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CONTENTS

Recreational impacts on soils in Paanajärvi National Park (Republic of Karelia, Russia)

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Abstract

The impact of controlled tourism on soils was investigated in Paanajärvi National Park, Republic of Karelia, Russia. Even low degree of trampling was found to induce substantial changes in the properties of soil upper horizons, especially the forest floor. Our data indicate high compaction of the soil mineral horizons, their density reaching values critical for normal growth and development of the root system. The most important factors in soil resistance to trampling are moisture and type of the plant community.

Introduction

People have become more interested in ecotourism in the past few decades, and recreational impact of forest ecosystem has therefore increased (Recreational geography, 2004, Liddle, 1997). Hence, it is important to estimate and determine optimal load on ecosystems in protected areas (Satchell and Marren, 1976).

To control the condition of recreational forests one should take permissible values of diagnostic parameters of degradation of all ecosystem components into account (Lazareva, 1987). Soil is exposed to direct recreational pressure, wherefore the degree of change in its properties is the most objective criterion for assessing digression in recreation areas (Karpachevsky, 1981; Marphinina et al., 1984).

The first impact of recreation is trampling down of the ground cover and forest floor (Problems of the environment and natural resources, 2004). The forest floor compacted, its components grow finer, which results in deflation and exposure of mineral horizons (Monti, Mackintosh, 1979; Zhizhin, Zelensky, 1983; Pasternak, Smolnikov, 1985). As litter vanishes, soil freezing grows deeper, its hydrophysical properties change (Kochanovsky, 1962, 1964; Hill, Summer, 1967; Sokolovskaya, 1967, 1968; Grin'ko, 1968; Morozova, Lazareva, 1983, 2002), the plant cover becomes sparser and less abundant, forest productivity decreases (Tkachenko, 1937). Poorer water permeability reduces air supply to the soil, promotes evaporation from the soil and its surface (Taran, Spiridonov, 1977). Soil compaction deteriorates availability of nutrients to plants, reduces the amount of organic material, total humus, nitrogen, phosphorus (Zhuchenkov, 1964; Sokol, 1966; Krotova, 1969; Young, Gilmore, 1976; Sokolov, Zelikov, 1982). It also heavily inhibits growth of the root system (Problems of nature use optimization, 1988; Sokolov, Zelikov, 1988).

Material and methods

Research was carried out in Paanajärvi National Park, NW Republic of Karelia. The park was designated in 1997. Owing to remoteness from large settlements and infrastructure developments the recreational impact is quite low.

The park is situated in a region with a short growing season, low air temperature, high relative air humidity, low productivity coniferous forests, coarse textured parent rocks, frequent bedrock outcrops. Forests cover ca. 75% of the park territory, and over 90% of them are spruce forests (Gromtsev and Litinsky, 2003). Because of a heavily broken terrain the soil cover is motley, and fine structured. The soil cover in low-montane landscapes is made up of thin incomplete soils – Mountain podzolic and Primitive. Haplic Leptosols develop on slopes. Ferri-Carbic and Ferric Podzols in combination with Epistagni-Gleyic Podzols and Gley Terri-Fibric Histosols prevail in depressions of the crystalline bedrock, over very stony sandy loam till. Where bedrock outcrops, Primitive and Rudy-Podzolic soils develop. Glaciofluvial deposits in Olanga River valley are mostly overlain by Ferric and Histic Podzols, esker ridges – by Epi Podzols (Morozova et al., 2003).

Within the study, soil cover was investigated in 10 tourist sites. The trampling area mostly concentrates around buildings, and the disturbance outline depended on distances between the buildings.

Most of the sites are situated in pine forests (of the cowberry, crowberry-bilberry, lichen, cowberry-bilberry ground cover types), and one – in a herbaceous birch stand. Moisture conditions in the sites range from dry (lichen and cowberry pine stands) to semi-dry (crowberry-cowberry and cowberry-bilberry pine stands, herbaceous birch stand).

The sites were zoned with regard to the degree of the ground cover and forest floor degradation:

Heavy trampling zone (zone 1) has no vegetation. Forest floor is missing from most of the territory, and soil mineral horizons are exposed. The zone corresponds to digression degree V (Gesinruk, 1987) and may occupy 6-30% of a site.

