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DYNAMICS OF THE STRUCTURE OF TALLINN URBAN FORESTS

Abstract. Changes in the state and floristic composition of the undergrowth, shrub layer, and herbaceous layer caused by recreation pressure on urban forests were studied on sample plots established in Tallinn and the Lahemaa National Park in *Vaccinium* site type pine stands. The number of pine undergrowth was small on all sample plots and its state was not promising. A greater density and number of species of the shrub layer was estimated on urban sample plots. An increase in the number of species in the herb layer on urban sample plots was observed as well. Increase in the trampling pressure and improved light conditions bring forth the invasion of trampling-resistant open area species into the composition of ground layer vegetation.

Key words: urban forests, *Vaccinium* type pine stand, recreation pressure, undergrowth, shrub layer, herbaceous layer.

Environmental changes caused by human impact on the environment cause changes also in the appearance of forests, especially urban forests which are intensively used for recreation purposes. Forest shrub and ground layer vegetation, like other components of forest ecosystems, are sensitive to human impact.

The results of many researches dealing with the dynamics of lower layers of forests (Kellomäki, Saastamoinen, 1975; Kellomäki, 1977; Николин, 1975; Спиридонов, 1978; Рожков, Романов, 1979; Рысин, 1983; et al.) indicate that the state of undergrowth, shrub, and herb layers may be considered a good indicator of the state of the whole forest biocoenoses. Following this principle, several scales of diagnostic characteristics for determining the deterioration level of forest biocoenoses caused by recreation have been developed (e. g., Казанская, Ланина, 1975; Николин, 1975; Полякова, 1980; Рысин, 1983).

The state and floristic composition of the undergrowth, shrub layer, and ground layer of Tallinn forests were studied on the sample plots established for the determination of the ecological state of Tallinn urban forests. The sample plots were established in 1980—1982 in *Vaccinium* type pine stands of site index classes III and IV which are the most widely spread stands on the administrative territory of Tallinn (Pärn, 1990). The number of sample plots in age class III was 9, in age class IV — 10, and in age class V — 10; the area of the plots was 0.02—0.05 ha with at least 20 trees growing on each of the plots. Control sample plots were established in analogous stands of the Lahemaa National Park, approximately 70 km east of Tallinn, four sample plots for each age class.

On each sample plot the undergrowth and the number of trees and shrubs of the shrub layer were counted by species, the floristic composition (flowering plants) of the herbaceous layer was determined, and the area of the trampled territory was measured. Data on sample plots are given in Tables 1 and 2 and in the Figure.

