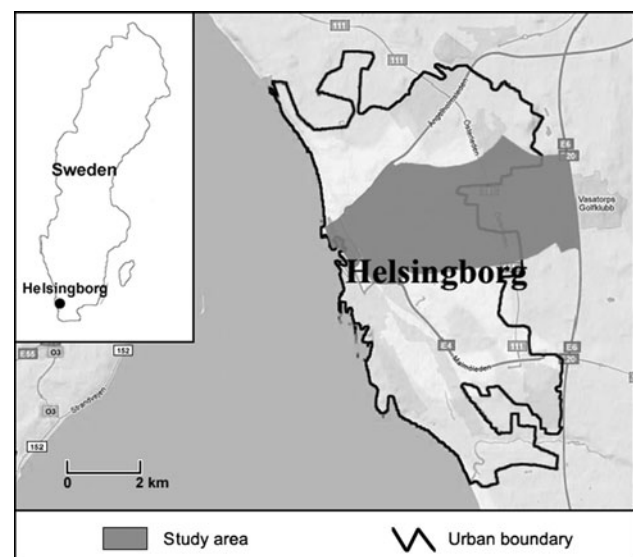


Fig. 1 Location of the study area

Method

Construction of a Modified Biotope Mapping Classification

On the basis of a biotope classification system designed by Gyllin and Hammer (2004), a modified classification was presented involving the four structural parameters as mentioned above (Table 1). Their system was based on a certain number of land use categories, such as “industrial sites”, “residential areas”, “public green spaces (amenity areas)”, “forest”, etc. These main categories were further subdivided into a maximum of five levels giving higher resolution and more detail (Gyllin and Hammer 2004). For example, “forest” was subdivided on the lowest level characterized by dominant species, such as “oak forest”, “elm forest”, “poplar forest”, “beech forest”, etc. As a complement to their model, the vegetation cover was estimated using a four-grade scale (0–10, 10–50, 50–90 and 90–100% cover). Their case study showed that biotope mapping combined with a vegetation cover investigation was a very fast and reliable tool, but the model could not provide primary biological data in relation to diversity. In

order to reflect the biological dimension, the hierarchy classification should be altered.

The modified classification focused on the green space of the study area (Table 1). The classification started with a broad category based on land cover type. Then, depending on the horizontal structure of green space, it went down to the second category where the canopy cover ratio of trees and shrubs was included. Level 3 was developed including type of grassland and type of woodland. According to the approximate age of dominant tree-layer species, woodlands were divided into three groups—less than 30 years, 30–80 years and more than 80 years—while they were marked if Ancient Woodland Indicator (AWI) species occurring. The continuity of forest was not directly included in our modified biotope classification, but this aspect was tested on the basis of using AWI species. Level 4 mainly focused on moisture condition of the grasslands and the balance between deciduous, conifer and swamp woodland types. The last level emphasized nutrient conditions of grasslands and vertical structure of the woodlands, divided into one-layered, two-layered, and multi-layered. In this study, we consider that one-layered could

Table 1 Modified biotope classification with five levels shown for green areas

Level 1	Level 2	Level 3	Level 4	Level 5
Green space	Open green area <10% canopy cover of trees/shrubs	With lawn area	Dry/Fresh/Wet	Poor/Rich
		With grazed land area		
		With meadow area		
	Partly open green area 10–30% canopy cover of trees/shrubs	With succession area	Dry/Fresh/Wet	Mainly shrubs Mainly trees Mixed
		With lawn area		
		With grazed land area		
	Partly closed green area 30–80% canopy cover of trees/shrubs	With meadow area	Deciduous Deciduous and conifer Conifer Swamp	One-layered Two-layered Multi-layered
		With succession area		
		Less than 30 years (with or without AWI species)		
	Forest >80% canopy cover of trees/shrubs >10,000 m ² (more than 50 m across)	30–80 years (with or without AWI species)	Deciduous Deciduous and conifer Conifer Swamp	One-layered Two-layered Multi-layered
More than 80 years (with or without AWI species)				
Clear cut (with or without AWI species)				
Less than 30 years (with or without AWI species)				
Grove, clump of trees, thicket, tree belt or avenue (less than 50 m across)	30–80 years (with or without AWI species)	Deciduous Deciduous and conifer Conifer Swamp	One-layered Two-layered Multi-layered	
	More than 80 years (with or without AWI species)			
	Less than 30 years (with or without AWI species)			

be canopy layer or understory; two-layered could be any combination of shrub layer, understory and canopy layer; more than two layers is considered as multi-layered. The whole modified classification was applied to this modified biotope mapping scheme.

The Mapping Process

The first step in the mapping process was to define the boundaries of homogenous biotopes. This was conducted through studies of aerial photos derived from National Land Survey of Sweden (2004) followed by field surveys. The following data were recorded for each biotope: location, size, land use type, vegetation structure, and mean age of dominant tree-layer plants. Finally, the modified biotope map was plotted, based on the studies of aerial photos and field work. For data storage, editing, assessment and mapping, the software ArcView 3.3 was used as the Geographic Information System (GIS). The size of every mapped area varies in different levels, depending on the homogeneous characteristic of each level of area. The smallest mapping unit was 1,000 m².

