Monitoring and Management of Visitor Flows in Recreational and Protected Areas
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Monitoring of Recreation-Affected Forest Stands in the National Park Losiny Ostrov

Mark Shapochkin[1], Vera Kiseleva[2]

[1] Deputy Director, National Park Losiny Ostrov, Poperecnyi prosek 1a, Moscow, 107113 Russia
[2] Head of the Division for Research and Coordination, National Park Losiny Ostrov, Poperecnyi prosek 1a, Moscow, 107113 Russia
Email: elkislnd@cityline.ru

Abstract: The effect of recreation on the forests of National Park Losiny Ostrov located within the boundaries of Moscow is examined. The methods of monitoring of recreation-affected forest stands are represented, and the preliminary results of their application for the revealing of the most damaged forest areas are discussed. Some practical measures are suggested in order to redistribute visitor flows across the territory of the most visited part of the national park.

INTRODUCTION

The monitoring and management of visitor flows are very urgent for the National Park Losiny Ostrov. Being organised in 1983, the park inherited high recreation loads, which have always existed in the forest massif of Losiny Ostrov, as it is surrounded by dwelling and industrial regions. The population of adjacent districts of Moscow reaches 2 mln people and that of Mytishchi, Korolev, Balashikha, and Shchelkovo (other cities of Moscow conurbation) exceeds 500 000 people. Let us take into account that new dwelling regions will be built in the peripheral part of Moscow and the nearest suburban areas. Therefore, the population of the regions bordering with the national park is expected to increase, as well as the recreation loads.

The major goal of the national park is to preserve the natural forest and wetland ecosystems under the conditions of an intensive daily recreation. For this purpose, a very accurate monitoring of the status of natural ecosystems is needed in order to detect and prevent their degradation at initial stages.

CHARACTERISTIC OF THE TERRITORY OF THE NATIONAL PARK LOSINY OSTROV

The National Park Losiny Ostrov occupies the territory of 120 km^2. This is a whole forest and wetland massif, dissected by the Moscow Circle Highway. Approximately 35 km^2 of forests are located within the boundaries of Moscow itself. The territory of Losiny Ostrov is a slightly wavy plain with an absolute altitude of 140-165 m above the sea level. It includes the chain of low moraine hills, the glaciofluvial terraces of the Yauza River, and the floodplain itself. The soil cover is represented by loamy or sandy-loamy soddy-podzolic and gley soddy-podzolic soils (Podzoluvisols and Gleyic Podzoluvisols, according to FAO Classification); Yauza floodplain is occupied by eutrophic bog soils (Histosols). The forests represent the most important recreational resources of the national park. They are quite diverse: lime, pine, and indigenous spruce forests constitute 11, 17, and 24% of the territory, respectively. A significant part of the national park (41%) is occupied by secondary birch forests. Despite the neighbourhood of urban areas, the natural complexes of the national park, especially of its central part, possess a high biological diversity: the list of plants found at the territory of Losiny Ostrov includes approximately 600 species, that of birds, more than 150 species, and that of mammals, almost 40 species. It is this relative wilderness of nature, which attracts multiple visitors.

RECREATIONAL SITUATION IN THE NATIONAL PARK LOSINY OSTROV

The direct calculations of visitor flows were made in 1990s by the students of Moscow State University. The observations demonstrated that in peak days, up to 150 000 visitors could be present at the territory of the national park simultaneously (Butorina & Chizhova, 1996). The researchers from the International Forest Institute (Moscow) calculated the recreation carrying capacity of the territory and real recreational loads on different functional zones. The calculations revealed the 5-6-fold exceeding of the carrying capacity, especially in the peripheral part of the national park (Project of Forest Management, 1998).

High visitor flows cause multiple negative effects on the ecosystems of Losiny Ostrov. Some of them are listed in Table 1.

