# Anthropogenic Effects on Understorey Vegetation in *Myrtillus* Type Urban Forests in Southern Finland

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The growth of urban population in Finland has resulted in increased fragmentation of urban forests and consequently increased recreational pressure on these forests. The effects of fragmentation and trampling on the ground and field layer vegetation were studied in mesic *Myrtillus* type Norway spruce-dominated urban forest stands of varying size in the greater Helsinki area. The number of residents living in the vicinity of the forest stands was an important factor affecting the understorey vegetation in urban forests. The cover of understorey vegetation in urban forests was remarkably lower than in rural areas, especially the ground layer cover, e.g. cover of *Pleurozium schreberi*, was significantly lower in urban forests than in the reference areas. Thus, the ground layer proved to be most susceptible to trampling. In the field layer, the cover of dwarf shrubs, especially of *Vaccinium myrtillus,* was lower in deteriorated than in undeteriorated urban forest stands.

**Keywords** fragmentation, GNMDS, trampling, vegetation monitoring, wear
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## 1 Introduction

About 80% of the Finnish population live in urban areas (Niemelä 1999). The population of the greater Helsinki (Helsinki, Vantaa, Espoo, Kauniainen), amounting to 1.15 million people, accounts for more than one-fifth of the entire Finnish population. It is estimated to reach 1.3 million by the year 2020 (Laakso and Vuori 1998). Forests are the most important urban green areas in Finland. The growth of the urban population in Finland has resulted in the fragmentation of previously more continuous forest cover within the settlement areas (Seppä 1997) and an increased recreational use of these forests. For example, trampling has increased considerably. These factors are profoundly changing forest ecosystems in urban areas (cf. LaPage 1962, Wagar

1964, Nylund et al. 1979).

The small size and isolation of the remaining forest patches may lead to a decrease of initial forest species assemblages. Changed environmental conditions in the forest fragments cause changes in species composition (Lovejoy and Oren 1981, Gilbert 1989). Species better adapted to the new conditions of the surrounding matrix are likely to colonize the patches and may eventually replace the initial forest species (Nylund et al. 1979). Moderate trampling creates suitable habitats for pioneer species in the community (Dyring 1984, Gilbert 1989). However, Florgård (1984, 2000) found that despite trampling, new species occurred in urban forests to an extremely little extent. Furthermore, the natural ability of the forest trees to regenerate diminishes (Lehvävirta 2002). When trampling is extremely intense and lasts a long time, even the most wear-resistant species will die and the exposed humus layer will gradually erode. These kinds of areas have been restored by adding dressing materials and sowing grass species, but this increases the management costs (Löfström 1996). All these alterations affect biodiversity and recreational use of urban forests.

Trampling has direct and indirect impacts on vegetation. Besides mechanical damages of vegetation, also soil properties may change (Bates 1935, Ingelög 1977, Bhuju and Ohsawa 1998). Indirect impacts may be more significant in the long run than the direct ones. Soil compaction causes oxygen shortage and lack of water and nutrients in the soil (Grable 1971, Kemper et al. 1971, Liddle 1997). Mineralisation of organic matter can be reduced even by slight increases in compaction (Kemper et al. 1971). Thus, studying the effects of trampling on the microbial flora of urban forest soils is in our interest in the near future. In this study we concentrate on direct effects of trampling on vegetation.

There are several factors affecting the ecological sustainability of urban forests. The number of potential recreationists in relation to forest area is one of the main factors to be considered in land use planning when trying to maintain initial forest vegetation in urban forests. Forest management, e.g. thinning, affects the forest's understorey vegetation composition mechanically (Jalonen and Vanha-Majamaa 2001) and through changes in light conditions (Brosofske et al. 1997, Jalonen and Vanha-Majamaa 2001) and thereby influences trampling tolerance (Kellomäki 1977, Kellomäki and Wuorenrinne 1979). The wear resistance of biotopes depends on vegetation's ability to endure trampling and recover from it (Holmström 1970, Kellomäki 1973). This depends on morphological characters of species and their growth rate, which in turn vary between different site types. The speed of recovery depends on intensity, timing and duration of trampling (LaPage 1967, Holmström 1970). Also, microclimate, soil moisture, soil texture and topography of the site affect the wear resistance of vegetation (Wagar 1964, Holmström 1970, Kellomäki and Saastamoinen 1975). Effects of these factors on forest vegetation and their complex interactions with each other require further investigations.

Some interesting questions surrounding ecological sustainability of urban forests are: What is the state of urban forests? How have anthropogenic effects e.g. spontaneous trampling affected understorey vegetation? Is it possible to preserve initial forest vegetation in small urban forest fragments? Acquiring such knowledge would be of great value when planning sustainable use of urban forests under increasing human impact, e.g. when determining limits of tolerance of vegetation to disturbance.

Our aim was to study the effects of fragmentation and trampling on the ground and field layers vegetation in urban forests. We hypothesized that various anthropogenic changes such as: changes in species composition, species abundance and species cover occur in these forests. The smaller the forest patch is and the more residents there are in the vicinity of the patch, the more deteriorated the vegetation will be.

## 2 Materials and Methods

Urban forest stands of varying size (0.6–1600 hectares) were chosen for the study from the greater Helsinki area (Table 1). Helsinki and Vantaa city forest management maps were used as reference when searching for *Myrtillus* type forest stands for the study. Mesic forest stands

**Table 1.** Selected environmental variables and their minimum, maximum and mean values (n = 76). Path area = the area of unconstructed paths per biotope, number of residents = the number of residents in 1999 within a radius of 1 km, number of school children = the number of children in schools and kindergartens within the radius of 300 m, stoniness = stone percentage by volume in the top 30 cm layer of mineral soil.

| Environmental variable | Min | Max | Mean | SD |
|---|---|---|---|---|
| Size of forest (ha) | 0.6 | 1632.0 | 69 ± 44 | 193.5 |
| Distance to the edge of forest (m) | 8.0 | 388.0 | 69 ± 17 | 73.9 |
| Size of biotope (ha) | 0.04 | 3.14 | 0.5 ± 0.1 | 0.6 |
| Path area ($m^2$/100 $m^2$) | 0 | 40.8 | 4.8 ± 1.9 | 8.1 |
| Number of residents | 122 | 16317 | 6472 ± 850 | 3720 |
| Number of school children | 0 | 1325 | 160 ± 78 | 341 |
| Shrub layer cover (%) | 0.5 | 35.5 | 10.8 ± 1.9 | 1.0 |
| Shrub layer height (m) | 0.6 | 4.5 | 2.1 ± 0.2 | 0.6 |
| Thickness of humus layer (cm) | 2.1 | 23.3 | 11.7 ± 0.7 | 3.3 |
| Stoniness (%) | 0 | 83.0 | 52.5 ± 5.5 | 24.1 |