Identification of Long-Continuity Woodland Sites Using AWI Species

Species which are particularly characteristic of ancient woodland sites, and rarely seen in secondary woodlands and other biotopes, are called AWI species (Peterken 1974; Rundlöf and Nilsson 1995; Esseen and others 1999). Usually, AWI species include moss, lichen, mollusc and vascular plant species. The presence of such species in woodland inventories is taken as evidence of a long continuity of woodland cover (Rose 1976). In this paper, the

long-continuity woodland was designated as being land which has been continuously wooded since AD1700. The date chosen was based on particular conditions of southern Sweden—around the year of 1700 marked the beginning of reasonably accurate historical information on local land use including old maps and estate records.

On the basis of Peterken (2000), Rose (1999) and Brunet's (1994) ancient woodland inventories, the AWI species were selected, and then identified long-continuity forest using the AWI species on the Green map of Skåne, Sweden (Table 2). These are vascular plants of the field-layer with the following characteristics: they (a) are capable of growing in the shade, (b) seldom occur outside woodlands, and (c) are slow colonizers (Rose 1999; Peterken 2000). The higher the number of AWI species (both number of species and number of individuals) occurring together, the higher the probability that the woodland has a long continuity (Rundlöf and Nilsson 1995; Rose 1999; Peterken 2000). In order to ensure the validity of the AWI species, land-use maps from 1700, 1810, 1910 and 1940 summarized by Sjöbeck (1930/1960) were analyzed as well as related estate records of Helsingborg. Finally a field check throughout the study area was conducted in 2009. The positions of the AWI species were marked on the map.

Comparison of Species Richness Between Long-Continuity and Short-Continuity Forests Using Vascular Plants

The sample plots were selected according to the results of identification of long-continuity woodland sites. The selected plots should be of similar size and structure. Between the spring and autumn of 2009, inventories of vascular plant within the sample plots were made, in order to compare the species richness of long-continuity sites

Table 2 Ancient woodland indicator (AWI) species list selected from three sources

AWI species name	Citation	AWI species name	Citation
<i>Actaea spicata</i>	Brunet (1994)	<i>Milium effusum</i>	Peterken (2000); Rose (1999); Brunet (1994)
<i>Adoxa moschatellina</i>	Peterken (2000); Rose (1999)	<i>Oxalis acetosella</i>	Peterken (2000); Rose (1999)
<i>Allium ursinum</i>	Peterken (2000); Rose (1999)	<i>Paris quadrifolia</i>	Peterken (2000); Rose (1999)
<i>Anemone nemorosa</i>	Peterken (2000); Rose (1999)	<i>Polygonatum multiflorum</i>	Rose (1999)
<i>Campanula latifolia</i>	Peterken (2000); Rose (1999)	<i>Pulmonaria obscura</i>	Rose (1999)
<i>Campanula trachelium</i>	Peterken (2000); Rose (1999)	<i>Pulmonaria officinalis</i>	Brunet (1994)
<i>Cardamine bulbifera</i>	Brunet (1994)	<i>Stachys sylvatica</i>	Brunet (1994)
<i>Circaea lutetiana</i>	Brunet (1994)	<i>Stellaria holostea</i>	Peterken (2000); Rose (1999)
<i>Galium odoratum</i>	Peterken (2000); Rose (1999); Brunet (1994)	<i>Stellaria nemorum</i>	Peterken (2000), Rose (1999); Brunet (1994)
<i>Hedera helix</i>	Brunet (1994)	<i>Valeriana dioica</i>	Peterken (2000)
<i>Maianthemum bifolium</i>	Peterken (2000); Rose (1999)	<i>Viola reichenbachiana</i>	Peterken (2000); Rose (1999)
<i>Melica uniflora</i>	Peterken (2000); Rose (1999); Brunet (1994)		

with short-continuity sites. A linear measurement method for species investigation was adopted. Three 60-meter parallel lines in each plot excluding 20-m peripheries were employed and the line spacing was approximately 30 m. Every species of vascular plant which touched, overlay or underlay each 2-m stretch at 4-m intervals of every line was investigated and recorded as one frequency score of this species. The frequency scores of each species were assigned according to summation of all its records of 2-m stretches in three lines. Species outside the three line sections were also recorded and were assigned one frequency score. Then, the number of vascular plant species (NVPS), Shannon's and Simpson's Diversity Indices (SHDI and SIDI) were used for calculating the species richness of each plot (Eqs. 1 and 2).

$$\text{SHDI} = - \sum_{i=1}^m \left(\frac{Ni}{N} \right) \times \ln \left(\frac{Ni}{N} \right) \quad (1)$$

$$\text{SIDI} = 1 - \sum_{i=1}^m \left(\frac{Ni}{N} \right)^2 \quad (2)$$

where Ni represents the frequency scores of the species i ; N represents the frequency scores of the total species in a certain sample plot; and m is the total number of species in a particular sample plot. Finally, Independent-Samples T test method (SPSS 17 software) was used for a comparison of the species richness between long-continuity and short-continuity sites.