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Table 1

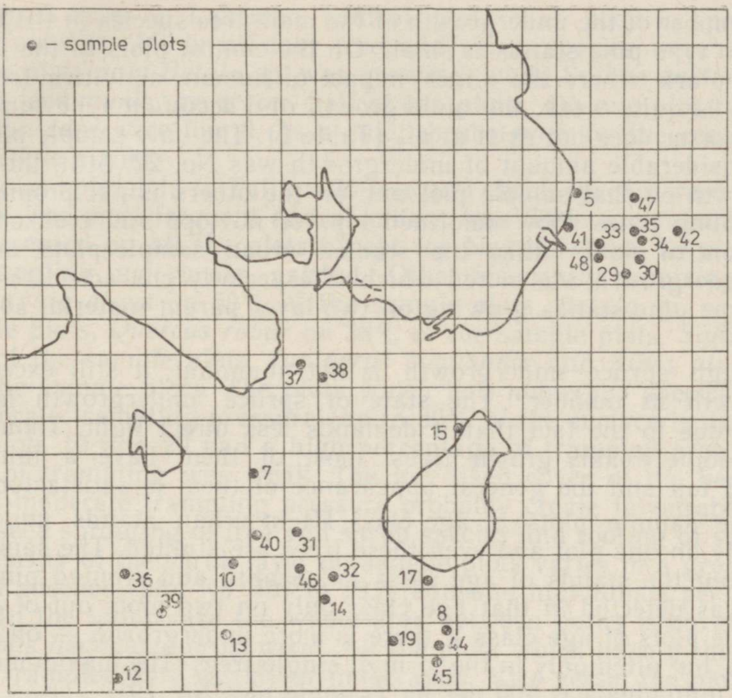
General data on studied sample plots

No.	Locality (forest district)	Age class	Stand density	Undergrowth/ vital per ha	Density of shrub layer per ha	Trampled area, %	Herbaceous layer	
							Total number of species	Number of char. species
12	Harku	III	0.8	—	2460	22	17	8
13	Harku	III	0.9	—	6980	5	14	5
17	Harku	III	0.7	200/20	2540	14	16	8
32	Municipal	III	0.9	—	9000	26	9	1
35	Iru	III	0.8	—	1030	23	10	7
36	Harku	III	0.8	—	600	55	6	3
37	Municipal	III	0.8	—	270	87	18	4
39	Municipal	III	0.7	—	480		24	3
40	Municipal	III	0.7	—	—	80	14	3
5	Municipal	IV	0.8	—	10140	36	21	5
7	Municipal	IV	1.0		920		24	3
10	Municipal	IV	0.7	460/60	2520	67	24	8
14	Harku	IV	0.8	—	19480	14	21	5
15	Harku	IV	1.0	—	4860	7	19	4
29	Iru	IV	0.8	2480/210	680	77	20	8
30	Iru	IV	0.6	—	720	47	16	9
38	Municipal	IV	0.9	—	3000	17	27	0
42	Municipal	IV	0.8	—	1140	18	24	7
44	Harku	IV	0.8	—	2540	17	27	5
8	Harku	V	0.6	160/40	1900	14	19	10
19	Harku	V	0.7	2120/400	860	11	12	8
31	Municipal	V	0.7	—	2800	84	21	6
33	Iru	V	0.8	880/280	1840	24	23	7
34	Iru	V	0.9	—	400	8	16	10
41	Municipal	V	1.0	20/—	3840	18	24	3
45	Harku	V	0.9	—	1380	31	23	4
46	Municipal	V	0.8	—	7840	29	17	4
47	Iru	V	0.7	240/40	2240	14	13	9
48	Iru	V	0.9	20/—	920	45	19	7

Table 2

General data on control sample plots

No.	Locality (forest district)	Age class	Stand density	Undergrowth per ha	Density of shrub layer per ha	Trampled area, %	Herbaceous layer	
							Total number of species	Number of char. species
21	Palmse	III	0.8	80	200	0	11	9
49	Palmse	III	1.1	80	40	0	11	8
53	Sagadi	III	0.7	—	—	0	7	6
22	Valgejõe	IV	0.8	10580	320	0	9	6
25	Käsmu	IV	0.8	330	40	2	11	8
28	Sagadi	IV	0.8	560	200	6	17	10
50	Palmse	IV	0.8	80	140	0	7	7
23	Sagadi	V	0.9	60	20	0	8	6
24	Palmse	V	0.9	—	—	0	7	6
26	Käsmu	V	0.8	740	300	0	12	9
51	Sagadi	V	1.0	40	1860	0	10	8



Sketch-map of Tallinn.

Results and Discussion

Undergrowth. Natural regeneration and its development in forest depends on many factors. The most important among them are stand age, composition, intensity of seed production, soil conditions (especially the state of the litter layer), climatic conditions, and the density of the herbaceous layer. In connection with the growing intensity of urbanization processes, recreation pressure has become the decisive factor in the determination of the fate of undergrowth in urban and suburban forests (Таран, Спиридонов, 1977; Репшас, Палишкис, 1983).

The abundance of undergrowth, its state and distribution under the tree layer indicate the state and tolerance of stands to the impact of various factors (Зукерт, Трапидо, 1975; Таран, Спиридонов, 1977; Карпачевский et al., 1978; Полякова et al., 1981; Дыренков, 1983). Therefore, these indices have found implementation in various systems of the estimation of forest deterioration level (Казанская, Ланина, 1975; Николин, 1975; Савицкая, 1979; Полякова, 1980).