Recreation activities	Character	Effect	Ecological consequences
Visitor flows along roads and paths	Linear		Introduction of non-typical plant species along roads; waste
Picnics	Point	Logging, emergence of new fireplaces surrounded by severely disturbed areas	Formation of multiple hot spots of forest degradation
Spontaneous out-of-path recreation	Spatial	Emergence of multiple new unmanaged paths	Soil compaction, disturbance of soil aeration and moisture regime, losses of organic matter, disturbance of soil vegetation cover, enfeeblement of trees, and degradation of an ecosystem as a whole
Recreation + dog airing	Linear or spatial	Disturbance of wild birds and animals	Reduction of the number of ground-nesting birds and small mammals, concentration of animals in the central part of the national park

Table 1. Ecological issues of mass recreation in the NP Losiny Ostrov

In addition, disturbed ecosystems loose their aesthetic properties, which enhances the advance of visitor flows towards the central undisturbed part of the national park. As a result, the area of recreation-affected natural ecosystems enlarges.

In order to regulate the visitor flows, several strategies are used in the national park.

Functional zonation based on recreation intensity (Figure 1). The central part of the park forms the nature conservation zone where the access is allowed to a limited number of visitors (mainly, researchers). This zone is designated to maintain the ecological stability and biological diversity of the whole national park. The most visited peripheral part forms the recreational zone, which is designated for a short-term outdoor rest and recreation. The belt between them is a buffer zone designated for regulated recreation and ecological education. However, at present, the functional zonation should be revised, because the real recreational situation does not correspond to the existing boundaries of functional zones. Figure 1 demonstrates that some areas of the nature conservation zone are at the same time the most visited ones.

Ecological education. Together with preventing the violations of the regime of the national park, the ecological education helps to reduce the effect of the most aggressive human activities, such as logging, fires, mechanical damage to trees, picking up rare plant species, etc. Another important aim of ecological education is to transform spontaneous visitor flows into organised groups. The effect of such groups on the nature of the national park can be controlled. At present, the national park offers 11 ecological excursions; the summary carrying capacity of the ecological roots is ca. 50 000 visitors annually (calculated according to Kalikhman et al., 1999). However, their real carrying capacity is limited by the number of rangers and level of management.

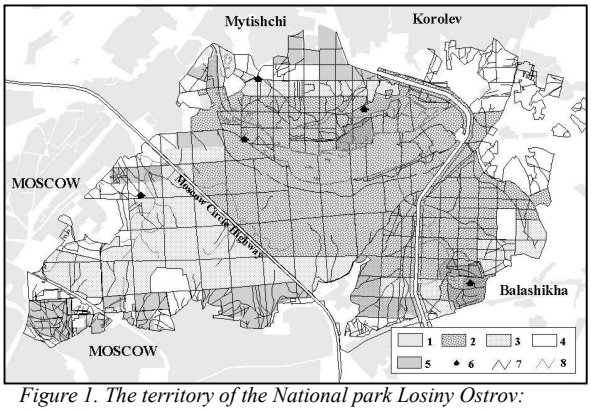

Figure 1. The territory of the National park Losiny Ostrov: (1) urban areas, (2) nature conservation zone, (3) excursion zone, (4) recreational zone, (5) areas with the highest recreational loads, (6) visit-centres, (7) major pedestrian roads, and (8) rivers and streams

Management of the recreational zone and, especially, roads and paths. It should increase the recreational carrying capacity of the elements of NP territory: paths, sport and playgrounds, banks of ponds, etc. In addition, the attraction of visitors to some well-managed areas should remove the visitor flows from those parts of forest ecosystems, where high recreational loads are not desirable. Unfortunately, the recreation infrastructure in Losiny Ostrov is very primitive and the level of service is very low. For example, there are no special service areas in our functional zonation.

The prospective goals of the management of the recreational zone are: (a) the maintenance of the biodiversity and (b) the formation of recreation-resistant forest stands. This envisages a detailed analysis of the structure of forest fund, the determination of the most and least damaged ecosystems, and the alternation of species and age structure of the forests of the recreational zone. For this purpose, the visitor flows and their effect on the ecosystems should be evaluated.

Although the direct calculation of visitor flows is the most widespread method, we avoided using it in our monitoring studies. There are several reasons for that.

The territory of the national park is paled fragmentarily, so there are many uncontrolled entrances and paths.