Distribution of Animal Species in Relation to Spatial Vegetation Structure

The target animal species were mainly mammals and birds. Various structural factors, which could affect the target animals, were analyzed. Referring to Wirén (1995), the bird species were divided into three groups: large, medium-sized and small. The observations focused on the distribution of animals in the green areas in relation to spatial vegetation structure, mainly horizontally. Several parallel line transects were used for the observation in each green area, and the line spacing was approximately 30 m. Each point of the observation was on the line transects at intervals of 30-m. All animals were identified within eyeshot of the observer. Each record was made when one individual stayed at least 3 min in the same site, and birds flying over the observation site were not recorded (Ralph and others 1993; Sauer and others 1994). In open and partly open green areas, the distances between animals and the nearest trees or shrubs were measured; the number of observed animal species within forests and partly closed green areas were recorded. The observations were carried out four times per week from mid-spring to early autumn 2008, and

were not conducted during heavy wind or in heavy rain. Each time we spent about 6 h in the field.

Results

Modified Biotope Mapping

Figure 2 shows a modified biotope map with focus on level 2 aspects of the classification. The study area is about 16 km², including approximately 5 km² green space. Forest covered the largest area of green space, taking up 43.3%, followed by partly open green area 25.2%, open green area 16.5%, grove and tree belt 12.2% and partly closed green area 2.8% (see Appendix).

The study area from the city center to the outskirts of the city could roughly be divided into three zones on the basis of main roads and different land use (Fig. 2). Zone I mostly contains built-up areas in city center and residential areas; zone II is a mixture of various biotopes and residential areas; and zone III is located in the outskirts of the city mainly consisting of recreational areas and cultivated fields (Fig. 3).

The green spaces in zone I are mainly city parks and mature private gardens within residential areas. The vegetation structure is mainly rather simple, as in the private gardens where short-cut lawns with a few trees and shrubs dominate. One of the city parks is an exception covered by multi-layered deciduous and coniferous stands including many old trees.

Green areas open for recreation cover about half the area in both zone II and III. Various structural patterns in zone II are mostly distributed in the west with a mixture of open and partly open grasslands, groves, tree-belts and forests/woodlands. The middle part is dominated by an allotment area and housing areas; the east part mainly consists of single-layered, young forests and partly closed green areas (Fig. 2). Zone III has a more complex vegetation structure than zone II. Forest accounting for 28% is the largest green area category, dominated by young and middle aged multi-layered deciduous stands. Old multi-layered forests and middle-aged one-layered coniferous forests are scattered within the cultivated land and open green areas. The partly closed green areas in zones II and III cover 13 and 7% respectively and chiefly consist of orchards dominated by apple trees.

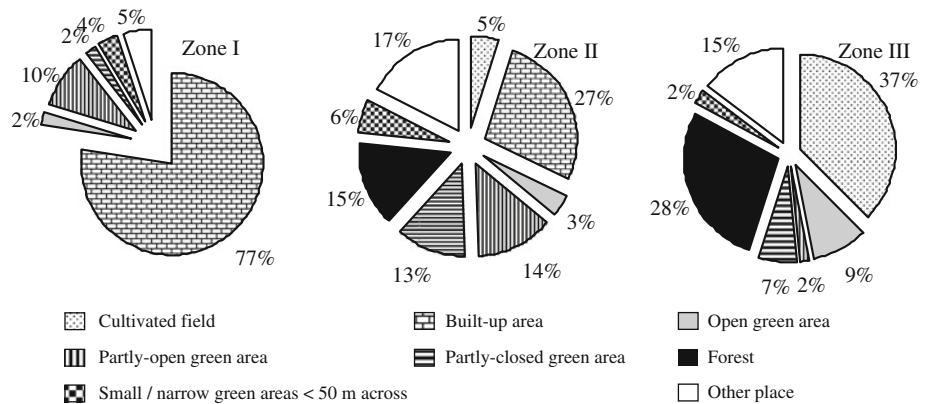
Identification of Long-Continuity Woodland Sites

The AWI species were distributed more in the eastern part of the study area and were present in woodlands classified as more than 80 years old and in many middle-aged

Fig. 2 Modified biotope map focusing on green space on the basis of horizontal structure



Fig. 3 Proportions of different land cover in each zone



woodlands (30–80 years old), but did not occur in young woodlands (less than 30 years old) (Fig. 4; Table 3).

An analysis based on the old land-use maps, historical records and field studies showed that five sites, Fredriksdal (a botanical garden), Kyrkogården (a cemetery), Öresundsparken (a city park), Brytstugans koloniförening (an allotment area) and Lundsgård (a private housing area), had a short history as wooded areas, since the former land uses at these sites were either cultivated fields or open (partly open) green areas. So the AWI species found were probably introduced or presented by other occasional causes (Fig. 4). The rest of the sites were probably spontaneous occurrences of AWI species since no proof indicated a short history of woodland. East part of Bruces skog had nine, Prinsaskogen and Hunnetorp both had six AWI species whilst these species were widely distributed amongst these areas, which means these sites could have a higher probability of longer woodland continuity than the other

wooded areas (Table 3). The woodland sites without any AWI species, such as Filbornaskogen and West Bruces skog, do not have a long woodland continuity as shown by the historical land-use maps. The former land use at both these sites was cultivated field.

