The impact of recreational pressure on urban pine forest vegetation in Riga city, Latvia

Inga Straupe, Ilze Jankovska, Solvita Rusina, Janis Donis

Abstract: - The article focuses on the analysis of impact of recreational pressure on *Myrtillosa* type pine forest vegetation in Riga city, Latvia. The composition of the plant communities, projective coverage of tree, shrub, herb and moss layer as well as the coverage of each separate species and plant strategy types has been evaluated. All urban *Myrtillosa* type pine forests can be divided into two groups – unimpacted and impacted pine forests. Insignificant changes of forest environment are preserved in in three plant communities 1 - *Pyrola rotundifolia-Pinus sylvestris* (Bulli and Mangalsala), 2 – *Pleurozium schreberii-Pinus sylvestris* (Bolderaja, Jaunciems and Smerlis), 3 – *Calamagrostis epigeios-Pinus sylvestris* (Jugla and Bikernieki). Significant changes and degradation are observed in other three plant communities of impacted pine forests: 4 – *Amelanchier spicata-Pinus sylvestris* (Kleisti, Katlakalns, Sampeteris and Ulbroka), 5 – *Acer platanoides-Pinus sylvestris* (Imanta); 6 – *Cotoneaster lucidus-Pinus sylvestris* (Mezaparks, Vecdaugava and Babelite. Vegetation analyses didn't confirm the predicted model of spatial distribution of forest recreational visits/year on foot. Further research is needed in order to obtain more precise results that take into consideration the missing parameters of environmental, site and social attributes.

Keywords— *Myrtillosa* type pine forest, recreational pressure, Riga city, urban forest vegetation.

I. Introduction

URBAN areas include greenspaces which include substantial forest resources that have the potential for significantly improving the quality of the urban environment and the well-being of its residents. Urban forests can strongly influence the physical/biological environment and mitigate many impacts of urban development by moderating climate, conserving energy, carbon dioxide, and water, improving air quality, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife, and enhancing the attractiveness of cities. In an urbanized society, urban green areas are important as a place for contact with nature. The level of biodiversity of urban green areas is often surprisingly high, representing nature close to where people live. Urban forests can be viewed as a 'living technology', a key component of the urban infrastructure that helps to maintain a healthy environment for urban dwellers and stability of urban ecosystems [1]-[5].

Forests are prominent components of the landscape in most urban areas, at the same time urban forests provide a wide range of recreational and outdoor leisure opportunities. Reduced stress and improved physical health for urban residents have been associated with the presence of urban forests. Urban forests also have high educational values by representing nature and natural processes in cities and towns, and they have often been used as testing and education areas for forestry and other disciplines [2]-[4], [6].

The role of urban green spaces differs widely between European cities and towns due their different environmental and socio-cultural background. In Latvia, as in other countries of North Europe, the decline of nature throughout the twentieth century and the alienation between people and natural world were not so significant. The recreational and aesthetic benefit of urban forests is traditionally important especially in the Nordic and Baltic countries, because the forest is a major element of the landscape and national economy [5], [7]. At the same time urban forests are a part of a complex environment, complicated diverse and interconnected ecosystems, which consist of groups of trees, shrubs, herbs, mosses, lichens, animals, as well as microorganisms and soil, which are interrelated and influence each other and the environment. Unorganized recreation and excessive recreation loads cause significant disturbances to forest ecological functions for example changes in soil, forest, forest vegetation and lighting, as a result of which mosaic type forest structure is formed – disturbed and undisturbed forest compartments [8]-[15].

Over the last decades in urban forests particularly especially sensitive pine forests, as a result of anthropogenic disturbances, the forest ecosystem is changing and even

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degrading considerably [16]. The urban environment provides a unique opportunity to meld landscape design with ecological management, therefore the objective is to develop the stability of the stand, its recreational properties ensure forest functions and protection against degradation and to develop the respective infrastructure, which would increase the forest accessibility and at the same time preserve its biological values [12], [14], [17], [18].

Several approaches for assessment of the recreational pressure on urban forests have been used, including both direct measures of vegetation (e.g. percentage cover of vegetation on trampled and undisturbed sites, functional trait composition) and indirect measures, like number of residents within an area [19].

The knowledge about relationship among recreational load assessed from social data (e.g. interviews) and real condition of vegetation of hemiboreal forest types in urban areas is not well known. This information is needed for the purposes of urban planning and management with the aim to preserve indigenous forest vegetation in urban areas.