Moderate trampling zone (zone 2) has ground cover around trees only; forest floor is compacted and worn out (thickness ranging from 1 to 3 cm). The zone corresponds to the digression degree III-IV and covers ca. 25% of a site on average.

Slight trampling zone (zone 3) – vegetation is suppressed, forest floor is slightly compacted (no more than 5 cm thick). The zone may occupy up to 30-35% of a site and corresponds to the digression degree II-III. The zone is present not in all sites.

The diagnostic technique is based on comparison of trampled areas with reference ones (controls), not exposed to human impact. The parameters used to assess soil cover degradation were forest floor thickness, stock and bulk density, bulk density of soil mineral horizons, since these parameters respond most explicitly to trampling and can be easily determined (Lazareva, 1987). Changes in soil hydrophysical parameters in the bilberry-cowberry pine stand were not investigated because soil in the sites was very stony.

Results

Changes in the forest floor under the impact of recreation

A first manifestation of recreational impact is reduction in the area covered by forest litter, changes in its thickness, density and stock (Tab. 1).

Table 1. Forest floor parameters in the sample plots situated in different forest types

Forest type, soil	Trampling area	Litter-covered area, %	Litter thickness		Stock		Bulk density	
			cm	% of change	kg/m^2	% of change	g/cm^3	% of change
Crowberry-cowberry pine stand, sandy Epi Podzol	1	10±5	0.9±0.5	84±9	2.6±0.1	32±12	0.26±0.22	480±84
	2	80±15	1.8±0.6	75±12	2.9±0.8	21±10	0.19±0.12	360±37
	3	100	3.0±1.7	60±24	3.4±0.6	102±5	0.15±0.08	240±50
	control	100	7.6±2.1	0	3.4±0.5	0	0.05±0.01	0
Lichen pine stand, sandy loam Ferric Podzol	1	0	0	100	0	100	-*	-
	2	70±10	1.0±0.5	70±3	1.5±0.5	29±10	0.15±0.03	250±50
	control	100	3.1±0.3	0	2.1±0.4	0	0.07±0.01	0
Cowberry pine stand, sandy loam Epi Podzol	1	0	0	100	0	100	-	-
	2	70±15	2.0±0.9	82±7	3.6±0.1	8±5	0.18±0.02	350±50
	control	100	10±1.0	0	3.9±0.2	0	0.04±0.03	100
Bilberry-cowberry pine stand, loamy Carbi-Ferric Podzol	1	5±3	1±0.5	86±6	-	-	-	-
	2	30±10	2±1.5	68±17	-	-	-	-
	3	100	4±1.5	47±14	-	-	-	-
	control	100	7±1.0	0	-	-	-	-
Herbaceous birch stand, loamy Humi-Haplic Podzol	1	0	0	100	-	-	-	-
	2	80±10	0.5±0.3	90±5	-	-	-	-
	control	100	5±1.0	0	-	-	-	-

*- - no data

In most (80-90%) of the heavy trampling area (zone 1) forest floor is either missing or fragmented and highly compacted (0.20-0.26 g/cm^3), with a thickness of 0.5-1 cm. In all sample plots, changes in these parameters grow less pronounced as the degree of trampling decreases. Floor density in all sites increases significantly parallel to the degree of trampling damage. In zone 3 already it is 2.5-3.5 times higher, in zone 1–5 times. However, these changes differ among sites. Very heavy recreation-induced deterioration of the forest floor was observed in the crowberry-cowberry pine forest, where floor thickness dropped compared to the control by an average of 84% in zone 1, by 75% in zone 2, and by 60% in zone 3. The reason is that the site has been in use for a long time.

In lichen and cowberry pine stands, as well as in the herbaceous birch stand, forest floor is lacking from the whole of the heavy trampling zone. Sites in the bilberry-cowberry stand feature bedrock outcrops, and litter is found only in depression among boulders, i.e. in no more than 5-10% of the territory.

No clear trend was detected in relationship between the change of forest floor stocks and the degree of trampling. Thus, stocks in sites with low recreation load increased (by 10% at maximum); where the load was heavy the parameter decreased to 30% of the control.