**Table 2.** Stand characteristics on 76 sample plots in urban forests. The mean and its lower and upper boundary with 95% reliability (one sample t-test). Spruce = *Picea abies*, pine = *Pinus sylvestris*, birch = *Betula pendula* and *B. pubescens*, other broad-leaved trees = *Populus tremula, Alnus glutinosa, Salix caprea* and *Sorbus aucuparia*.

| Tree species | Volume ($m^3$/ha) | Basal area ($m^3$/ha) | # of stems (#/ha) | % of the # of stems |
|---|---|---|---|---|
| Spruce | 134 ± 31 | 13 ± 3 | 367 ± 70 | 47 ± 7 |
| Pine | 88 ± 27 | 9 ± 2 | 129 ± 32 | 19 ± 5 |
| Birch | 35 ± 15 | 3 ± 1 | 111 ± 35 | 16 ± 5 |
| Other broad-leaved trees | 10 ± 5 | 1 ± 1 | 195 ± 79 | 18 ± 6 |

dominated by Norway spruce (*Picea abies*) and initially in site characteristics described as *Myrtillus* type (MT) (Cajander 1926), with stand ages over 80 years were selected and biotope mapped. Biotope mapping was based on the understorey vegetation, and was used to ensure that the selected biotopes were internally homogenous enough (Toivonen and Leivo 1993). The most disturbed areas were rejected because the initial forest site type was difficult to identify with certainty due to major vegetation changes. The total number of homogenous MT biotopes inventoried was 69 and they were situated in 40 different forest stands. The biotope size varied from 0.01 to 3.4 hectares (Table 1). Distance to the edge of forest stand was measured from centre of each biotope to estimate the impact of edge effect on the vegetation (Table 1).

To characterize the biotopes and monitor the effects of fragmentation, and trampling, one or two circular sample plots 100 $m^2$ in size (radius 5.64 m) were located in each biotope, depending on the size of the biotope (Jalonen et al. 1998). For the assessment of tree layer structure and cover, tree species, height, and diameter of each tree were measured on each plot to calculate the height of the dominant trees, stems per hectare, basal area, and volume ($m^3$/ha) for each tree species (Table 2). And further, as measures of shrub layer cover, the cover percentages for each shrub species (using the same scale as in understorey vegetation inventories) and the mean height of the shrub layer were estimated for each plot (Table 1). As measures of wear, the path area (width × length), the thickness of humus layer, and the area of exposed mineral soil were measured for each sample plot (Table 1). In addition, the stoniness percentage by volume in the top 30 cm layer of mineral soil (Viro 1952, 1958, Tamminen 1991) was estimated for each sample plot (Table 1). The percentage cover of the understorey vegetation was inventoried by two persons. The scale for estimating cover percentages was calibrated before the inventory. Four 1 $m^2$ sub-plots located within each sample plot 4 m in the direction of all principal compass points from the centre point of the sample plot were used in the inventories. Species cover was estimated visually using a scale of 0.25–100%: 0.25, 0.5, 1, 2, 3, 5, 10, 15, 20…100. The nomenclature here follows Hämet-Ahti et al. (1998) for vascular plants and Koponen (1994) for mosses, and Piippo (1993) for liverworts.

The biotopes were classified into five classes according to the level of wear. The wear classification applied here is a modification of Holmström's (1970) classification.

Class 1: Undeteriorated vegetation; no paths or only small path area (path width < 30 cm), high cover of understorey vegetation.

Class 2: Slightly deteriorated vegetation; narrow paths (30–50 cm), decreased understorey vegetation cover, cover of vascular plants over 50%.

Class 3: Deteriorated vegetation; wide paths (> 50 cm), exposed tree roots, low cover of understorey vegetation (> 50%), cover of vascular plants approximately 50%.

Class 4: Highly deteriorated vegetation; large path area, large areas of exposed mineral soil, only scarce patches of understorey vegetation left, total understorey cover under 50%.

Class 5: Vegetation totally worn-away, mineral soil exposed.

According to the classification, approximately 40% of the biotopes belonged to Class 1, 50% to Class 2, and 10% to Class 3. Only one biotope belonged to Class 4, and thus Classes 3 and 4 were combined for the analyses.

As measures of recreation pressure (Table 1) the numbers of residents (years 1985, 1995, and 1999) in the surroundings of the study areas within the radius of one and two kilometres were studied by referring to the resident register (Pääkaupunkiseudun … 1992–1999, Vantaan … 1999). In addition the number of children in kindergartens and schools within a radius of 300 metres from the centre of each biotope were registered (year 1999) and used as a measure of recreation pressure.

Urban and rural forest understorey vegetation data from southern Finland was compared to determine how urban pressures have changed species composition and abundance. This reference data was collected from commercial forests of the same site type and same age during the National forest inventory (National forest … 1985–86) and the study of Jalonen and Vanha-Majamaa (2001).

GNMDS (Global Non-Metric Multi-Dimensional Scaling) (Minchin 1991) and one-way analysis of variance (ANOVA), Tukey's HSD test and t-test were used in analyzing the data. In GNMDS, the Bray-Curtis coefficient was used as a dissimilarity measure. Vector fitting procedure with Monte-Carlo tests were used to analyze the correlation of environmental variables with ordination. A selected list of variables explored is given in Table 3. Three-dimensional solution of GNMDS ordination of 71 sample plots was selected to minimize the stress and maximize the correlation of environmental variables with the ordination configuration. Five of the 76 original sample plots, whose vegetation greatly differed from vegetation of other sample plots and, thus, would have distorted the ordination configuration if included, were rejected as outliers. The mean values of the cover percentages for the four sub-plots per sample plot were used in the statistical analysis. The species numbers used were the total numbers of species found in each sample plot.