Our aim was to find out whether assessment of recreational pressure on forests from social interviews and GIS software is a good surrogate for determination and prediction of pine forest vegetation conditions without field studies. We hypothesized, that vegetation in forest tracts experiencing strong recreational pressure will differ from those experiencing lower recreational pressure in terms of species composition, vegetation vertical structure, and species strategy types.

II. Problem Formulation

A. Description of territory

The development of urban forests in the capital of Latvia – the city of Riga has a long history. Riga has been the owner of forests since the thirteenth century and urban forests have always been accessible for inhabitants. After the Second World War, the urban forests in the inner city and green belt around the city were protected by the legislation of the Soviet period. According to Donis [20] 0.8% of all Latvian forests are considered urban forests and 20% of urban areas covered by forests. Cities such as Riga tend to be set within and surrounded by large tracts of forest, which expand beyond the urban boundary [21].

Riga (the city area covers 304.05 km^2, there are 706.4 thousand inhabitants and the density of the population is 2331.4 per 1 km^2) is one of the biggest owners of forests in Europe: Riga municipality owns more than 55.600 ha of forests and in inner city there are 4243.7 ha of forests [22]. The dynamics of land use and management of green space in Riga city are based on the main laws in Latvia which define the management, maintenance and spatial characteristic of urban forest - Law on Forest, Protecting Zone Law and Spatial Planning Law, and the numerous documents and regulations of municipality [23]-[26]. According to Latvia's legislation, urban forests' timber production and clear-cutting is not allowed and main management activities are applied to the pattern elements of forest and technical aspects of forest management. The legislation does not specify differences between maintenance and management of rural and urban forest, and there are disagreements between management, functional significance and demands for real use of urban forests.

Riga city forests consist of 15 forest tracts which are connected with rural forests and some small, isolated forests – the remnants of ancient forest or planted forests (Fig. 1). The main tree species is Scots pine *Pinus sylvestris* L. (46.9 km^2 or 88% of total forest area) on the poor sandy soil and is characterized by landscape attractiveness to recreational pressure.

Fig.1 Riga city forest tracts: 1-Bulli, 2-Bolderaja, 3-Kleisti, 4-Imanta, 5-Mezaparks, 6-Vecdaugava, 7-Katlakalns, 8-Sampeteris, 9-Jaunciems, 10-Babelite, 11-Ulbroka, 12-Smerlis, 13-Mangalsala, 14-Jugla, 15-Bikernieki.

B. Methods of vegetation research

The research was carried out in Myrtillosa type pine forests, which constitutes the highest proportion (33%) of the prevailing forests on dry sites in Riga city [25], [27]. In each forest tract during the vegetation season of 2011, 45 vegetation sample plots were arranged and surveyed (the area of each sample plot - 400 m^2). The age of pine is 80-94 years. The Braun-Blanquet method was used to describe the plant communities: the total projective coverage of tree (E3), shrub (E2), herb (E1) and moss (E0) layer as well as the coverage of each separate species was evaluated in the sample plots in percentage [28].

C. Methods of estimation of recreational pressure on forest tracts

The first at national level research survey for the study of forest non-market services and the contribution to the Latvia economy was conducted in 2010. In survey, carried out in cooperation with professional polling agency the LTD SKD (December, 2010) was an on-site face-to-face survey and the quantitative Omnibus poll method was used. At least 1000 respondents at the age of 18-74 from the whole country as representative were selected. The common error of the research with such selection amount is ±3.1%, with 95% probability level. The survey included Travel Cost, Contingent Valuation and Willingness-to-Pay components as well as several social-economic characteristics with respect to sex, age, education, income level and geography.

The research of forest vegetation needs to be done, modeling the distribution of visitors in forest tracks for different distances by using of GIS technique [29]. It would be potential to interpret results of forests' ecological and social functions as well as to develop more advanced management of urban forests. The order of implementation in the GIS was the following:

1) to generate the areas around residential neighbourhoods in given distance;

2) to generate the buffers around forest blocks in given distance;

3) to proceed spatial joining of number of inhabitants in buffer zones with forest polygons;

4) to count the average number of visits/per year to forest blocks;

5) to visualize the obtained data in color-schemes.

In all, 9 questions were asked and in current research were used results, concerning: (a) targets of recreation, (b) frequency of visits to forest (in working days, in weekends, in vacations/holidays), (c) distance to the site (in kilometers), (d) mode of transport (on foot, by bicycle, car, public transport).