Species Richness of Vascular Plant of Long-Continuity and Short-Continuity Forests

Four long-continuity sites were selected according to above identification results of long-continuity woodland sites, and then five short-continuity sites were sampled in accordance with the characteristics of the long-continuity sites (Fig. 5). They were one-two layered mature forests with the size of each plot approximately 2 ha (Table 4). The NVPS of long-continuity sites ranged between 38 and 51, and the range of short-continuity sites was between 15 and 28. The NVPS values between both forest types showed a very

Fig. 4 Distribution map of the AWI species

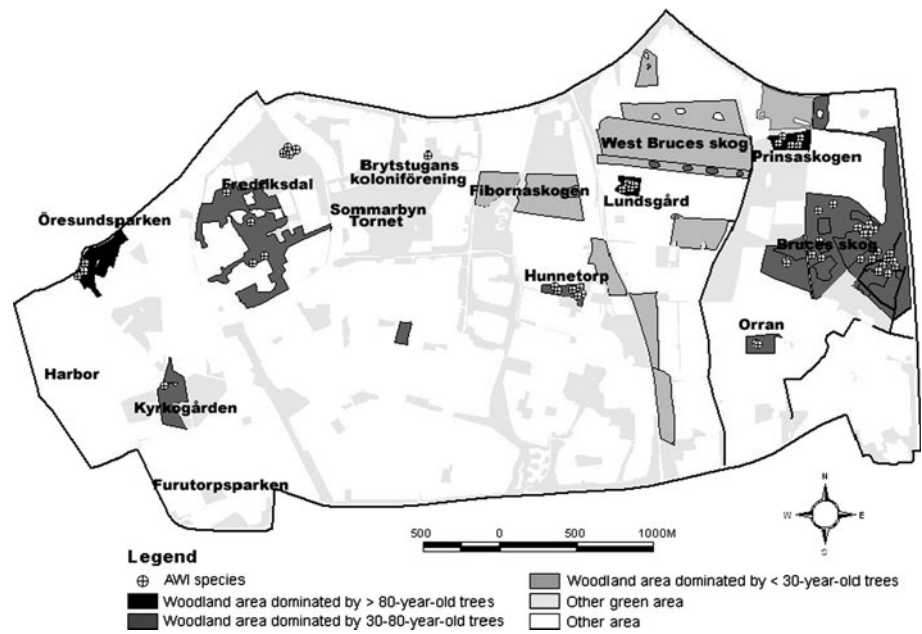
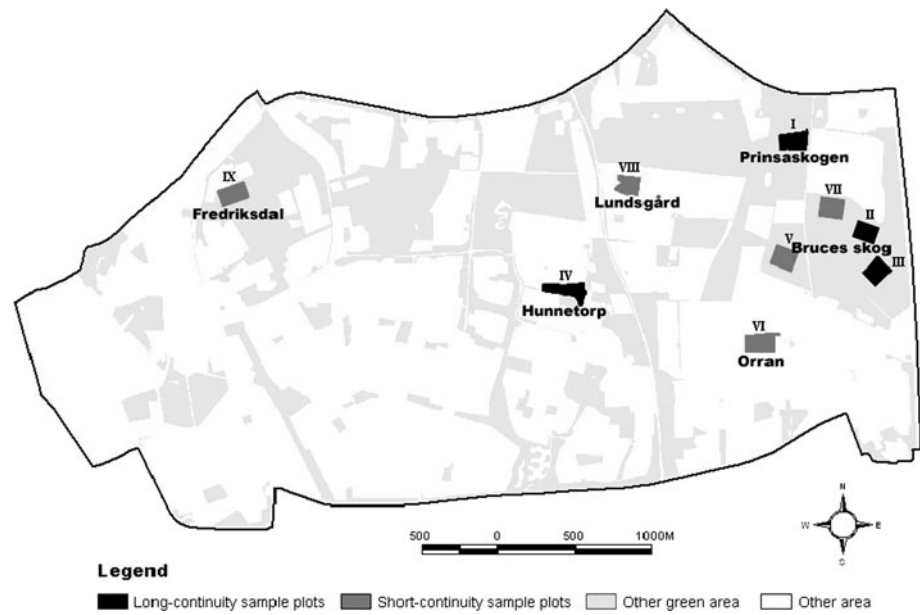


Table 3 Distribution of the AWI species in the study area (Fig. 4)