# 3 Results

The main vegetation gradient according to GNMDS ordination indicated the level of wear ranging from lightly trampled to more worn areas (Fig. 1). The ground layer vegetation cover

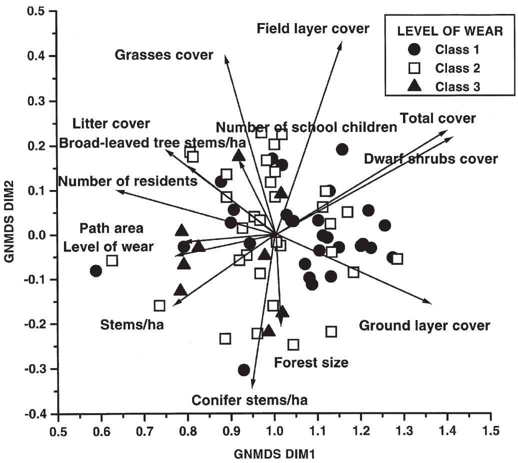


**Fig. 1.** Three dimensional GNMDS ordination of 76 sample plots in urban forests. Dimension 1 against 2 is presented with vectors of selected environmental variables. The length of each vector shows the strength of the correlation in comparison with other vectors. (See Table 3 for correlations.) Path area means area of unconstructed paths per sample plot; cover percentage of grasses includes cover of all grass species and *Luzula pilosa*; number of residents is the number of residents in 1999 within a radius of 1 km; number of school children is the number of children in schools and kindergartens within a radius of 300 m; stems/ha is the total number of tree stems per hectare and total cover means the total cover of understorey vegetation.

**Table 3.** Correlations (Max R) of selected vectors with the ordination configuration (Figs. 1, 2 and 3) and their statistical significance (P). Total understorey vegetation cover = the cover of field and ground layer, field layer cover = the cover of grasses, herbs and dwarf shrubs, ground layer cover = the cover of mosses, liverworts and lichens, level of wear = biotope's wear class (1–3). For other variable explanations see caption of Table 1.

| Variable | Max R | P |
|---|---|---|
| Total number of tree stems per hectare | 0.50 | 0.000 |
| Stems per hectare, coniferous trees | 0.61 | 0.000 |
| Stems per hectare, broad-leaved trees | 0.53 | 0.001 |
| Total understorey vegetation cover | 0.81 | 0.000 |
| Field layer cover | 0.77 | 0.000 |
| Ground layer cover | 0.81 | 0.000 |
| Grass species cover | 0.79 | 0.000 |
| Dwarf shrub cover | 0.87 | 0.000 |
| Total litter cover | 0.63 | 0.000 |
| Number of residents | 0.62 | 0.000 |
| Size of forest | 0.38 | 0.015 |
| Level of wear | 0.40 | 0.011 |
| Path area | 0.37 | 0.022 |
| School children | 0.40 | 0.005 |
| Thickness of humus layer | 0.31 | 0.060 |
| Stoniness | 0.09 | 0.916 |
| Shrub layer cover | 0.26 | 0.196 |
| Shrub layer height | 0.19 | 0.517 |
| Area of exposed mineral soil | 0.14 | 0.711 |
| Distance to the edge of forest | 0.30 | 0.095 |
| Size of biotope | 0.36 | 0.025 |

decreased and the path area increased when the number of residents in the vicinity of the forest area increased. The total understorey vegetation cover and the cover of dwarf shrubs increased when the level of wear decreased, indicating the dwarf shrubs' sensitivity to trampling. The size of forest patch was not in direct connection with the level of wear. The correlations of stoniness, the cover, the height of shrub layer, and the area of exposed mineral soil, were not statistically significant (Table 3).

Another gradient was the gradient of vegetation changes according to the dominant tree species from spruce-dominated forests to forests with increasing number of broad-leaved trees (stand characteristics shown in Table 2). The species composition of understorey vegetation was changed when the number of broad-leaved trees was over 500 stems per hectare. Litter cover increased with an increasing number of broad-leaved trees, whereas the ground layer cover increased with increasing spruce dominance and decreasing litter cover.

Typical MT forest species (Cajander 1926, Kujala 1979), such as *Melampyrum pratense*, *Linnaea borealis*, *Trientalis europaea* and *Vaccinium myrtillus*, had their optimum when the level of wear decreased (Fig. 2). When the level of wear increased, typical mesic species (Kujala 1926, Hämet-Ahti 1998, Reinikainen et al. 2000), such as *Convallaria majalis* and *Melica nutans* were common in the understorey vegetation. Forest species favouring habitats with increasing numbers of broad-leaved trees (Hertz 1932,