Results showed that the recreational target - 'walking' was chosen by 60% of Riga city inhabitants. 34% of respondents are doing it on foot. The present research showed that the mean distances for recreational target 'walking' in Riga city is 1.5 km in working days. In following step was developed the model that predicts the number of visits to a specific (focal) forest area for recreational activities. Through the use of GIS, opportunities exist to describe and analyse spatially explicit factors and processes, but also to forecast future scenarios through the use of predictive models. The recreational components have to be integrated into a model to be able to predict the distribution of visits from given origins – nearby residential areas over the competing destinations within the radius, done on foot [30]. Figure 2 presents the results obtained from the GIS analysis about accessibility and average distribution of visits/year to the forest areas on foot for the most popular recreational target - walking in Riga city region. The simplest way to assess the accessibility of a destination for a given origins is to determine the airline or Euclidean distance [30]. It was not taken into consideration the existing site attributes, roads and paths network, environmental qualities, seasonality and other components which can affect the frequency of recreational visits. Figure 2 shows that are the relationship between urban forests location and distribution of residential areas and prove that the urban pressure occurs mostly in the isolated forests located in proximity to city center or dwelling places.

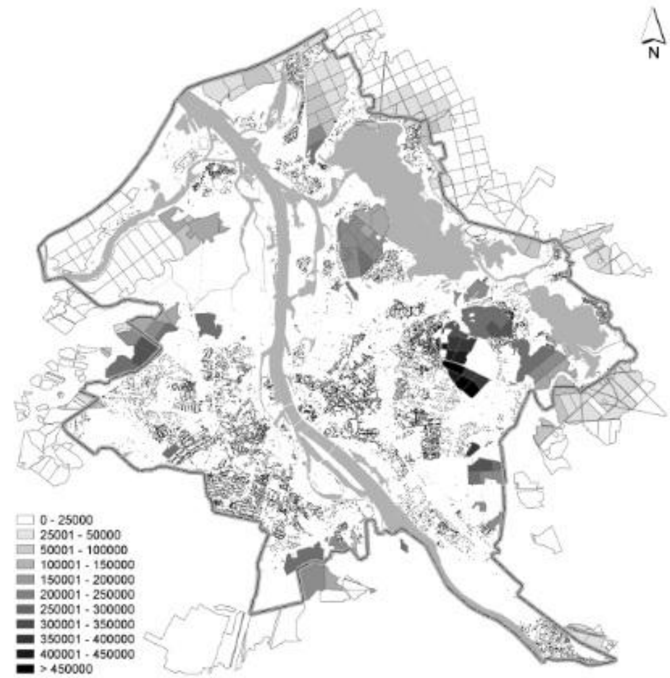

Fig. 2 Distribution of forest recreational visits/year on foot to the forest tracts at the distance 1.5 km from the residential area in Riga city.

D. *Data processing methods*

The occurrence of plant species is characterized by the constancy class which is calculated by referring the number of those sample plots where the species has been identified to the number of the whole group of sample plots: I - < 21, II - 21-40, III - 41-60, IV - 61-80, V - 81-100% [19]. Data processing was carried out with the software programme Community analysis package (Pisces Conservation Ltd.) For the credibility evaluation statistical methods were used [31].

The vegetation data have been stored in a database using TURBOVEG Software [33].

Cluster analysis was applied to classify vegetation data using Sorensen's measure of distance and flexible beta at -0.25 was used as a linkage grouping method. Differences in the species composition among plant communities were tested by means of the Indicator Species Analysis [34], which is based on calculation of the proportion of coverage and abundance of each species in a single classification unit of vegetation (sample plots), in comparison to all other data set (the other classification units). The ideal indicator species of a group is a species that occurs only in this group (and all plots of the group), and not in any other groups. The significance of the indicator values obtained is calculated with a Monte Carlo test [35].

The ecological gradients in vegetation have been analyzed with an indirect ordination method, Non Metric Multidimensional Scaling (NMS) [35]-[37] with the use of computer software PC-ORD 5 [38]. The NMS analysis used square root transformed data on herb species coverage to reduce the weight of rare species. This reduced the potential effect of the variable sample size. The explained variation of ordination axes has been assessed by using a determination coefficient between Euclidean distance in the ordination space and the relative Euclidean distance in the original multidimensional space [35]. All NMS ordinations were conducted with PC Ord version 5, in the 'slow and thorough' autopilot mode, using a Sørensen distance matrix. The NMS returned a three-dimensional ordination for the quadrat data (total r 2 = 0.78, final stress = 11.4, instability = 0.00, number of iterations - 85)

Ellenberg's indicator values for light, moisture, reaction and nitrogen [39], as well as data on the vegetation layer coverage, were used to explain ordination. Ellenberg's indicator values were calculated by using the herb layer data in computer software JUICE [40], taking into consideration only the presence of a species, but not its coverage. Mean indicator values were calculated for each plot from all present vascular plant species for which an indicator value according to Ellenberg et al. [39] was available.