Position of AWI species	Scientific name	Current land cover	Ancient status	Age class
Brytstugans koloniförening	<i>Galium odoratum</i>	Partly-open lawn area	–	–
East part of Bruces skog	<i>Anemone nemorosa</i> , <i>Maianthemum bifolium</i> , <i>Milium effusum</i> , <i>Oxalis acetosella</i> , <i>Paris quadrifolia</i> , <i>Polygonatum multiflorum</i> , <i>Stellaria holostea</i> , <i>Valeriana dioica</i> , <i>Viola reichenbachiana</i>	2 layered deciduous forest	Long continuity	30–80-year-old trees
Fredriksdal	<i>Adoxa moschatellina</i> , <i>Allium ursinum</i> , <i>Campanula latifolia</i> , <i>Galium odoratum</i> , <i>Polygonatum multiflorum</i> , <i>Pulmonaria obscura</i>	2 layered deciduous forest	Short continuity	30–80-year-old trees
Hunnetorp	<i>Anemone nemorosa</i> , <i>Galium odoratum</i> , <i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i> , <i>Paris quadrifolia</i> , <i>Polygonatum multiflorum</i>	2 layered mixed forest	Long continuity	30–80-year-old trees
Kyrkogården	<i>Campanula trachelium</i>	1 layered deciduous partly closed area	Short continuity	30–80-year-old trees
Lundsgård	<i>Adoxa moschatellina</i> , <i>Anemone nemorosa</i> , <i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i> , <i>Polygonatum multiflorum</i> , <i>Stellaria holostea</i>	2 layered deciduous forest	Short continuity	>80-year-old trees
Prinsaskogen	<i>Anemone nemorosa</i> , <i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i> , <i>Polygonatum multiflorum</i> , <i>Stellaria holostea</i> , <i>Viola reichenbachiana</i>	2 layered deciduous forest	Long continuity	>80-year-old trees
Öresundsparken	<i>Anemone nemorosa</i> , <i>Campanula trachelium</i> , <i>Polygonatum multiflorum</i>	2 to multi layered mixed partly closed area	Short continuity	>80-year-old trees
Orran	<i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i>	1 to 2 layered deciduous forest	Short continuity	30–80-year-old trees

Fig. 5 Distribution of sample plots**Table 4** Area, NS, SHDI, SIDI and main vascular plants of long-continuity and short-continuity plots

Plots	Area (ha)	NVPS	SHDI	SIDI	Ancient status	Species of vascular plant (frequency scores ≥ 5)
I	2.11	51	3.34	0.95	Long continuity	<i>Anemone nemorosa</i> , <i>Convallaria majalis</i> , <i>Corylus avellana</i> , <i>Dryopteris filix-mas</i> , <i>Holcus lanatus</i> , <i>Impatiens parviflora</i> , <i>Juncus effuses</i> , <i>Lysimachia vulgaris</i> , <i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Sambucus nigra</i> , <i>Stellaria holostea</i> , <i>Viola reichenbachiana</i>
II	1.91	38	2.96	0.93	Long continuity	<i>Anemone nemorosa</i> , <i>Anemone ranunculoides</i> , <i>Corylus avellana</i> , <i>Dryopteris filix-mas</i> , <i>Fagus sylvatica</i> , <i>Lonicera periclymenum</i> , <i>Maianthemum bifolium</i> , <i>Milium effusum</i> , <i>Oxalis acetosella</i> , <i>Paris quadrifolia</i> , <i>Polygonatum multiflorum</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Sorbus aucuparia</i> , <i>Stellaria holostea</i>
III	1.94	43	3.21	0.95	Long continuity	<i>Alnus glutinosa</i> , <i>Anemone nemorosa</i> , <i>Anemone ranunculoides</i> , <i>Deschampsia cespitosa</i> , <i>Deschampsia flexuosa</i> , <i>Dryopteris filix-mas</i> , <i>Fragaria vesca</i> , <i>Fraxinus excelsior</i> , <i>Geum urbanum</i> , <i>Impatiens parviflora</i> , <i>Milium effusum</i> , <i>Oxalis acetosella</i> , <i>Prunus avium</i> , <i>Ribes rubrum</i> , <i>Rubus idaeus</i> , <i>Rubus laciniatus</i> , <i>Stellaria holostea</i> , <i>Valeriana dioica</i> , <i>Viola reichenbachiana</i>
IV	2.19	40	3.23	0.95	Long continuity	<i>Acer pseudoplatanus</i> , <i>Alnus glutinosa</i> , <i>Anemone nemorosa</i> , <i>Betula pendula</i> , <i>Convallaria majalis</i> , <i>Corylus avellana</i> , <i>Fagus sylvatica</i> , <i>Galium odoratum</i> , <i>Maianthemum bifolium</i> , <i>Oxalis acetosella</i> , <i>Picea abies</i> , <i>Poa trivialis</i> , <i>Polygonatum multiflorum</i> , <i>Prunus padus</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Sambucus nigra</i>
V	2.05	24	2.58	0.89	Short continuity	<i>Anemone nemorosa</i> , <i>Betula pendula</i> , <i>Dryopteris filix-mas</i> , <i>Frangula alnus</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Rubus nessensis</i> , <i>Sorbus aucuparia</i> , <i>Trientalis europaea</i>
VI	2.19	28	2.69	0.89	Short continuity	<i>Convallaria majalis</i> , <i>Fagus sylvatica</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Sambucus racemosa</i> , <i>Trientalis europaea</i>
VII	2.07	15	1.95	0.79	Short continuity	<i>Acer pseudoplatanus</i> , <i>Anemone nemorosa</i> , <i>Anemone ranunculoides</i> , <i>Dryopteris filix-mas</i> , <i>Fagus sylvatica</i>
VIII	1.85	28	2.70	0.89	Short continuity	<i>Acer pseudoplatanus</i> , <i>Anemone nemorosa</i> , <i>Anemone ranunculoides</i> , <i>Corylus avellana</i> , <i>Quercus robur</i> , <i>Rubus idaeus</i> , <i>Sambucus nigra</i>
IX	2.16	25	2.61	0.89	Short continuity	<i>Acer pseudoplatanus</i> , <i>Epilobium montanum</i> , <i>Fagus sylvatica</i> , <i>Impatiens parviflora</i> , <i>Sambucus nigra</i> , <i>Tilia cordata</i> , <i>Ulmus glabra</i>