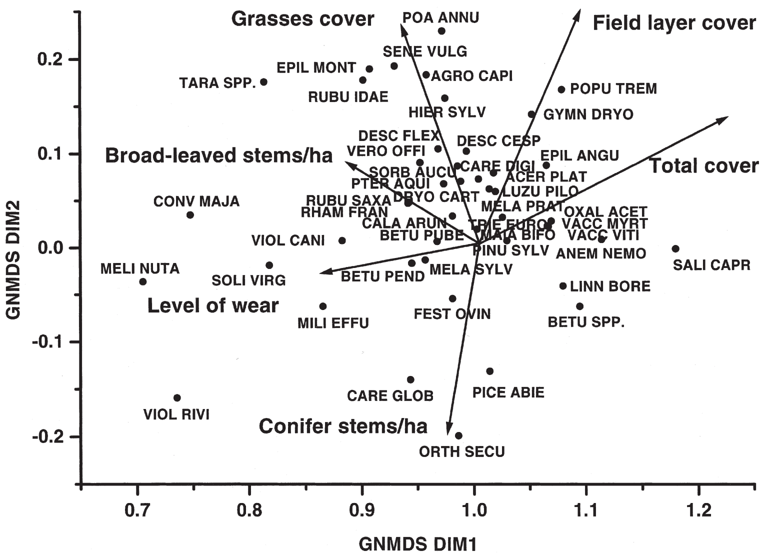


**Fig. 2.** Field layer species ordination. Abbreviations of the species are explained in Appendix.

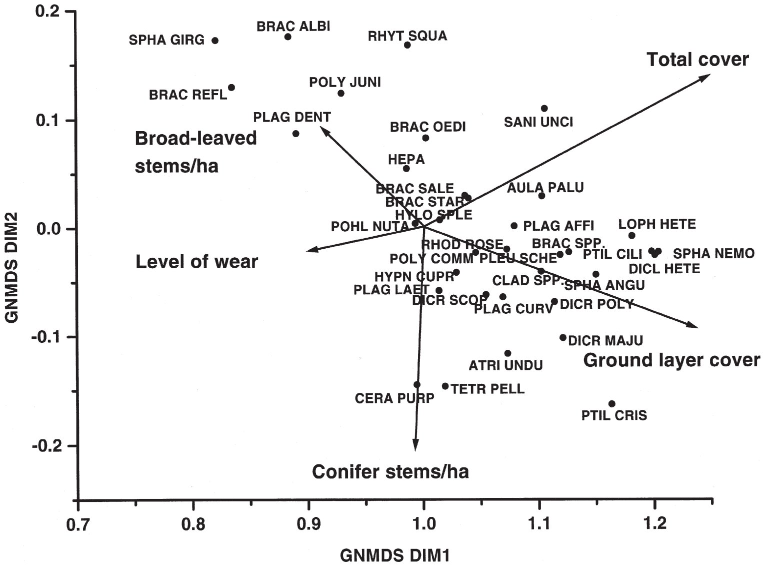


**Fig. 3.** Ground layer species ordination. Abbreviations of the species are explained in Appendix.

Kuusipalo 1985, Hämet-Ahti 1998), such as *Calamagrostis arundinacea*, *Rubus saxatilis* and *Pteridium aquilinum*, were also separated from the species typical in spruce-dominated forests (Sjörs 1948, Reinikainen et al. 2000), such as *Orthilia secunda* and *Carex globularis*. Grasses and ruderal species (Hämet-Ahti et al. 1998), e.g. *Poa annua*, *Agrostis capillaris*, *Senecio vul-*

**Table 4.** Mean understorey vegetation cover percentages in urban forests and reference areas. Reference areas: I: Year 1995 data (Jalonen and Vanha-Majamaa 2001), II: NFI 1985–86 data (National forest… 1985–86). Statistically significant differences (one-way ANOVA) are indicated with boldface characters. * U indicates urban forests and numbers reference areas which differ with statistical significance from each other (Tukey's HSD test P<0.05).

| Understorey vegetation | Urban forests U (n=76), (SD) | Reference areas I (n=43), (SD) | II (n=23), (SD) | P | Sig. diff. * |
|---|---|---|---|---|---|
| Total cover | 68.5 (27.0) | 93.5 (21.3) | 105.5 (38.0) | **0.000** | U-I, U-II |
| Field layer cover | 46.8 (21.5) | 38.9 (16.5) | 44.6 (27.0) | 0.090 | - |
| Dwarf shrubs | 29.1 (15.4) | 22.4 (12.2) | 27.0 (18.4) | **0.039** | U-I |
| VACC MYRT | 20.3 (12.8) | 20.2 (11.0) | 20.9 (16.5) | 0.978 | - |
| VACC VITI | 2.6 (3.0) | 1.5 (1.7) | 5.3 (6.3) | **0.000** | U-II |
| Grasses | 8.3 (8.9) | 6.1 (4.9) | 9.9 (11.5) | 0.177 | - |
| CALA ARUN | 2.4 (5.4) | 2.0 (3.6) | 3.9 (8.4) | 0.430 | - |
| DESC FLEX | 4.5 (5.8) | 3.3 (2.9) | 4.0 (6.3) | 0.492 | - |
| Ground layer cover | 21.7 (18.6) | 54.6 (15.2) | 60.8 (24.6) | **0.000** | U-I, U-II |
| PLEU SCHR | 7.0 (9.4) | 21.6 (11.8) | 22.9 (16.3) | **0.000** | U-I, U-II |
| DICR SPP. | 6.6 (8.7) | 14.3 (8.8) | 22.4 (20.7) | **0.000** | U-I, U-II |
| HYLO SPLE | 0.9 (3.4) | 4.2 (3.2) | 4.3 (4.6) | **0.000** | U-I, U-II |
| BRAC SPP. | 2.8 (4.8) | 3.9 (6.2) | 1.0 (3.6) | 0.097 | - |
| *Sphagnum* spp. | 0.9 (3.5) | 6.4 (13.9) | 6.2 (10.7) | **0.003** | U-I, U-II |
| Liverworts | 0.1 (0.4) | 1.1 (1.5) | 0.1 (0.1) | **0.000** | U-I |

*garis*, *Rubus idaeus*, *Taraxacum* species, *Hieracium sylvaticum* and *Veronica officinalis*, grew in the smallest forest patches with increasing grass cover and in slightly deteriorated (Class 2) urban forests in addition to common MT species.

The ground layer species variation was more pronounced in relation to tree species than the level of wear (Fig. 3). A number of species, e.g. *Brachythecium albicans*, *B. reflexum* and *Plagiothecium denticulatum*, increased with increasing numbers of broad-leaved trees. These species were clearly distinguished from species that were connected to spruce, e.g. *Plagiothecium laetum*, *Ptilium crista-castrensis*, *Tetraphis pellucida* and *Dicranum majus*. The majority of the typical *Myrtillus* type moss species (Cajander 1926, Kujala 1979) had their optimums when the level of wear decreased. For example, *Pleurozium schreberi*, *Sphagnum* species and *Ptilidium ciliare* had their optimums where the ground layer cover was highest and disappeared first when the level of wear increased. The first species appearing along the gradient of decreasing wear was the pioneer species (e.g. Jonsson and Esseen 1990) *Pohlia nutans*. *P. nutans*, *Dicranum scoparium* and *Brachythecium oedipodium* were the only moss species occurring in the most disturbed areas.

The total understorey vegetation cover was lower in urban forests than in reference areas due to a marked decrease in the cover of moss species (Table 4). The ground layer cover in urban forests was only half of that in the reference areas, and the difference was statistically significant for *Pleurozium schreberi*, *Dicranum* species, *Hylocomium splendens*, *Sphagnum* species and liverworts. Neither field layer, dwarf shrubs, grasses nor individual field layer species cover indicated clear differences between urban forests and reference areas.