III. PROBLEM SOLUTION

In Riga urban pine forests in total 154 vascular plant species, including 44 tree and shrub species were found (in the tree layer -10 species, shrub layer - 37, and herbaceous plant layer - 32 species) and 110 herbaceous as well as 18 moss species. The number of species in sample plots does not differ significantly, although the highest number was found in Mangalsala (64 species), but the lowest – in Imanta forest (22 species) (Fig. 3). The coefficient of occurrence and constancy class show how stable a species is in a particular habitat: the higher constancy class, the more stable position the species occupies in the plant community. The researched plots are located in anthropogenically impacted forests, therefore the tendency of species inconstancy has been observed.

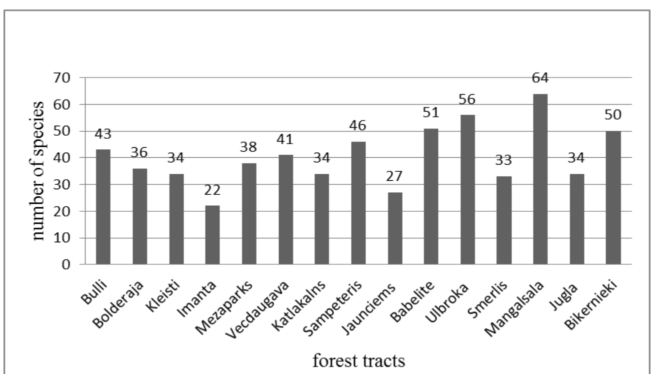

Fig.3 The number of species in Riga *Myrtillosa* type pine forest tracts

The most often (constancy class V) found tree species is *Pinus sylvestris* and shrub species are *Sorbus aucuparia* and *Amelanchier spicata*. There are neither herbaceous plant nor moss species in this class. In the constancy class IV *Quercus robur, Acer platanoides and Frangula alnu*s in the shrub layer and herbaceous species *Luzula pilosa*, *Lerchenfeldia flexuosa*, *Fragaria vesca*, *Rubus idaeus* are observed. The constancy class III is represented by *Acer platanoides* in the tree and herb layer, *Padus avium* in the shrub layer and *Sorbus aucuparia* in the herb layer, as well as herbaceous species *Trientalis europaea*, *Vaccinium vitis-idaea*, *Vaccinium myrtillus*, *Chamaenerion angustifolium*, *Maianthemum bifolium*, *Solidago virgaurea*, *Impatiens parviflora*) and moss species - *Pleurozium schreberi* and *Hylocomium splendens*, which are typical of coniferous forests.

The results obtained show that in forest ecosystem the layers of herbs and mosses respond most sensitively to different unfavourable disturbances [41], [42]. Low level of constancy may be indicative of two reasons: either the species has just been established and will be developed in the future or it will be suppressed by other species and cast out of the plant community. Apparently, in the pine forests the species with low constancy are typical grassland species [43]. It should be taken into account that after the disturbance succession starts in the forest. As a result of that the plant communities which are similar to the previous vegetation are restored. Therefore long-term monitoring is required to precisely characterise the conditions of forest vegetation [44].

The boreal coniferous forest species are the most commonly found (*Pinus sylvestris*, *Vaccinium vitis-idaea*, *Vaccinium myrtillus*, *Trientalis europaea*, *Maianthemum bifolium*, mosses *Pleurozium screberi* and *Hylocomium splendens*), however, *Quercus robur*, *Acer platanoides* and *Padus avium* are determining species of nemoral forest. The species introduced in Latvia such as *Amelanchier spicata*, as well as adventive species *Impatiens parviflora* have been naturalized in urban forests. They both are considered to be very expansive synanthropic species, which are rapidly overtaking more fertile soils in trampled down places [45]-[47]. The species *Chamaenerion angustifolium*, *Fragaria vesca* and *Rubus idaeus* are rapidly developing after anthropogenic disturbances, which are connected with the improvement of light conditions (open spaces, cutting-areas, forest edges, roadsides) and more rapid decomposition of nutrients in such places.

In order to determine the impact of recreation on Riga forest tracts, the composition of vegetation and projective coverage has been evaluated. Cluster analysis resulted in 6 plant communities is shown in Fig.3.