Several authors (Таран, Спиридонов, 1977; Полякова et al., 1981) have observed that in older undamaged *Vaccinium* type pine stands there exists abundant pine undergrowth. It has been reported that in the case of a weak recreation pressure at first even an increase in the number of undergrowth occurs, as the decreased thickness of the litter layer in trampled areas and the exposure of soil on camp fires create better conditions for the germination of tree seeds and plant growth. An increase in recreation pressure brings forth a progressive damage of seedlings and young trees, their vitality decreases and in the case of a strong pressure the undergrowth of the main tree species of pine forests is almost absent or damaged to feebleness (Бредихина, Родионов, 1966; Надеждина, 1978; Левина, Петухова, 1980; Крестьяшина, Арно, 1983; et al.).

The number of the undergrowth of the main tree species in the Estonian *Vaccinium* type pine stands is small. On the control plots in the Lahemaa National Park where the direct impact of human activities (recreation pressure) is quite weak, the undergrowth of *Vaccinium* type pine stands is very poor or does not exist at all (Table 2). The only sample plot which had a considerable amount of undergrowth was No. 22. Still, the state of undergrowth on that sample plot and on the others is not promising. As a rule, young pines show deformed tops or no tops and crooked trunks. On the control plots, unlike the studied urban sample plots, also some spruce undergrowth was noted which is especially characteristic of *Vaccinium* type pine stands growing on two-layer parent material soils (Lõhmus, 1974).

Although spruce undergrowth is not abundant, it still exceeds pine undergrowth in number. The state of spruce undergrowth is better, probably due to the fact that it demands less direct light. Though there are also some weakly grown trees, most of them have a fairly well-developed top and the general appearance of them is satisfactory.

On the sample plots of age class III in urban stands undergrowth exists only on one plot and even these trees are stunted. The same can be noted about the stands of age class IV. Scanty and stunted pine undergrowth was detected in that age class only on two plots out of nine. On the sample plots of age class V there is more undergrowth — on six plots out of ten, but often only in the form of single trees. The maximum number of viable individuals is 400 per ha (sample plot No. 19).

Spruce undergrowth was reported only on a few sample plots as single small trees.

The probable reasons for the bad state of undergrowth are the considerably high canopy density, trampling, and the existence of a thick and shadow-resistant shrub layer on several sample plots. On those plots where the undergrowth is more abundant (sample plots 19, 29, and 33) there is only a sparse shrub layer and the stand density is relatively low (0.7—0.8). On the sample plots where, in spite of a sparse shrub layer, there is still no natural regeneration of main tree species (sample plots 30, 36, 37, 40, and others), heavy soil trampling has been observed. Still, the existence of a normal natural regeneration in larger openings (e.g. in Kloostrimetsa forest) should be noted.

Shrub layer. In recreation forests the shrub layer has a specific importance in directing the movement of visitors along the formed paths, thus diminishing the possibility of trampling the whole forest floor. Besides that, thick shrubberies or shrub groups are good refuges for many plant, bird, and animal species (Рысин, Полякова, 1987).

Increased recreation pressure causes changes also in the health conditions and species composition of the shrub layer. In the case of weak recreation pressure at first only a thinning of the shrub layer is observed, but heavier recreation pressure brings forth an increase in the abundance of the shrub layer and in the number of species. At the same time, species not typical of the given phytocoenoses appear (Надеждина, 1978; Левина, Петухова, 1980). Several authors (Балашова, 1973; Васильева, 1973; Репшас, Палишкис, 1983) have reported an increase in the number of *Juniperus communis* and especially *Sorbus aucuparia* in pine stands exposed to human impact. The reasons are believed to be improved light conditions as a result of the thinning of stands and a greater resistance of these species to human stress.

Vaccinium type pine stands in Estonia have usually a sparse shrub layer. The most widely spread species are *Juniperus communis*, *Sorbus aucuparia*, and *Rubus idaeus* (Lõhmus, 1974, 1984).

The shrub layer in Lahemaa control plots was poor in species and sparse (Table 3). All in all four tree and shrub species were observed. On all the plots only *Betula* sp. was growing, while *Sorbus aucuparia* and *Juniperus communis* grew on half of the plots. On one plot two small *Acer platanoides* were found. As a rule, shrubs grew on the control plots only as single plants.