The cover of dwarf shrubs and the cover of *Vaccinium myrtillus* were lower in Class 3 than in Class 1 (Table 5). The frequencies of common species (belonging to 12 most common species in urban forests in our study areas) characteristic of the *Myrtillus* site type (Cajander 1926, Kujala 1979) decreased when the level of wear increased (Table 6). The frequencies of *Brachythecium oedipodium* and of the pioneer species *Pohlia nutans* increased with increasing level of wear. The difference in species numbers between

**Table 5.** Mean cover percentages of the most common understorey vegetation species in urban forests in three wear classes. Statistically significant differences (one-way ANOVA) are indicated with boldface characters. * Numbers indicate classes which differ with statistical significance from each other (Tukey's HSD test P<0.05). CL means class and C% cover percentage.

| Understory vegetation | CL 1 (n=31) C%, (SD) | CL 2 (n=35) C%, (SD) | CL 3 (n=10) C%, (SD) | P | Sig. diff. * |
|---|---|---|---|---|---|
| Total cover | 74.3 (26.6) | 70.7 (25.1) | 43.0 (22.0) | **0.004** | 1-3, 2-3 |
| Field layer | 50.4 (24.0) | 48.3 (17.8) | 30.5 (19.0) | **0.031** | 1-3, 2-3 |
| Ground layer | 24.0 (18.4) | 22.3 (19.6) | 12.4 (13.7) | 0.229 | - |
| Dwarf shrubs | 28.0 (16.4) | 21.1 (11.6) | 13.4 (8.8) | **0.009** | 1-3 |
| Grasses | 7.2 (9.2) | 10.0 (9.1) | 5.7 (6.1) | 0.260 | - |
| Herbs | 7.2 (8.1) | 7.0 (6.8) | 3.4 (3.2) | 0.320 | - |
| Bryophytes | 23.9 (18.4) | 22.3 (19.6) | 12.4 (13.7) | 0.230 | - |
| VACC MYRT | 24.9 (14.9) | 18.4 (10.4) | 12.5 (8.4) | **0.013** | 1-3 |
| PLEU SCHR | 9.2 (9.3) | 6.6 (10.2) | 1.5 (2.4) | 0.078 | - |
| PTER AQUI | 4.0 (11.6) | 1.3 (3.3) | 1.3 (4.0) | 0.337 | - |
| DESC FLEX | 3.5 (4.7) | 6.0 (6.8) | 2.5 (3.7) | 0.109 | - |
| DICR SCOP | 3.1 (4.8) | 2.0 (3.4) | 1.3 (2.0) | 0.326 | - |
| VACC VITI | 3.0 (3.4) | 2.6 (2.8) | 0.9 (0.8) | 0.125 | - |
| DICR POLY | 2.7 (4.3) | 2.1 (3.5) | 1.5 (2.9) | 0.659 | - |
| CALA ARUN | 2.6 (6.9) | 2.5 (4.6) | 1.2 (2.0) | 0.755 | - |
| MELA PRAT | 2.5 (4.1) | 1.2 (2.3) | 0.5 (0.9) | 0.127 | - |
| DICR MAJU | 2.3 (4.5) | 2.3 (6.5) | 0.3 (0.9) | 0.567 | - |
| MAIA BIFO | 2.1 (2.6) | 2.0 (3.0) | 1.7 (2.3) | 0.910 | - |
| SORB AUCU | 2.0 (3.1) | 5.4 (5.7) | 3.7 (6.4) | **0.025** | 1-2 |
| BRAC OEDI | 1.3 (2.3) | 3.3 (6.1) | 3.0 (4.4) | 0.196 | - |
| PICE ABIE | 0.5 (1.1) | 1.8 (5.8) | 2.5 (6.0) | 0.390 | - |
| HYLO SPLE | 0.6 (1.8) | 0.6 (1.6) | 2.6 (8.3) | 0.199 | - |

the wear classes decreased with increasing level of wear except for grasses, but were not statistically significant (Table 7). There were no statistically significant differences in tree species ratio, stems per hectare, basal area, and volume between the different wear classes.

**Table 6.** Species frequencies in urban forests in wear classes 1–3 (n=76).

| Species | Class 1 Freq. % | Class 2 Freq. % | Class 3 Freq. % |
|---|---|---|---|
| MELA PRAT | 67.7 | 42.9 | 30 |
| TRIE EURO | 83.9 | 60 | 50 |
| DICR POLY | 77.4 | 65.7 | 50 |
| VACC VITI | 96.8 | 82.9 | 70 |
| LUZU PILO | 77.4 | 62.9 | 70 |
| BRAC OEDI | 77.4 | 82.9 | 90 |
| POHL NUTA | 58.1 | 77.1 | 80 |

## 4 Discussion

According to our results, the recreational use of residents living in the vicinity of the forest areas appears to be important factor affecting understorey vegetation in urban forests. When the recreation pressure towards a certain forest area increases, the level of wear increases. The size of forest patch was not in direct connection with the level of wear as suggested by the results of an earlier study by Kellomäki and Wuorenrinne (1979) based on smaller amount of data. There were also deteriorated areas along the edges of larger forest patches and in the inner parts of large patches in the vicinity of constructed paths and attractive natural elements.

*Myrtillus* type is edaphically comparatively uniform and differences in vegetation are caused mainly by tree stand factors (Kuusipalo 1983,

**Table 7.** Mean species numbers in urban forests in wear classes 1–3. Statistical test used was one-way ANOVA with Tukey's HSD test $P<0.05$ for statistical significance. Sp.# means the number of species.

| Understorey vegetation | Class 1 Sp. #, (SD) | | Class 2 Sp. #, (SD) | | Class 3 Sp. #, (SD) | | P | Sig. diff. |
|---|---|---|---|---|---|---|---|---|
| Total | 19.9 | (4.6) | 18.5 | (4.1) | 16.6 | (3.5) | 0.095 | - |
| Field layer | 10.7 | (2.4) | 10.8 | (2.9) | 9.4 | (3.1) | 0.347 | - |
| Ground layer | 9.1 | (3.8) | 7.7 | (3.1) | 7.2 | (3.0) | 0.142 | - |
| Grasses | 2.3 | (1.1) | 2.4 | (1.2) | 2.6 | (1.1) | 0.752 | - |
| Herbs | 3.9 | (1.2) | 3.8 | (2.2) | 2.6 | (1.5) | 0.111 | - |
| Bryophytes | 8.9 | (3.7) | 7.5 | (3.1) | 7.2 | (3.0) | 0.161 | - |

Lahti and Väisänen 1987). The vegetation in the selected MT biotopes was homogenous and thus, there was no difference in wear resistance between the biotopes. Therefore, it was justified to classify the biotopes into five classes according to the level of wear. Finally, there were no statistically significant differences in tree layer characteristics between the different wear classes.