All 6 plant communities can be divided into two groups – unimpacted and impacted pine forests. Clusters 1 to 3 are unimpacted pine forests with three plant communities: 1 - *Pyrola rotundifolia-Pinus sylvestris* community (Bulli and Mangalsala), 2 – *Pleurozium schreberi-Pinus sylvestris* community (Bolderaja, Jaunciems and Smerlis), 3 – *Calamagrostis epigeios-Pinus sylvestris* community (Jugla and Bikernieki). Clusters 4 to 6 are impacted pine forests with three plant communities: 4 – *Amelanchier spicata-Pinus* *sylvestris* community (Kleisti, Katlakalns, Sampeteris and Ulbroka), 5 – *Acer platanoides-Pinus sylvestris* community (Imanta); 6 – *Cotoneaster lucidus-Pinus sylvestris* community (Mezaparks, Vecdaugava and Babelite).

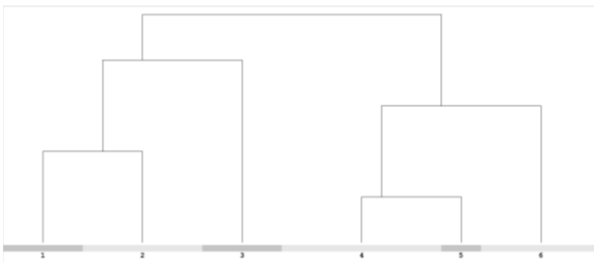

Fig.4 Cluster analysis of Riga *Myrtillosa* pine forest vegetation. Clusters - Riga city plant communities: 1 - *Pyrola rotundifolia-Pinus sylvestris* community (Bulli and Mangalsala), 2 – *Pleurozium schreberi-Pinus sylvestris* community (Bolderaja, Jaunciems and Smerlis), 3 – *Calamagrostis epigeios-Pinus sylvestris* community (Jugla and Bikernieki), 4 – *Amelanchier spicata-Pinus sylvestris* community (Kleisti, Katlakalns, Sampeteris and Ulbroka), 5 – *Acer platanoides-Pinus sylvestris* community (Imanta); 6 – *Cotoneaster lucidus-Pinus sylvestris* community (Mezaparks, Vecdaugava and Babelite).

In Riga pine forests in total 10 tree species are found. Pure pine stands or pine in admixture with *Betula pendula*, *Populus tremula* or *Acer platanoides* are found only in unimpacted forests. The presence of pioneer species *Betula pendula* and *Populus tremula* indicates minor natural disturbances in the coniferous forest. In other forest tracts - impacted forests - in tree stands there are several species in admixture (*Betula pendula*, *Populus tremula*, *Quercus robur*, *Ulmus glabra*, *Tilia cordata*, *Tilia platyphyllos*, *Populus sp*.), including *Alnus glutinosa* found in Bolderaja. The occurrence of broad-leaved trees indicates forest euthrofication and changes in the plant communities [10], [11], [45].

The average projective coverage of tree layer in unimpaced and impacted forest tracts is similar (respectively 50% and 53%), it differs significantly between forests of cluster 2 and 3 (Table I).

Table I

Mean values of vegetation layer coverage in six Riga pine forest communities

No.	Trees Mean	Std. Dev.	Shrubs Mean	Std. Dev.	Herbs Mean	Std. Dev.	Mosses Mean	Std. Dev.
1	46.67	11.69	26.67	8.76	56.67	22.29	$65.00^{4,5,6}$	8.94
2	62.78^{3}	10.86	22.89^{4*}	27.03	$63.11^{5,6}$	15.60	$74.67^{4,5,6}$	14.44
3	43.33^{2}	8.16	35.33	14.51	48.33	4.08	$73.33^{4,5,6}$	5.16
4	54.17	7.18	50.92^{2}	17.76	61.50	11.42	$24.00^{1,2,3}$	20.49
5	55.00	18.03	30.00	8.66	25.00^{2}	10.00	$0.00^{1,2,3}$	0.00
6	50.78	12.62	45.56	8.82	40.56^{2}	18.27	$18.00^{1,2,3}$	14.74

*Figures in superscript indicate plant communities for which the mean ranks significantly ($p<0.05$) differed according to non-parametric Kruskal-Wallis test.