Litter stocks in the site with moderate trampling in the cowberry pine stand changed slightly (decreased by 8%), whereas the reduction in the lichen pine stand was significant (by 29%).

Changes in hydrophysical properties under the impact of recreation

Density of soil mineral horizons is an informative and easily found criterion of trampling damage. This parameter can be used as the main diagnostic indicator of the critical condition of soils under recreational impact (Kruglyak, 2005). Trampling-induced changes in the density and moisture of soil mineral horizons are shown in Tab. 2.

Recreational land use results in soil compaction mainly to a depth of 10-15 cm. Moisture content in a denser soil is lower because of lower total porosity and impeded permeation. Thus, the density of upper mineral horizons in the heavy impact zone is 1.4-1.5 g/cm^3, i.e. 20-40% greater than reference values. Moisture content drops down to 10%, whereas soil moisture in the control site is 20-30%.

Table 2. Changes in soil hydrophysical properties of the sites under recreational impact

Forest type, soil	Trampling area	Bulk density of soil mineral horizons		Moisture of mineral horizons	
		g/cm^3	% of change	%	% of change
Crowberry-cowberry pine stand, sandy Epi Podzol	1	1.42±0.14	38±16	13.7±1.11	33.7±7.5
	2	1.29±0.06	23±10	14.1±1.57	31.6±9.1
	3	1.25±0.08	13±11	15.8±2.00	23.9±10.9
	control	1.03±0.15	0	21.0±2.10	0
Cowberry pine stand, sandy loam Epi Podzol	1	1.37±0.04	32±19	12.5±0.50	36.0±5.0
	2	1.23±0.04	28±15	16.7±1.59	14.7±9.2
	control	1.06±0.18	0	19.7±1.52	0
Lichen pine stand, sandy loam Ferric Podzol	1	1.38±0.06	24±2	14.7±0.76	26.7±8.0
	2	1.29±0.04	16±3	16.6±1.76	14.3±11.6
	control	1.11±0.12	0	18.0±3.50	0
Herbaceous birch stand, loamy Humi-Haplic Podzol	1	1.47±0.06	45±10	19.5±2.29	40.6±9.6
	2	1.25±0.04	23±8	20.8±1.10	31.5±3.0
	3	1.20±0.02	18±8	24.6±4.2	18.9±12.4
	control	1.05±0.08	0	30.3±0.4	0

Soil density increased most significantly in the site situated in the herbaceous birch stand. In the heavy trampling zone, soil density increased by 45%, and moisture loss was 41%. As trampling grew milder, the difference from the control in bulk weight decreased – by 23% in moderately and by 18% in slightly trampled sites. Moisture reduction also decreased to 32 and 19% of its content in the control, respectively.

Discussion

The survey has shown that the degree of disturbance of the soil cover varies among tourist sites. Differences in the change in characteristics of the forest floor and mineral horizons among the sites are due to distinctions in the ground cover, soil mechanical properties and stoniness, as well as duration of the impact in the sites.

The soils' resistance to trampling is influenced by moisture supply and type of vegetation. The moister is the soil, the thicker is the forest floor forming thereon and acting as a buffer that takes the load and prevents soil compaction (Problems of the environment …, 2004). Condition of the litter (thickness, stock, density) is one of the main indicators of the degree of recreational digression. The first thing to change as the result of trampling is the morphological structure of the forest floor. At early stages of the digression, the floor grows compacted (2-3-fold). Increase in the floor density entails a considerable decrease in its thickness even at early stages of recreational digression (by 60% in slight-, by 70-80% in moderate- and by 90-100% in heavy trampling zone).

Forest floor stocks are an integral parameter reflecting both increased density and reduced thickness due to trampling. Papers dealing with changes in forest floor properties under recreational impact reported of both loss of and increase in litter stocks (Bayfield, Brookes, 1979; Lazareva, 1987). Our data indicate that litter stocks increase somewhat in the slight trampling zone (by 2-10%), but decrease where the pressure intensifies (by 20-30%) (Tab. 1). Moisture conditions and characteristics of the ground cover significantly influence stocks of litter through its composition and thickness. The field layer in dry sites in the lichen pine stand is dominated by lichens, which are highly sensitive to trampling, get worn and compacted faster, and where forest floor thickness in control sites is quite low – 3-3.5 cm. Litter stocks there dropped by 29% in the moderate trampling zone. The field layer in the cowberry pine stand is dominated by dwarf shrubs – cowberry *Vaccinium vitis-idea*, bilberry *Vaccinium mirtylis.* They promote formation of thick litter (7-8 cm) more resistant to recreational impact. Changes in litter stocks there were less significant – 8% reduction.