### 4.1 Species Composition

The species composition changed when the level of wear increased in urban forests. The cover of most common forest species decreased but the species remained existent (see Table 5). At the same time, the proportion of several wear-resistant ruderal species low in frequency increased. These are species, which benefit from intermediate disturbance. This could be explained by the 'intermediate disturbance hypothesis' (Connell 1978), which predicts that species richness is higher in intermediately disturbed sites than in heavily disturbed or undisturbed ones. There were no statistically significant differences in the cover of the understorey vegetation between Class 1 and 2, but species composition changed between the classes. Thus, the total understorey vegetation cover in undeteriorated and slightly deteriorated urban forests was approximately of the same level. The most deteriorated areas were not included in the present study.

However, we suggest that when trampling is intensive enough the cover of vegetation decreases, but the species composition remains nearly the same. Initial forest species survive at least in patches of undeteriorated understorey vegetation between the networks of paths. Even if the forest patch is highly deteriorated, there are usually small patches of fairly unchanged vegetation left. This is well in accordance with results of Florgård (2000).

Dominant tree species affect the composition of the understorey vegetation (Kuusipalo 1983, Lahti and Väisänen 1987). Correspondingly, we found a distinctive light gradient in the understorey vegetation from the more shady Norway spruce -dominated stands to the better light conditions of forests with increasing numbers of broad-leaved trees. Light demanding understorey species (Kuusipalo 1985, Hämet-Ahti 1998), e.g. *Calamagrostis arundinacea, Pteridium aquilinum and Rubus saxatilis,* increased in urban forests with increasing number of broad-leaved trees. Moss coverage decreased with increasing amounts of leaf litter on the forest floor. Like Lahti and Väisänen (1987) concluded, mosses tend to withdraw from where the litter is abundant. Also, nutrients released and washed out of the tree crowns affect composition of understorey vegetation and especially composition of mosses, which absorb efficiently nutrients from rain drip. Fertility of the soil increases with increasing number of broad-leaved trees and affects understorey species composition (Lahti and Väisänen 1987).

The results of earlier studies (Liddle 1975, Kellomäki 1977, Nylund et al. 1979) suggest that grasses are the most wear-resistant species, and further, that grasses and some tolerant herbs can replace more sensitive dwarf shrubs because of their better regeneration ability (Kellomäki and

Saastamoinen 1975, Nylund et al. 1979). However, we did not find a higher cover of grasses in urban forests than in the reference areas. Neither was the cover of grasses in deteriorated areas higher than in the undeteriorated areas. Thus, it seems that trampling does not increase the proportion of grasses in urban forests. This is in accordance with the results of Dyring (1984). In addition to increased recreational use, edge effect (changed light conditions, microclimate, etc.) may change the vegetation in fragmented urban forest areas. The increasing amount of light may explain the increase of grasses in small urban forest patches and along the edges of larger forest areas.

As in previous studies (cf. Kellomäki 1973, Nylund et al. 1979), we found that initial MT species were sensitive to trampling. However, contrary to the conclusions of Nylund et al. (1979), we found that *Melampyrum sylvaticum* was common also in intermediately deteriorated areas and thus seemed to tolerate trampling better than other initial MT species. The other exception was *Maianthemum bifolium,* which was also common in intermediately deteriorated areas as Nylund et al. (1979) concluded. According to our results, *Convallaria majalis* is one of the most wear-resistant species, which is in accordance with findings of Nylund et al. (1979). Other wear-resistant, although relatively rare, species is *Melica nutans*. They are species of mesic forests, which seem to benefit from the additional nutrient inputs in urban forests. For example nitrogen load at urban areas is still considerably high (in 1997 emissions of nitrogen oxides (NOx) in the capital area were 23 800 tons per year) (YTV, Helsinki Metropolitan Area … 2000). Nylund et al. (1979) found that, for example, *Agrostis* species, *Poa annua* and *Veronica* species became more common as a result of trampling. In our study, these species were common and abundant in the smallest forest patches where there was more light due to the edge effect and where wear was more pronounced than in the larger forest patches.

*Pohlia nutans* and *Dicranum scoparium* were the most wear-resistant moss species in our study, which is well in accordance with the results of Hoogesteger and Havas (1976) and Ukkola (1995). *P. nutans* is a pioneer species which fast colonizes bare soil (Rydgren et al. 1998) and *D. scoparium* is a common species in trampled areas and even on paths because its vegetative reproduction is fast (Koponen 1994). Of other resistant species *Brachythecium* species may have benefited from nitrogen loads (fertilization and deposit) in urban areas (Mäkipää 2000). *Pleurozium schreberi* proved to be one of the most sensitive *Myrtillus* site type species according to our results. Other sensitive species included *Dicranum majus, D. polysetum* and *Ptilium crista-castrensis.* This is in accordance with the results of Ukkola (1995) and Hoogesteger and Havas (1976), who found that *P. schreberi*, *D. polysetum* and *P. crista-castrensis* are sensitive to trampling.

### 4.2 Understory Vegetation Cover

The visual estimation of cover percentages is a subjective method, which may cause error in cover estimates (Tonteri 1990). However, as compared to other cover estimation methods, it is less time-consuming and still relatively reliable method (Vanha-Majamaa et al. 2000). It should also be taken into account that the cover of different plant species may vary considerably between years due to many natural reasons, such as weather conditions. Jalonen and Vanha-Majamaa (2001) showed in their study that especially the cover of field layer might vary significantly between years. Despite these possible errors when comparing vegetation data from different years and areas, it is likely that the significant difference in vegetation cover between rural and urban areas discovered holds true, and that the understorey vegetation cover in urban forests has decreased as compared to rural reference areas.