Significant length of park boundaries with dwelling regions, which are the sources of visitor flows, demands a large number of accounting persons, so the work becomes too expensive.

The intensity of visitor flows varies with season, day of week, period of the day, weather conditions and many other factors. As a result, an almost continuous account is needed to get reliable results.

Direct calculations give an absolute number of visitors, but not the spatial distribution of recreation effect. At the most, it characterises the recreation loads on basic linear elements, while in the NP Losiny Ostrov, the spontaneous out-of-road recreation causes the greatest damage to forest ecosystems.

However, we do not underestimate the results of direct account. They can be used successfully in sociological studies and planning of the development of recreational and tourist infrastructure, especially in the most visited sites.

METHODS OF COMPLEX MONITORING

The programme of monitoring of recreation-affected forest stands is a part of the general complex programme of forest monitoring in the NP Losiny Ostrov. The latter is based on the results obtained at permanent observation sites (Shapochkin and Lameborshai, 2000). However, the permanent observation sites are point objects and do not characterise the spatial distribution of negative factors. The recreational monitoring was initiated in order to detect the most damaged forest areas and elaborate the strategy of redistribution of visitor flows across the territory of the NP. The works are rather ecosystem-oriented than visitor-oriented, therefore, the status of forest ecosystems was the general criterion of acceptable visitor flows.

The current research programme partly includes the traditional methods of evaluation of recreation effect, which were elaborated in the former USSR in 1970s (Mukhina, 1972; Chizhova and Smirnova, 1976; Kazanskaya et al., 1977). However, the methods of complex monitoring of recreation-affected forest stands elaborated by M. S. Shapochkin are much wider.

According to this complex approach, the monitoring studies include three stages.

1. Selection of monitoring objects

The unit of monitoring is the forest inventory unit, i.e., a forest area with a homogeneous species and age composition of the tree layer, soil, and vegetation cover. In order to characterise the studied territory in a representative way, the forest inventory units are selected in proportion to the share of each species and age class in the whole forest fund of the territory and distributed evenly across the territory. Hence, a statistically reliable sampling is made. Each forest inventory unit is characterised by several circle test sites. The number of test sites (from 3 to 10) is determined in accordance with unit size and density of forest stands. Within a unit, the test sites are located regularly with the interval of 25-30 m in a latitudinal or longitudinal direction, depending on unit configuration.

2. Field observations

The tree layer, which determines the properties of a forest ecosystem, was characterised by tree species, considering the ecosystem biological productivity expressed via the basal cover of trees and wood storage.

From the centre of each test site, the trees are accounted using standard forest survey devices (angle gauge or prism). A qualitative characteristic of sanitary status of each accounted tree is given according to a 6-gradation scale. The following gradations are set: 1 – healthy, 2 – weakened, 3 – strongly weakened, 4 – declining, 5 – dead-standing trees of a current year, and 6 – dead-standing trees of previous years. The centremost trees are used for more detailed observations, the predominating species being represented by 3 and accompanying species, by 1 tree each. For these test trees, the height and diameter are measured, and the samples of timber are bored out in order to determine the radial increment during the last 10 and 20 years. The distance from the site centre to the three nearest trees is determined in order to calculate the number of trees per hectare, which characterises both ecosystem productivity and aesthetic properties.

The lower layers of forest communities were characterised by Dr. V. I. Obydennikov and his colleagues from Moscow Forest University. The undergrowth, grass, and moss layers of studied forest inventory units are described using the series of small observation plots. The status of undergrowth is evaluated quantitatively via the number of young trees per unit area and qualitatively, via its viability. It is a very important characteristic of ecosystem self-reproduction capacity. For grass and moss layers, the number and abundance of species and projective cover are determined. The decrease in projective cover and increased percentage of photophilous species and weeds determine the degree of recreation effect.

Sometimes, the visual determination of the category of tree sanitary status is not reliable. In connection with this, visual observations and measurements of tree increment were completed by anatomic analysis of wood tissues, which were conducted by the Assistant Professor of Moscow Forest University V. D. Lomov. The samples of wood tissues of the trees of different species and sanitary status were collected at the circle test sited. The tissues of trees growing under optimal ecological conditions were regarded as control

samples. Wood samples are conserved for further xylotomic studies. The series of characteristics is determined, such as the width of annual layer, width of early and late wood, thickness of tracheid membranes, their lifetime, etc.