significant difference in the SPSS 17 ($F = 0.030$, Sig. = 0.868; $t = 5.147$, $P = 0.001$). The SHDI values between long and short-continuity forests also showed a very significant difference ($F = 1.066$, Sig. = 0.336; $t = 3.889$, $P = 0.006$), their values ranged from 2.96 to 3.34, and from 1.95 to 2.70, respectively. The SIDI values between long and short-continuity sites were significantly different ($F = 3.160$, Sig. = 0.119; $t = 3.247$, $P = 0.014$), with a mean value of 0.945 in long-continuity sites and of 0.87 in short-continuity sites. The main species (frequency scores ≥ 5) list of each sample plot are shown in Table 4. The number of the main species in long-continuity plots was also relatively higher than the species in short-continuity plots. The results reveal that the long-continuity plots have higher species richness than the short-continuity plots.

Distribution of Selected Animal Species in Relation to Spatial Vegetation Structure

The dominant species observed amongst the animals are shown in Table 5. The total number of observed animals was about 7,200, consisting of 78% avian species and 22% mammals. 57% were found in forests and partly closed green areas. Small birds showed a strong relationship to woodland, as 82% small birds were observed in forests and partly closed green areas. The proportion of medium-sized birds, large birds and rabbits observed in forests and partly closed green areas declined, taking up 58, 49 and 14%, respectively. However, only 3% of large birds were found in one-layered young plantations.

Of all the observed animals located within open and partly open green areas excluding large birds, the majority of the observations were close to trees and shrubs. Figure 6 shows the distance for nearly all rabbits' observations was less than 12 m, and about 60% of them were found within 2 m, especially to dense shrubbery. About 70% of the observed small birds were distributed within 4 m to trees or shrubs, and most of them within 12 m. Only a few small birds were located within 20–30 m. The distribution of medium-sized birds in relation to trees and shrubs had nearly the same distribution patterns as to the small birds,

but with a few more observed at longer distances. The distribution of large birds was different to previous animal groups. There was a smaller ratio of large birds observed near trees and shrubs, with more at 4–12 m, as well as a relatively high percentage of observations at distances of more than 12 m (Fig. 6).

Discussion

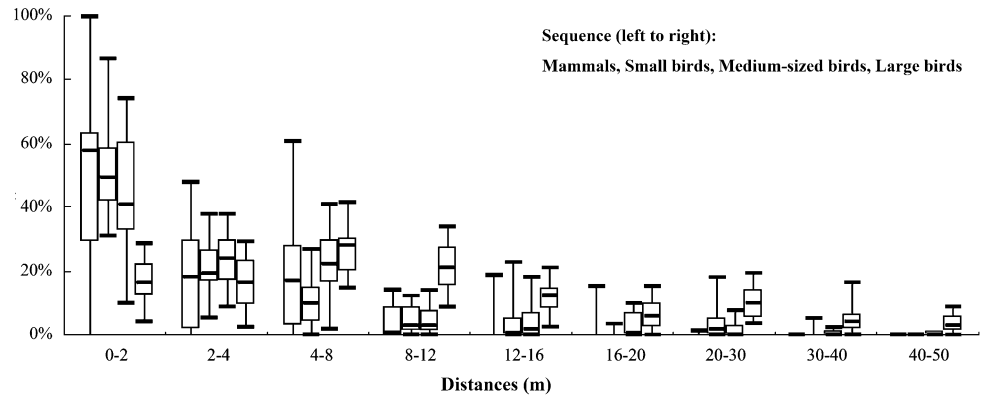
Urban biotopes in the city of Helsingborg (southern Sweden) were investigated by a modified biotope mapping approach. It was found that the area of green space takes up one third of the study area, and the forest (200 ha) covers the largest share of the green space included in the mapping, approximately accounting for the same size as open and partly open green area together. The results from the maps also show a dynamic variety of landscape in relation to vegetation structure from inner city (Zone I) to the outskirts of the city (Zone III), and the characteristics of vegetation structure correspondingly vary from simple to relatively complex. The current landscape pattern of Helsingborg was caused by a substantial influence of built-up environment with a relatively highly fragmented habitat network. Cumulative work that has been achieved so far indicates that consequences of fragmentation for flora and fauna are extensive; impacts range from a positive effect (McGarigal and McComb 1995; Meyer and others 1998) to a negative effect (Trzcinski and others 1999; Fujita and others 2008) on biodiversity (Tschardt and others 2002; Zaviero and others 2006). But it is affirmative that this fragmentation could cause the changes in distribution and abundance of organisms in a landscape, no matter what the positive or negative effect on biodiversity is. The vegetation structure of existing habitats could be an immediate factor influencing the distribution and abundance of organisms. Therefore, we investigated biodiversity in an urban context using a biotope mapping scheme integrated with vegetation structural parameters.