The most remarkable difference between urban forests and the reference areas was in ground layer cover. As in earlier studies (e.g. LaPage 1967, Nylund et al. 1979, Ukkola 1995), it appeared that bryophytes were the most susceptible to trampling disturbance. Especially the cover of the most common and abundant M*yrtillus* site type species, such as *Pleurozium schreberi*, *Hylocomium splendens*, *Dicranum* and *Sphagnum* species, was lower in urban forests than in the reference areas. This is in accordance with the results of Jalonen and Vanha-Majamaa (2001) who found that the ground layer was more susceptible to mechanical effects of felling machinery than the field layer. This may be due to much more slowly increase of moss cover than vascular plant cover after disturbance. Lack of surviving underground structures or low ability for recovery from surviving structures under prevailing conditions may explain the more slowly recovery of mosses (Rydgren et al. 1998).

The cover of the understorey vegetation decreased considerably in the most disturbed areas. The cover of dwarf shrubs, especially of *Vaccinium myrtillus*, diminished in these areas. Dwarf shrubs are sensitive to trampling (Kellomäki 1973). According to our results, the cover of *Vaccinium vitis-idaea* did not differ between the wear classes. This supports the results of earlier studies, suggesting that the trampling tolerance of *V. vitis-idaea* is higher than that of *V. myrtillus* with thin and thus, more susceptible leaves (Kellomäki and Saastamoinen 1975, Nylund et al. 1979).

### 4.3 Species Numbers

Holmström (1970) and Nylund et al. (1979) suggested that there is an increase in the number of species in areas subjected to moderate trampling. However, our results indicate that species numbers will not change significantly when trampling increases. On the contrary there was a decreasing trend in species numbers although the differences between wear classes were not statistically significant. According to LaPage (1967), understorey vegetation species numbers decrease most dramatically in the initial stage of trampling disturbance. In the following years, there will be no notable changes in species number because the proportion of trampling-tolerant species is increasing at the same time as the proportion of less-resistant species is decreasing. Due to different sample plot size, species numbers of reference areas and urban areas studied were not comparable.

## 5 Conclusions

The ground layer cover differed with statistical significance between urban forests and reference areas. The vegetation of the most disturbed urban forest patches was highly changed or almost completely worn-away. In slightly deteriorated forests initial forest species were still present, although the cover percentages were decreased and the proportion of species benefiting from human influence was higher. The smallest forest patches with the greatest recreation pressure were the most disturbed. Thus, in urban forests the number of potential recreationists in relation to the size of forest patches is one of the main factors to be considered in land use planning when trying to maintain initial forest vegetation.

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*Total of 58 references*

**Appendix.** Species which occurred in more than one sample plot and their frequency and mean cover percentage in sample plots according to classes indicating the level of wear.

| Abbreviation | Scientific name | Class 1 | | Class 2 | | Class 3 | |
|---|---|---|---|---|---|---|---|
| | | Freq. (n=31) | Mean cover% | Freq. (n=35) | Mean cover% | Freq. (n=10) | Mean cover% |
| **Field layer** | | | | | | | |
| ACER PLAT | *Acer platanoides* | | | 4 | 0.09 | | |
| AGRO CAPI | *Agrostis capillaris* | 3 | 0.01 | 5 | 0.25 | 3 | 0.75 |
| ANEM NEMO | *Anemone nemorosa* | 2 | 0.04 | | | | |
| BETU PEND | *Betula pendula* | 3 | 0.04 | 8 | 0.47 | 1 | 0.03 |
| BETU PUBE | *Betula pubescens* | | | 4 | 0.22 | 2 | 0.15 |
| BETU SPP. | *Betula* species | | | 1 | <0.01 | 1 | 0.01 |
| CALA ARUN | *Calamagrostis arundinacea* | 13 | 2.61 | 20 | 2.72 | 4 | 1.18 |
| CARE DIGI | *Carex digitata* | 7 | 0.14 | 5 | 0.07 | 2 | 0.10 |
| CARE GLOB | *Carex globularis* | 7 | 0.10 | 4 | 0.25 | | |
| CONV MAJA | *Convallaria majalis* | 2 | 0.46 | 6 | 0.91 | 1 | 0.01 |
| DESC CESP | *Deschampsia cespitosa* | | | 2 | 0.07 | 1 | 0.01 |
| DESC FLEX | *Deschampsia flexuosa* | 27 | 3.50 | 30 | 5.97 | 8 | 2.48 |
| DRYO CART | *Dryopteris carthusiana* | 3 | 0.06 | 6 | 0.12 | | |
| EPIL ANGU | *Epilobium angustifolium* | 1 | 0.02 | 3 | 0.05 | 1 | 0.03 |
| EPIL MONT | *Epilobium montanum* | | | 2 | 0.03 | | |
| FEST OVIN | *Festuca ovina* | 2 | 0.10 | | | 1 | 0.08 |
| GYMN DRYO | *Gymnocarpium dryopteris* | 1 | 0.18 | 1 | 0.04 | | |
| HIER SYLV | *Hieracium sylvaticum* | 1 | <0.01 | 4 | 0.13 | 1 | 0.08 |
| LINN BORE | *Linnaea borealis* | 13 | 0.62 | 11 | 0.22 | 2 | 0.18 |
| LUZU PILO | *Luzula pilosa* | 24 | 0.94 | 22 | 0.99 | 7 | 0.49 |
| MAIA BIFO | *Maianthemum bifolium* | 27 | 2.13 | 27 | 1.98 | 9 | 1.70 |
| MELA SYLV | *Melampyrum sylvaticum* | 5 | 0.09 | 7 | 0.60 | 1 | 0.03 |
| MELA PRAT | *Melampyrum pratense* | 21 | 2.48 | 15 | 1.25 | 3 | 0.51 |
| MELI NUTA | *Melica nutans* | | | 3 | 0.03 | | |
| MILI EFFU | *Milium effusum* | 1 | 0.01 | 1 | <0.01 | 1 | 0.06 |
| ORTH SECU | *Orthilia secunda* | 5 | 0.04 | 1 | 0.14 | 1 | 0.08 |
| OXAL ACET | *Oxalis acetosella* | 6 | 0.05 | 7 | 0.30 | 1 | 0.01 |
| PICE ABIE | *Picea abies* | 11 | 0.54 | 12 | 1.78 | 3 | 2.51 |
| PINU SYLV | *Pinus sylvestris* | 5 | 0.03 | 4 | 0.02 | 3 | 0.06 |
| POA ANNU | *Poa annua* | 1 | <0.01 | 1 | <0.01 | | |
| POPU TREM | *Populus tremula* | 7 | 0.74 | 5 | 0.23 | 1 | 0.08 |
| PTER AQUI | *Pteridium aquilinum* | 6 | 4.02 | 8 | 1.29 | 1 | 1.25 |