On the sample plots in Tallinn 26 tree and shrub species were growing (Table 3). The most frequent and abundant was *Sorbus aucuparia*, which was represented on all the plots except for No. 40 where, as a result of heavy trampling, no shrubs existed. Other frequently occurring species were *Frangula alnus* on 59% of the sample plots, *Betula* sp. on 45% of the sample plots, *Quercus robur* on 38% of the sample plots, *Salix caprea* on 34% of the sample plots, *Juniperus communis* and *Ribes alpinum* on 31% of the sample plots. The plots which had numerous species showed only moderate trampling pressure (up to 30% of the surface is damaged). Sample plots 10 and 29 had a high percentage of trampled area, but the intensity of trampling was weak. The increased cover of the herbaceous layer and moderate trampling pressure probably create favourable conditions for seed sprouting of tree and shrub species and rooting of seedlings.

The density of the shrub layer on sample plots varies to a great extent from total absence (plot No. 40) to 19.5 thousand individuals per ha (plot No. 14). In the latter case the whole area between paths is covered with thick *Sorbus aucuparia* brushwood. All the plots which have a thick shrub layer are trampled only weakly or moderately. Vice versa, the plots under heavy trampling pressure have a thin shrub layer with few species or none at all (plot No. 40). Although such trampling-dependent variation in the density of the shrub layer is common for most of the sample plots, these phenomena are not connected proportionally (correlation coefficient $r=0.26$).

Table 3

Frequency of shrub layer species on sample plots

Species	Studied sample plots, %	Control sample plots, %
Acer negundo L.	3	—
Acer platanoides L.	24	18
Alnus incana (L.) Moench	3	—
Betula sp.	45	82
Berberis vulgaris L.	3	—
Corylus avellana L.	3	—
Cotoneaster niger (Thunb.) Fries	6	—
Crataegus sp.	3	—
Frangula alnus Mill.	59	—
Juniperus communis L.	31	36
Lonicera xylosteum L.	6	—
Populus tremula L.	24	—
Prunus padus L.	17	—
Quercus robur L.	38	—
Ribes alpinum L.	31	—
R. nigrum L.	3	—
R. rubrum L.	3	—
R. uva-crispa L.	6	—
Rosa sp.	10	—
Rubus idaeus L.	27	—
Salix caprea L.	34	—
Sambucus racemosa L.	10	—
Sorbus aucuparia L.	97	4
Symphoricarpos albus (L.) Blake	3	—
Tilia cordata Mill.	3	—
Viburnum opulus L.	3	—

Herbaceous layer. When trampling pressure increases, considerable changes take place also in the herbaceous layer of forests. Those changes have been investigated quite profoundly in various forest types and their general regularities have been elucidated.

It has been established that the initial forest herb layer perishes as a result of heavy trampling pressure. This process is the most intensive when trampling starts. After that, the initial vegetation is replaced by a secondary, light-requiring and trampling-resistant vegetation which consists mostly of meadow plants and weeds. Initial vegetation fragments survive only on weakly trampled plots, mostly in the vicinity of tree trunks (Kellomäki, 1977; Балашова, 1973; Таран, Спиридонов, 1977; Горшинин et al., 1979; Дыренков, 1983).

The herbaceous layer in natural *Vaccinium* type pine stands, just like the shrub layer, is not rich in species (Laasimer, 1965; Lõhmus, 1974, 1984). The most characteristic and frequently occurring species in that forest site type are the following: dwarf shrubs *Rhodococcum vitis-idaea* (L.) Avr., *Vaccinium myrtillus* L., *Calluna vulgaris* (L.) Hull, and *Empetrum nigrum* L.; herbaceous plants *Melampyrum pratense* L., *Trientalis europaea* L., *Maianthemum bifolium* (L.) F. W. Schmidt, *Lerchenfeldia flexuosa* (L.) Schur, *Calamagrostis epigeios* (L.) Roth, *Polygonatum officinale* All., *Luzula pilosa* (L.) Willd., etc. All these species were found also on most of the Lahemaa control plots. Besides that, also other species, which are less frequent and more sensitive to trampling stress, occurred on those plots, such as *Linnaea borealis* L., *Monotropa hypopitys* L., and *Goodyera repens* (L.) R. Brown.