The comparision of projective coverage (%) of tree layer and *Pinus sylvestris* shows that the lowest pine coverage is in forests where deciduous trees *Acer platanoides*, *Quercus robur*, *Betula pendula*, *Populus tremula*, *Ulmus glabra* were found in admixture. The highest pine projective coverage is in unimpacted forest group where there are practically no other species. Successful regeneration of Scots pine (it occurs in the shrub and herb layer) has been observed only in unimpacted forests (cluster 1 and 2) which indicate the possibility of the preservation of pine as a species also in the future. In some forests Scots pine occurs in shrub, but in some – in herb layer. The frequent occurrence of Norway maple *Acer platanoides* and penduculate oak *Quercus robur* in all layers of vegetation indicates rapid spread of these species, the increase in the soil fertility and the changes in the lighting in the forest stand.

In Riga pine forests 37 tree and shrub species occur in the shrub layer, in average 9-12 species in forest tract. The highest number of species (14 species) has been found in impacted forests. The average projective coverage of the shrub layer differs significantly between unimpacted and impacted forests (respectively 28% and 42%). It can be seen that fruitification has taken place. It shows gradual expansion of shrub communities and deciduous forests in the territory of Latvia, which is connected with climate changes and enrichment of the environment with nutrients, especially with nitrogen [10], [15], [48]. Dense undergrowth hinders not only forest regeneration, but it also makes the forest stands uniform, out of full vision, impenetrable and unsuitable for recreation [49]. In these places it is advisable to carry out such activities as thinning and partial cutting of undergrowth to improve the landscape [18], [50].

In the herb layer overall 142 species of vascular plants (16 tree, 16 shrub and 110 herbaceous plants) occur. In order to analyse the composition of species of herb layer, the data on the belonging of a species to a certain functional group have been used [51]. In Riga pine forests the most widespread species are boreal - 40; 31 species belong to grassland plant group which expand in impacted forest soils; 37 species are nemoral, 17 - nitrophytic species (indicate a nitrogen-rich environment); 8 species are hygrophytic (characteristic of wet soils, which are formed in the lowlands of forest microrelief). The adventive species are *Acer negundo*, *Cerasus sp*., *Impatiens parviflora* and *Solidago canadensis*, while 16 are other species: the majority of which are introduced species - garden escapers, such as *Aesculus hippocastanum*, *Amelanchier spicata*, *Cotoneaster lucidus*, *Symphoricarpos albus*, *Rosa rugosa*, *Ligustrum vulgare* and *Berberis vulgaris*.

Unimpacted forests are characterised by typical boreal forest understorey species, like *Calluna vulgaris*, *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Trientalis europaea*, *Melampyrum pratense*, *Pyrola rotundifolia*, *Lerchenfeldia flexuosa*, *Pleurozium schreberi*, *Hylocomium splendens*, *Calamagrostis epigeios*, *Luzula pilosa* etc. Vegetation types with an understorey vegetation of low productivity are most easily damaged due to their slow rate of regeneration after disturbance [19]. The second group – impacted forests, is characterised by herbs typical for ruderal and nitrophytic habitats (*Impatiens parviflora*, *Chelidonium majus*). Several invasive shrub species are constant in this group (e.g. *Cotoneaster lucidum*, *Amelanchier spicata*). Tree species of rich nemoral forests, like *Acer platanoides*, and *Tilia cordata* are common, as well. The average projective coverage of the herb layer in unimpacted and impacted Riga forest communities (respectively 56% and 42%) differ significantly (Table I).

Differences in vegetation were revealed also in plant strategy types [52] – the first group is richer in stress tolerators, the second group contained more ruderals (Fig.5, Table II). There were no evident differences in geographical location of different plant communities in Riga city (Fig.1). No consistent relationship among recreational load and plant community were found. NMS ordination showed that medium and strong recreational load was not connected with one particular plant community. Instead, both groups of plant communities (unimpacted and impacted pine forests) were located close to each other.

Based on correlations of NMS axes scores with means of Ellenberg indicator values, vegetation structure (cover of vegetation layers, plant strategies), and diversity parameters (Table I, Table II and Table III), axis 1 can be interpreted as combined soil fertility, temperature, and light gradient. Along this axis, moss cover and the Ellenberg indicator value for nutrients and temperature decreased, and the Ellenberg indicator value for light increased. Axis 2 showed correlations with weighted means of Ellenberg indicator values or other vegetation parameters. The third axis with the low proportion of explained variance could not be interpreted ecologically.