The recreation effect on soils is characterised by soil compaction and changes in some morphological and chemical properties. The compaction is measured by a durometre and expressed in kg/cm^2. Soil compaction is measured both under tree canopy, where the vegetation cover looks undisturbed, and at disturbed fragments of soil cover of a circle test site, such as paths, areas around fires, etc. The measurements are made in 3-5 replicates. The percent of bare soil surface (without vegetation cover and forest litter) is evaluated and considered as an important indicator of the degree of recreational digression (Kazanskaya, 1972). The thickness of forest litter and upper humuc horizon is measured, the latter being sampled. The content of moisture, organic matter, and base cations, and soil acidity are then determined.

The series of field measurements should be repeated each 5 years. For the most visited and endangered sites, the frequency of observations can be increased.

3. Data Processing

The data of field observations provide an integral characteristic of studied forest inventory units. For each unit, the following values are calculated:

- basal cover of trees by species and categories of sanitary status,
- mean weighed category of sanitary status, which is an integer indicator of unfavourable ecological conditions,
- radial increment of test trees, which is then recalculated into the volume increment, and the losses of volume increment with time are determined, and
- mean weighed percentage of bare soil and soil compaction.

These calculated parameters make it possible to reveal the critical areas of forest stands. The following critical values are set (Table 2).

Measured and calculated values are mapped, and the indirect characteristic of spatial distribution of the effect of visitor flows is obtained.

The losses of volume increment and organic matter are used to calculate the ecological damage, which is represented in financial equivalent per unit area. For this purpose, the computer programme created in the All-Russian Research Institute of Forestry is used.

Parameter	***Unit of measure***	***Critical value***
Mean weighed category of sanitary status	***none***	***2.5***
Losses of annual increment	***%***	***Exceeding normal values by the factor of 2 and more***
Percent of bare soil	***% of test site area***	***25***
Stage of recreational digression	***none***	***transition from stage 3 to stage 4***

Table 2. Critical values assessed for the characteristics of recreation-affected forest stands.

DISCUSSION OF PRELIMINARY MONITORING RESULTS

In 2001, the first stage of field observations was conducted in the recreational and excursion zones of the city part of the national park. Here, the secondary birch forests constitute approximately 60% of the forest fund. The rest is represented by pine and lime forests, spruce and oak forming fragmentary stands. Twenty-seven forest inventory units subjected to the recreational loads of different intensity were studied. Nineteen of them are represented by secondary birch forests and 6, by pine forests of both natural and artificial origin. The age of examined forest stands varies from 30 to 150 years and the relative density of stands, from 0.3 to 0.9. The species composition of the tree layer is either simple or complex, the predominating species constituting from 30 to 100% of the stand. To characterise this sampling, 127 circle test sites and 455 test trees were examined.

The mean weighed category of sanitary status of studied units varies from 1.5 to 3.0. For the majority of units, this index is between 1.5 and 2.5, i.e., they are referred to the category of weakened. Two units, located at the distance of ca. 1 km from the boundaries of the national park at the intersection of two roads, are classified as strongly weakened. Seven of the rest 25 units comprise the fragments of strongly weakened forest stands. These areas should be considered in the first turn, when the redistribution of visitor flows is planned. Healthy forest stands with the category of 1.4 were observed only at 3 separate test sites at the distance of more than 1.5 km from the park boundary, and no completely healthy forest inventory units were found. That is, healthy stands occupy only 2% of the studied area. This points to a general trend towards the decline of forests in the city part of the national park. Hence, a very accurate monitoring of their status is needed in order to prevent their degradation.