The floristic composition (only flowering plants) of the urban *Vaccinium* type pine forests in Tallinn was determined on 29 sample plots. All in all 103 plant species occurred in their dwarf shrub and herb layers. According to the characteristic occurrence of plant species in the biotopes the composition of vegetation was as follows: 25 typical forest plant species, 29 species occurring both in forest and open area communities, and 49 species occurring mainly in open area communities. Among the latter there were 9 meadow grass species and 10 weed species.

In spite of a considerable human impact the most frequently occurring forest plants were typical of the given site type, such as *Rhodococcum vitis-idaea* (on 86% of the sample plots), *Lerchenfeldia flexuosa* (on 67% of the sample plots), *Vaccinium myrtillus* (on 67% of the sample plots), and *Luzula pilosa* (on 59% of the sample plots). Other typical plants of *Vaccinium* type pine forests were found considerably less frequently. For example, *Maianthemum bifolium* was found on 38% of the sample plots, *Melampyrum pratense* on 34% of the sample plots, *Trientalis europaea* on 21% of the sample plots, and *Empetrum nigrum* L. which is often found in the Lahemaa control plots, was growing only on 14% of the sample plots. Among the plants belonging to other forest types the most frequently occurring was *Calamagrostis arundinacea* (L.) Roth on 72% of the sample plots, while the others were much rarer. It is interesting to note that *Goodyera repens* was found on a couple of sample plots in the Kloostrimetsa forest.

The most frequently occurring forest and open area species were *Fragaria vesca* L. on 69% of the sample plots, *Chamaenerion angustifolium* (L.) Scop. on 55% of the sample plots, and *Veronica chamaedrys* L. on 52% of the sample plots.

Among open area species there were no species with a high frequency. The most frequently found species belonged to meadow plants: *Dactylis glomerata* L., *Agrostis stolonifera* L., and *Trifolium repens* L. on 52% of the sample plots, *Vicia cracca* L. on 41% of the sample plots, and *Poa pratensis* L. on 34% of the sample plots.

Although among forest plants the most frequently found species were typical of the initial ground vegetation, the number of them on many sample plots was not big. As a rule, those sample plots where only a few characteristic species have survived (up to 25% of the total number of species) are characterized by a bigger number of open area species (more than 60%) and coverage rather than by heavy trampling pressure. In most of the stands forest plants are not trampled to perishing, but they are unable to compete under the changed conditions against the spreading of more resistant open area plants. This is especially true about older stands.

In younger stands belonging to age class III the general number of species and original ground vegetation is smaller than in older stands even on weakly trampled sample plots. Evidently, this is caused by smaller light intensity due to the higher crown closure. Increase in the trampling pressure brings forth a considerable decrease in the coverage of ground vegetation and the number of characteristic species.

The direct impact of heavy trampling pressure is clearly demonstrated on sample plot No. 40 (the Mustamäe forest park) where herbaceous plants have survived only in the vicinity of trees.

Increased illumination, e.g. on sample plot No. 37 (the Pelguranna forest) which lies near the forest edge, brings forth a large coverage with open area plants, especially meadow grasses, even if the whole forest floor is moderately trampled and forest plants are compelled to draw back into the vicinity of trees.

Those sample plots where the number of the species of the initial ground vegetation exceeds half of the total number of the herb layer species lie mostly in less frequently visited spots inside large forested areas. Spreading of open area species into these plots is more difficult.

Therefore, the above-mentioned changes in forest ground vegetation as a result of human impact take place also in the urban forests of Tallinn. The most sensitive to trampling pressure is the ground vegetation of young stands, but in older stands with increased light intensity a rich trampling-resistant herbaceous layer develops from open area species. However, in both cases the role of the original ground vegetation in the community diminishes.

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