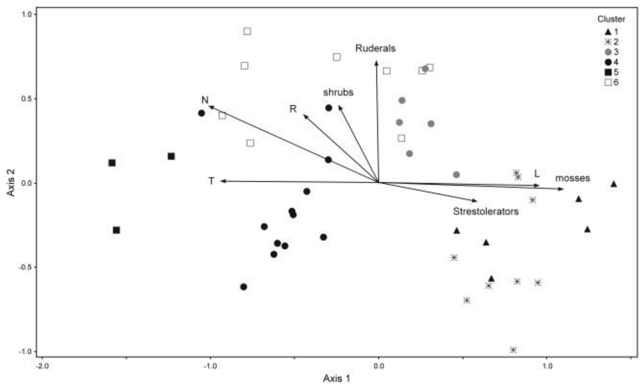

Fig.5 NMS ordination diagram with passively overlaid Ellenberg indicator values (L – light, N – nitrogen, T – temperature, R – reaction, vegetation structure data (mosses - cover of moss layer, shrubs - cover of shrub layer), and plant strategies (ruderals and stress tolerators). Cluster numbers the same as in Fig. 3.

Species richness and plant strategy types were quite similar in all plant communities, and no significant differences were found between mean ranks of unimpacted and impacted pine forests. Species poor plant communities were present both in impacted and unimpacted forests. Nevertheless, the highest species richness was observed in two less impacted plant communities - *Pyrola rotundifolia-Pinus sylvestris*, and *Calamagrostis epigeios-Pinus sylvestris* community, and the lowest – in the most strongly impacted forest with *Amelanchier spicata-Pinus sylvestris* plant community. Also, the tendency of higher amount of stress tolerators was observed in unimpacted pine forests. The most impacted forest tract (*Acer platanoides-Pinus sylvestris* community) contained the least number of stress tolerators – 14.3% in comparison with 26-31% in other forests (Table II).

Structure of vegetation layers was strongly informative concerning moss layer. In the moss layer 18 species are found, from which most species (*Dicranum polysetum*, *Dicranum scoparium*, *Hylocomium splendens*, *Plagiomnium affine*, *Plagiomnium undulatum*, *Pleurozium schreberi*, *Polytrichum juniperinum*, *Ptilium crista-castrensis*, *Rhytidiadelphus squarrosus*, *Rhytidiadelphus triquetrus*) are characterized by poor sand soils in coniferous and coniferous-deciduous forests, five species (*Brachythecium rutabulum*, *Cirriphyllum piliferum*, *Eurhynchium angustirete*, *Eurhynchium striatum*, *Homalothecium sericeum*) indicate the soils rich in humus, but three species (*Climacium dendroides*, *Polytrichum commune*, *Rhodobryum roseum*) - wet soils. Significant differences in mean ranks of moss layer cover were observed in unimpacted versus impacted forests.

Table II

Mean values of species diversity and plant strategy types in six Riga pine forest communities

No.	Species richness Mean	Std. Dev.	Shannon index Mean	Std. Dev.	C Mean	Std. Dev.	S Mean	Std. Dev.	R Mean	Std. Dev.
1	45.50[2,5]	9.97	2.87 [2,5]	0.21	52.90[5*]	4.82	29.33[5]	2.93	17.77	3.07
2	28.33[1,3]	5.50	2.29[1]	0.26	57.59	4.93	30.70[5,6]	3.45	11.71[3,6]	3.68
3	41.67[2,5]	12.13	2.70	0.14	52.87[5]	1.74	27.23[5]	1.54	19.90[2]	1.96
4	34.75	6.12	2.60	0.13	55.13[5]	7.06	28.03[5]	3.57	16.84	5.11
5	17.00[1,3]	3.00	2.26[1]	0.15	69.77 [1,3,4,6]	10.50	14.30[1,2,3,4,6]	4.89	15.93	5.95
6	34.44	5.57	2.58	0.21	55.79[5]	3.93	25.59[2,5]	3.84	18.62[2]	2.67

Abbreviations: C - competitors, S - stress tolerators, R - ruderals

*Figures in superscript indicate plant communities for which the mean ranks significantly ($p<0.05$) differed according to non-parametric Kruskal-Wallis test

Unimpacted forests posess very well developed moss layer with mean coverage from 65 to 75% in comparison with impacted forests where moss layer covered only 0 to 24%. There were no significant differences in mean ranks of other layer coverage. Nevertheless, the tendency of thicker shrub layer was observed in impacted forests where shrub layer coverage was 30-50 % in comparison with unimpacted forests where shrub layer covered only 23-35 %.