The vegetation cover and upper soil horizons of many test sites are damaged. On paths, the forest

litter is destroyed completely, the thickness of the humus horizon is reduced by 25-50%, and the soil is compacted significantly. Bare soil surface constitutes up to 15-20% of the area of some test sites. At the same time, 25% of test sites have an undisturbed soil cover. When the percent of bare soil surface exceeds 5%, the compaction of the upper soil horizons is observed. The mean weighed soil compaction of disturbed forest units is 3-4 kg/cm^2, while normally, it constitutes 1-2 kg/cm^2 in forest soils. Soil compaction on paths and around fires reaches 15-20 kg/cm^2. The spatial distribution of the percentage of bare soil and soil compaction demonstrates that the forest stands located within a 1-kilometer belt along the boundaries with dwelling regions are the most affected by recreation (Figures 2 and 3).

At present, no forest stands with the 4th degree of recreational digression were found, i.e. all studied ecosystems have a potential for self-regulation and reproduction. However, the area with a pre-critical 3rd stage of recreational digression demands an immediate improvement. It should include:

- the reconstruction of path net in order to make the existing paths more comfortable for visitors and concentrate the major visitor flows along these managed roads,
- the creation of a dense artificial undergrowth, which will prevent the penetration of visitors into the forest massif and give refuge to birds, and
- the organisation of some new playgrounds or lawns to attract the visitors there.

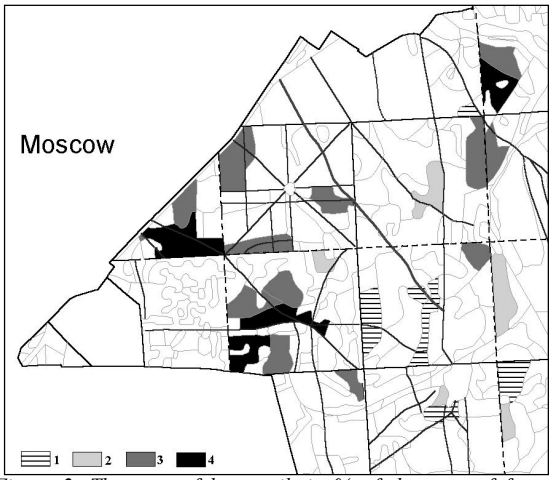

Figure 2. The area of bare soil, in % of the area of forest inventory units: (1) below 1%, (2) 1-5%, (3) 5-10%, and (4) 10-25%. Here and on Figure 3, solid lines represent major pedestrian roads

In addition, some corrections in GIS layers must be made. For example, the area with the highest recreational loads must be enlarged, as compared to that represented at Figure 1.

The preliminary analysis of the composition of vegetation cover demonstrates that typical forest species predominate at the majority of test sites.

Figure 3. Soil compaction, kg/cm^2: (1) 1.0-2.0, (2) 2.0-2.5, (3) 2.5-3.0, and (4) >3.0

Meadow flora and weeds appear only along roads, broad paths, boundaries of playgrounds etc.

The coefficients of correlation between the examined characteristics were determined in order to reveal their interrelation. The coefficients proved to be low, which points to a complex character of interrelation among the intensity of recreation and the status of forest ecosystems. The highest coefficient of correlation (equal to 0.38 at P = 0.90) was found between the sanitary status of forest stands and the area of damages soil and vegetation cover.

We expect that the equations of multiple regression will make it possible to reveal the most important factors determining the status of forest stands, and probably, to reduce the number of measured parameters.

CONCLUSIONS

The monitoring studies indicated the appropriateness of the complex monitoring methods for the evaluation of visitor flow effect on the forest ecosystems of the National Park Losiny Ostrov.

The results obtained can be used for the compilation of thematic maps and new layers of geoinformational systems, as well as for the calculations of ecological damage.

The first stage of monitoring studies revealed the areas where the forest stands are in a pre-critical status, according to the category of sanitary status of trees and percent of disturbed soil and vegetation cover. Immediate measures reducing the recreation press must be undertaken in these areas, including the improvement of roads and passes, creation of artificial undergrowth, and translocation of visitor flows to other areas.

The analysis of increment losses, anatomic features of wood tissues, and soil chemical properties is expected to provide a more detailed information about the status of recreation-affected forest stands. The statistical treatment of obtained data will help to determine the leading factors of

forest degradation and the interrelations among the characteristics of forest stands and recreation effect.

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