A weighty negative factor of recreational use of forests is compaction of the soil mineral horizons. All sites surveyed demonstrated an increase in soil compaction and a reduction in soil moisture as the trampling damage aggravated. These changes however differed depending on natural site conditions and duration of land use. Most studied soils are coarse-textured, and some data (Bgantseva et al., 1987) indicate that degradation processes induced by recreational impact are less explicit and take more time to develop when the substratum is sandy and sandy loam soils. Surveys have shown soil density in the tourist sites to increase to 1.40 g/cm^3 on average, and to a maximum of 1.55 g/cm^3, whereas the optimal density range for coarse-textured soils is 1.20-1.45 g/cm^3, and densities over 1.6 g/cm^3 are classified as critical. Plant roots encountering soil layers denser than 1.4 g/cm^3 become distorted, their development in inhibited (Kachinsky, 1947). Thus, the density of soils in the heavy trampling zone often exceeds the optimal level.

The greatest recreation-induced soil damage was detected in the sites situated in the herbaceous birch stand, and the crowberry-cowberry and lichen pine stands. The reason for that in the herbaceous birch stand and crowberry-cowberry pine stand is more intensive exploitation. However, these forest types are quite resistant to recreation. A lichen pine stand, on the contrary, would suffer heavy soil degradation even upon a short period of exposure to the impact, because the field layer there is very vulnerable and the forest floor is thin.

Hence, forest types can be arranged in the following series depending on vulnerability to recreation: lichen pine stand – rocky cowberry pine stand – rocky bilberry pine stand – cowberry pine stand – cowberry-bilberry pine stand – crowberry-cowberry pine stand – herbaceous birch stand.

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Effects of recreation on root mass in upper soil layers (Paanajärvi National Park)

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Abstract

Effects of recreation on root mass in upper soil horizons were investigated. Increase in recreational pressure was found to reduce the root mass. Most heavily inhibited are fine (physiologically active) roots, this effect being most explicit in the forest floor.

Introduction

Continually growing public demand for recreation necessitates research into the consequences of impacts on the forest environment as a major place people choose to rest in. Active visitation of forest impairs the soil cover, changes soil hydrophysical properties and, hence, deteriorates the function of tree root systems.

Tree stand productivity is closely related to the development of root systems (Kazimirov and Morozova 1973, Kalinin 1983), wherefore their suppression has a negative effect on the above-ground part of the stand.

The root system is known to play a crucial part in the life of a plant. Roots anchor plants in the soil, improve its forest-growing qualities, enrich the soil with organic material (Kalinin 1983, Melekhov 1980). Root systems derive mineral nutrients from the soil, and after the roots die back the nutrients are accumulated in the humus accumulation horizon, where the bulk of roots usually develop.

Root mass is the greatest in the upper soil layer (0-20 cm). Sucking (physiologically active) roots mostly concentrate at the verge of the forest floor and the mineral horizon, since this area contains most nutrients. Also, according to Kongokhova (1998), moisture in the upper soil layer is more easily available to roots, wherefore they are more advanced in this layer as regards both abundance and weight.

Functioning of the active (sucking) part of the root system predetermines the intensity of absorption of water and mineral nutrients a tree needs to grow and develop. Soil compacted by recreational activities resists more to growth of roots, for their permeation in smaller pores is more difficult. As the result, nutrient supply to the tree and colonization of new soil areas is impeded. Recreation may cause mechanical damage to roots. Skeletal roots in sites visited by many tourists often become exposed, their bark is stripped, harming the trees, as they become easy target to pests and pathogens. Trees with damaged roots often become affected by rots and cancers (Kardell and Nilson 1986).