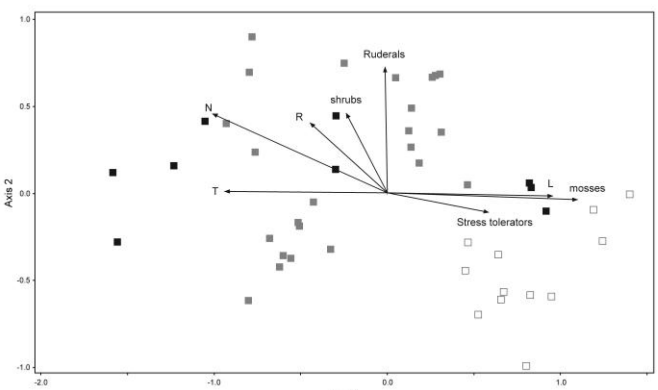

Fig. 6 NMS ordination diagram with the information on recreational pressure according to social interviews: open symbols – the least impacted forests (till 25 000 visits per year), grey symbols – medium impacted forests (100 001-250 000 visits per year), black symbols – strongly impacted forests (300 001 and more visits per year). Vectors of Ellenberg indicator values and vegetation structure and their abbreviations are the same as in Fig. 5.

Ellenebrg indicator values indicated quite the same site conditions in all plant communities. Significant differences in mean ranks of Ellenberg indicator values were obtained only for some plant communities, and they were not consistent between unimpacted and impacted pine forests. Elleneberg indicator values for nitrogen and soil reaction indicated less fertile and more acidic conditions in unimpacted forests in comparison to impacted forests (Table III).

Table III

Mean Ellenberg indicator values in six Riga pine forest communities

L		T		K		M		R		N	
Mean	**Std.Dev.**	**Mean**	**Std.Dev.**	**Mea n**	**Std.Dev.**	**Mea n**	**Std.Dev.**	**Mean**	**Std.Dev.**	**Mean**	**Std.Dev.**
5.83	0.29	4.864,5*	0.09	4.61	0.29	5.38	0.13	4.902	0.39	4.035	0.54
5.864	0.15	4.664,5	0.5	4.814	0.29	5.13	0.44	3.661,5, 6	0.36	3.494,5, 6	0.66
5.834	0.13	4.945	0.2	4.58	0.15	5.28	0.13	4.57	0.39	4.64	0.27
5.362, 3	0.26	5.271,2	0.12	4.442	0.15	5.24	0.19	4.54	0.41	4.862	0.57
5.29	0.33	5.631,2, 3	0.13	4.3	0.25	5.606	0.16	5.662	0.73	6.181,2	0.81
5.54	0.29	5.12	0.23	4.5	0.16	5.045	0.21	4.852	0.61	4.852	0.63

Abbreviations: L - light, T - temperature, K- continentality, M - moisture, R - soil reaction, N - nitrogen

*Figures in superscript indicate plant communities for which the mean ranks significantly ($p<0.05$) differed according to non-parametric Kruskal-Wallis test

I. Conclusions

In Riga city all the *Myrtillosa* type pine forests can be divided into two groups – unimpacted and impacted pine forests. Insignificant changes of forest environment and typical boreal forest vegetation (significant proportion of boreal forest species and high projective coverage of boreal mosses) are preserved in three plant communities 1 - *Pyrola rotundifolia-Pinus sylvestris* community (Bulli and Mangalsala), 2 – *Pleurozium schreberi-Pinus sylvestris* community (Bolderaja, Jaunciems and Smerlis), 3 – *Calamagrostis epigeios-Pinus sylvestris* community (Jugla and Bikernieki). Other three plant communities are impacted pine forests: 4 – *Amelanchier spicata-Pinus sylvestris* community (Kleisti, Katlakalns, Sampeteris and Ulbroka), 5 – *Acer platanoides-Pinus sylvestris* community (Imanta); 6 – *Cotoneaster lucidus-Pinus sylvestris* community (Mezaparks, Vecdaugava and Babelite): the composition of vegetation and projective coverage of layers indicate the increase significant changes and their degradation - the proportion of boreal species is low (they are found mainly in the tree and shrub layers), nemoral tree species are more represented, ground vegetation is trampled down, adventive and introduced species - garden escapers prevail and there is low coverage of mosses. Vegetation analyses didn't confirm the predicted model of spatial distribution of forest recreational visits/year on foot. In this model was used not taken into consideration the existing site attributes, roads and paths network, environmental qualities, seasonality and other components which can affect the frequency of recreational visits. Further research is needed in order to obtain more precise results that take into consideration the missing parameters of environmental, site and social attributes.

Acknowledgment

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