Our results show that the AWI species are found in mature and elder stands rather than in young stands, and

Table 5 Selected animal species in observations

Category	Observed animal species
Large birds (Body length between 35–50 cm)	Wood pigeon (<i>Columba palumbus</i>), magpie (<i>Pica pica</i>), rook (<i>Corvus frugilegus</i>), jackdaw (<i>Corvus monedula</i>)
Medium-sized birds (Body length between 20–30 cm)	Blackbird (<i>Turdus merula</i>), common starling (<i>Sturnus vulgaris</i>)
Small birds (Body length between <15 cm)	Great tit (<i>Parus major</i>), greenfinch (<i>Carduelis chloris</i>), house sparrow (<i>Passer domesticus</i>), tree sparrow (<i>Passer montanus</i>)
Mammals	Rabbit (<i>Oryctolagus cuniculus</i>)

Fig. 6 Percentage of mammals, small birds, medium-sized birds and large birds distributed at different distances from trees/shrubs in open and partly open green areas



that the vertical structure of these woodlands is relatively complex (Fig. 4). Biotopes with old and well-stratified vegetation will generally support more species richness than biotopes with vegetation concentrated to single layer (Hunter 1990). AWI species may, however, also occur spontaneously in stands with young trees, because long woodland continuity could include short periods of relative openness after forest fires, storms, radical felling of trees or clear-cut forestry. This means that long-continuity woodland does not necessarily mean woodlands with old trees or a total coverage of trees (Kirby and Goldberg 2002). Nevertheless, the openness may change the microclimate and the ground flora could be affected consequently (Brunet and von Oheimb 1998; Brunet and others 2000). The presence of a large number of AWI species (both the number of species and the number of individuals) is hence most likely to indicate mature stands with long continuity, rather than young stands with long continuity.

However, some studies found similar number of species in ancient forest and in recent forest (Bossuyt and others 1999) and some others even observed a lower diversity in ancient forest than in recent forest (Koerner and others 1997). Generally, recent forests display similar or higher species richness due to higher connectivity between the forests and species source, higher presence of generalist species, higher light availability and higher fertility that increase the presence of non-forest species. In our research, we tried to uniform the factors which could affect species richness in the forests, such as size, location, age class, spatial structure of both long-continuity and short-continuity forests, and so on. The result of the comparison of species richness of vascular plant between long-continuity and short-continuity sites indicates that long-continuity forests have higher species richness than short-continuity forests. An explanation would be that long-continuity forests may contain much of the same biodiversity present in more recent woodlands, furthermore, the sheer age of the habitat itself and the absence of major physical disturbance also gives rise to a continuum of conditions favored by a variety of other species. This would include species which are

either slow to establish (e.g., AWI species) or which require very particular conditions in order to survive (e.g., red list species). The same relationship between continuity and species richness has also been observed in semi-natural grasslands where not only recent management regimes (grazing or mowing), but also the historical continuity of grassland habitats, has an important impact on the biodiversity and flora qualities (Kull and Zobel 1991; Austrheim and Olsson 1999; Cousins and Eriksson 2002). Therefore, continuity as one of the temporal parameters in the biotope mapping is indispensable, and these sites need to be given an extra attribute (i.e., long continuity) apart from their other attributes (stand age, horizontal and vertical structure) in the classification.

The use of AWI species indicating woodland continuity has some limitations. The association of a species with ancient woodland may vary across different regions, i.e., a set of indicator species can work satisfactorily in one region but may not be appropriate in others; and sometimes AWI species also occur in secondary woodlands and other biotopes (Peterken 1974; Peterken 2000; Kirby and Goldberg 2002; Rolstad and others 2002). For example, where secondary woodlands adjoin primary woodlands, they will acquire species associated with older woods much more quickly than isolated secondary woods do. In order to increase accuracy of long continuity of land-use/cover, historical documents are needed.

Our results also show that the distribution of animals is correlated with spatial vegetation structure. Rabbits and small and medium-sized birds show a strong connection to trees or shrubs either by direct utilization or by staying close to it when in open and partly open green areas (Fig. 6). In our observation, rabbits were found in open and partly open green areas, groves with more than one-layer and tree belts, and edges of multi-layered forests, but most of the rabbits were seen in the grassland but close to dense shrubs and trees. Their activity distances were mostly within 12 m to them, and approximately 60% of rabbits preferred staying within 2 m. The explanation could be that they have to dodge human activities and avoid predators, so

they need shelters for protection. Small and medium-sized birds were observed in all types of forests, partly closed green area and mainly tree-covered partly open green area. They were not often seen in open green areas without tree cover or only sparse shrubbery (especially small birds). Their horizontal sphere of activity was mainly within 4 m to trees and shrubs. The reason might be that they are prone to be attacked in open green areas, and more dependent on shelters than big birds because of the negative correlation between body size and loss of energy (Wirén 1995). Large birds occurred in every green space except simple layered young plantation. In open and partly open green areas, they were not obviously related to the trees and shrubs and they were randomly distributed within the areas (Fig. 6). Food preference would be the main reason to the distribution, predator avoidance or shelter might be considered as minor factors (Sallabanks and others 2006). In addition, a high number of animals occurred also in other areas, such as orchards, agricultural fields after harvest, and places where animals were fed by people.