| Abbreviation | Scientific name | Class 1 | | Class 2 | | Class 3 | |
|---|---|---|---|---|---|---|---|
| | | Freq. (n=31) | Mean cover% | Freq. (n=35) | Mean cover% | Freq. (n=10) | Mean cover% |
| RHAM FRAN | *Rhamnus frangula* | 1 | <0.01 | 1 | 0.01 | | |
| RUBU IDAE | *Rubus idaeus* | | | 3 | 0.06 | 1 | 0.10 |
| RUBU SAXA | *Rubus saxatilis* | 2 | 0.01 | 4 | 0.05 | | |
| SALI CAPR | *Salix caprea* | 1 | <0.01 | 2 | 0.04 | | |
| SENE VULG | *Senecio vulgaris* | | | 2 | 0.04 | | |
| SOLI VIRG | *Solidago virgaurea* | 2 | 0.06 | 3 | 0.08 | 1 | 0.03 |
| SORB AUCU | *Sorbus aucuparia* | 29 | 2.05 | 29 | 5.41 | 9 | 3.73 |
| TARA SPP. | *Taraxacum species* | | | 2 | 0.03 | | |
| TRIE EURO | *Trientalis europaea* | 26 | 1.09 | 21 | 0.96 | 5 | 0.79 |
| VACC MYRT | *Vaccinium myrtillus* | 31 | 24.95 | 34 | 18.41 | 10 | 12.53 |
| VACC VITI | *Vaccinium vitis-idaea* | 30 | 3.04 | 29 | 2.63 | 7 | 0.86 |
| VERO OFFI | *Veronica officinalis* | 2 | 0.03 | 2 | 0.01 | | |
| VIOL CANI | *Viola canina* | 1 | 0.02 | 1 | <0.01 | | |
| VIOL RIVI | *Viola riviniana* | 1 | 0.02 | 1 | <0.01 | | |
| **Ground layer** | | | | | | | |
| ATRI UNDU | *Atrichum undulatum* | 4 | 0.05 | 6 | 0.28 | | |
| AULA PALU | *Aulacomnium palustre* | 3 | 0.09 | 4 | 0.07 | | |
| BRAC ALBI | *Brachythecium albicans* | | | 1 | 0.04 | 1 | 0.25 |
| BRAC OEDI | *Brachythecium oedipodium* | 24 | 1.30 | 29 | 3.35 | 9 | 3.03 |
| BRAC REFL | *Brachythecium reflexum* | 3 | 0.01 | 2 | 0.08 | 2 | 0.06 |
| BRAC SALE | *Brachythecium salebrosum* | 8 | 0.08 | 4 | 0.06 | 3 | 0.14 |
| BRAC SPP. | *Brachythecium species* | 1 | <0.01 | 3 | 0.15 | 1 | <0.01 |
| BRAC STAR | *Brachythecium starkei* | 6 | 0.04 | | | 1 | 0.01 |
| CERA PURP | *Ceratodon purpureus* | 5 | 0.01 | 2 | <0.01 | | |
| CLAD SPP. | *Cladonia species* | 7 | 0.03 | 5 | <0.01 | | |
| DICL HETE | *Dicranella heteromalla* | 2 | 0.01 | | | | |
| DICR MAJU | *Dicranum majus* | 13 | 2.26 | 13 | 2.25 | 3 | 0.33 |
| DICR MONT | *Dicranum montanum* | 2 | 0.03 | | | | |
| DICR POLY | *Dicranum polysetum* | 24 | 2.71 | 23 | 2.09 | 5 | 1.52 |
| DICR SCOP | *Dicranum scoparium* | 24 | 3.11 | 25 | 1.99 | 8 | 1.28 |
| HEPA | *Hepaticae* | 16 | 0.09 | 14 | 0.18 | 2 | 0.04 |
| HYLO SPLE | *Hylocomium splendens* | 13 | 0.56 | 14 | 0.61 | 2 | 2.64 |
| HYPN CUPR | *Hypnum cupressiforme* | | | 3 | 0.15 | | |
| LOPH HETE | *Lophozia heterocolpos* | 2 | <0.01 | | | | |
| PLAG AFFI | *Plagiomnium affine* | 5 | 0.01 | 7 | 0.12 | 1 | 0.01 |
| PLAG CURV | *Plagiothecium curvifolium* | 7 | 0.17 | 5 | 0.07 | 3 | 0.06 |
| PLAG DENT | *Plagiothecium denticulatum* | 4 | 0.03 | 3 | 0.09 | 2 | 0.04 |
| PLAG LAET | *Plagiothecium laetum* | 19 | 0.24 | 15 | 0.42 | 4 | 0.27 |
| PLEU SCHR | *Pleurozium schreberi* | 29 | 9.18 | 31 | 6.64 | 90 | 1.54 |
| POHL NUTA | *Pohlia nutans* | 18 | 0.79 | 27 | 1.61 | 80 | 1.02 |
| POLY COMM | *Polytrichum commune* | 9 | 0.34 | 8 | 0.28 | 1 | 0.04 |
| POLY JUNI | *Polytrichum juniperinum* | 1 | <0.01 | 1 | <0.01 | | |
| PTIL CILI | *Ptilidium ciliare* | 2 | 0.01 | | | | |
| PTIL CRIS | *Ptilium crista-castrensis* | 1 | 0.16 | 3 | 0.40 | 2 | 0.02 |
| RHOD ROSE | *Rhodobryum roseum* | 5 | 0.03 | 4 | 0.03 | | |
| RHYT SQUA | *Rhytidiadelphus squarrosus* | 2 | <0.01 | 3 | 0.82 | 2 | 0.06 |
| SANI UNCI | *Sanionia uncinata* | 3 | 0.04 | 2 | <0.01 | 1 | 0.05 |
| SPHA ANGU | *Sphagnum angustifolium* | 6 | 1.35 | 4 | 0.37 | | |
| SPHA GIRG | *Sphagnum girgensohnii* | | | 2 | 0.07 | | |
| SPHA NEMO | *Sphagnum nemoreum* | 1 | 0.30 | 1 | <0.01 | | |
| TETR PELL | *Tetraphis pellucida* | 6 | 0.02 | | | | |