Because individual animals sitting in different vegetation strata are difficult to detect by observation, our results only show the percentage of selected animals within forests and partly closed green areas. In particular, 82% of the small birds were found in those areas, and only 3% of the large birds were found in one-layered young plantations. The simple explanations would be that shelters and predator avoidance could be of importance for surviving of small birds, and large birds have problems with sitting in shrubs and on tiny branches of trees. The tree and shrub cover are always regarded as a significant factor influencing the richness and abundance of animals (Wirén 1994). The correlation between vegetation structure and animals relies on cover-dependence, which might be due to, e.g., food preferences, predator avoidance, shelter, location of breeding or roosting site, and safety from human activities. The importance of these factors varies between species (Holmes and Robinson 1988; Rotenberry and Wiens 1998). For example, in a mature forest, the large branches of trees in the canopy layer will provide nesting sites strong enough to support large birds. Beneath the canopy layer, a well-developed understory or shrub layer will provide numerous nesting and foraging opportunities for smaller birds. The field layer of herbs and grasses supplies food and microhabitats for a wide range of butterflies and other invertebrates. To compare observed and random distributions in different vegetation strata statistically, the future work requires a more advanced method of analysis.

Mixed habitats such as open grasslands, partly-open grounds, woodlands, wetlands, and arable fields are of importance for the richness of flora and fauna concerning both quantity and diversity, because many species require more than one kind of habitat (Law and Dickman 1998).

Moreover, the size, shape, pattern and connectivity of each habitat also influence the distribution of animals; for example, there were fewer selected animals found in the small-sized or narrow linear green spaces than in others. Individual old trees have particular values that provide a number of microhabitats for other plant and animal species. Many species of beetles and other invertebrates may live in the cracks in gnarled and fissured old bark (Nilsson and others 2001). It is thus important to preserve and develop a varied landscape rich in different scales.

A personal relationship with biodiversity often takes place through outdoor recreation. Green spaces in an urban context directly provide opportunities for people to experience nature and wildlife. Diversely structured habitats concerning both spatial and temporal aspects are not only important for biodiversity qualities, but also for recreational opportunities and activities such as scenery appreciation, bird watching, flower picking, hiking and children's spontaneous play.

Conclusion

The existing and potential biotope qualities in an urban area are essential in order to preserve and enhance urban biodiversity and to provide various opportunities for people's recreation. One of the key factors in this perspective is the vegetation structure of each biotope, which plays a significant role. Our modified biotope mapping scheme involving temporal and spatial vegetation structures can be used as a planning tool for maintaining the urban environment and enhancing urban biodiversity as well as for recreational purposes. This scheme extends the temporal concept that it is not restricted to the phenological aspect or age of stands, but adds the continuity of land use. Previous studies (Selva 1994; Austrheim and Olsson 1999; Cousins and Eriksson 2002) and our investigations have noted that the land use continuity has a close relationship with biodiversity. Another strength is that a variety of stratified structure information will be of importance as a data base for future planning and management. For example, (1) the areas with long continuity and aged trees should be given more attention to avoid deterioration or loss, since they make a significant contribution to urban biodiversity and people's appreciation (Kirby and Goldberg 2002); (2) urban faunal qualities can be enriched by changing the design and management of urban green areas; and (3) the target animal's favorite vegetation structures can be imitated to meet requirements both for enhancing biodiversity and for recreational purposes.

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Appendix

Count, Area and Ratio of Modified Biotope Type in Helsingborg, Sweden

Modified biotope type	Count	Area (1,000 m ²)	Ratio (%)
Green space			
Open green areas <10% tree/shrub			(16.5)
with lawn areas	14	141	3.1
with grazed land areas	4	179	3.9
with meadow areas	12	193	4.2
with succession areas	5	242	5.3
Partly-open green area 10–30% tree/shrub			(25.2)
with lawn areas	20	843	18.5
with meadow areas	8	305	6.7
Partly-closed green area 30–60% tree/shrub			(2.8)
30–80 year of two-layered deciduous	1	13	0.3
30–80 year of multi-layered deciduous	1	59	1.2
>80 year of multi-layered mixed	1	61	1.3
Grove, clump of trees, thicket, tree belt or avenue			(12.2)
<30 year of one-layered deciduous	31	87	1.9
<30 year of two-layered deciduous	23	189	4.1
<30 year of multi-layered deciduous	9	192	4.2
<30 year of one-layered swamp	3	5	0.1
30–80 year of one-layered deciduous	2	5	0.1
30–80 year of two-layered deciduous	6	25	0.6
30–80 year of multi-layered deciduous	5	53	1.2
Forest			
<30 year of one-layered deciduous	4	247	5.4
<30 year of two-layered deciduous	1	8	0.2
<30 year of multi-layered deciduous	7	655	14.4

Appendix continued

Modified biotope type	Count	Area (1,000 m ²)	Ratio (%)
30–80 year of one-layered conifer	8	118	2.6
30–80 year of one-layered deciduous	4	9	0.2
30–80 year of multi-layered deciduous	4	760	16.7
30–80 year of multi-layered mixed	2	108	2.4
>80 year of two-layered deciduous	2	52	1.1
Clear cutting areas			
conifer to deciduous	2	13	0.3
deciduous to deciduous	1	1	0.0
Total		4,562	100

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