As the soil cover is trampled down in stands exposed to recreation, sucking roots rise closer to the surface, where they are damaged and infected. This results in disruption of physiological processes and reduced tree vitality.

Material and methods

Surveys were carried out in Paanajärvi National Park in Karelia. The objects of the study were actively used tourist routes and stopping sites. The sites surveyed are described in Table 1.

Table 1. Parameters of the sites surveyed

Site	Forest type	Composition	Age
1	Crowberry-cowberry pine forest	10P	90 few 160
2	Crowberry-cowberry pine forest	1st storey – 10P few B 2nd storey – 10S	100-160
3	Rupestrine bilberry pine forest	10P+E few B	120-250
4	Rupestrine cowberry pine forest	10P	100-120

Each site was zoned depending on the degree of ground cover and forest floor damage:

heavy and moderate trampling zone – plant cover missing or found rarely, only around trees; forest floor heavily compacted and worn out (up to 3 cm thick). Such areas are typical of sites exposed to most intensive human impact;

slight trampling zone – plant cover flattened, forest floor slightly compacted (up to 5 cm thick);

control – area with no signs of trampling damage.

Recreation-induced changes in the mass of roots up to 3 mm in diameter in upper soil horizons were analyzed. To this end, 10x10x20 cm soil cores were sampled throughout the site, taking heavy trampling areas into account. The sample depth was 20 cm since it is the most root-inhabited soil layer. Recreational impact on root mass was estimated in two soil horizons: the forest floor and the underlying mineral horizon. Roots up to 3 mm in diameter were picked out of the core samples (both forest floor and mineral horizon); fine physiologically active roots below 1 mm in diameter were separated. After grading, all roots were oven-dried and weighted.

Results

The studies have shown the weight of roots up to 3 mm in diameter to depend on the recreational load. As a rule, root mass in both the mineral horizon and the forest floor decreased as the site trampling damage increased (Tab. 2). This is true both for the total weight of roots up to 3 mm in diameter and for fine roots (below 1 mm) taken separately. Comparing changes in root weight among the horizons, roots in the forest floor normally respond to the load more acutely than in the mineral horizon, as can be seen from Table 2.

Table 2. Weight of roots less than 3 mm in diameter in the topmost 20 cm of soil

# of site	Degree of trampling damage	Weight of roots less than 3mm in diameter in the forest floor		Weight of roots less than 3mm in diameter in the mineral horizon		Weight of roots less than 1mm in diameter in the forest floor		Weight of roots less than 1mm in diameter in the mineral horizon	
		t/ha	% of change	t/ha	% of change	t/ha	% of change	t/ha	% of change
1	Inexplicit (control)	0.71	0	1.17	0	0.46	0	0.55	0
	Extreme and moderate	0.29	59	0.93	21	0.15	67	0.39	29
	Slight	0.40	44	0.84	28	0.20	57	0.42	24
2	Inexplicit (control)	0.71	0	1.17	0	0.46	0	0.55	0
	Extreme and moderate	0.01	99	0.32	73	0.01	98	0.12	78
	Slight	0.36	49	0.76	35	0.22	52	0.41	25
3	Inexplicit (control)	0.75	0	0.70	0	0.42	0	0.17	0
	Extreme and moderate	0.38	49	0.43	39	0.16	62	0.06	68
4	Inexplicit (control)	1.10	0	0.90	0	0.60	0	0.22	0
	Extreme and moderate	0.41	63	0.10	89	0.08	87	0.06	73

In site 2 however, changes in root weight were considerable both in the forest floor and in the mineral horizon (Tab. 2). Sites 1 and 2 are located in the same forest type (crowberry-cowberry pine forest), but root mass there decreased differently because of distinctions in the load and, hence, in soil compaction and deterioration of hydrothermal conditions. Thus, total root mass in the forest floor of the heavily- and moderately trampled zone in site 1 was ca. 60% lower than in the control, whereas in site 2 it was 99%. In this zone, the reduction in the weight of active roots (below 1 mm in diameter) compared to the control was nearly 70% in site 1 and 98% in site 2. In the mineral horizon of the heavily- and moderately trampled zone, the weight of roots below 3 mm in diameter changed by 20% in site 1, and by 70% in site 2. The weight of fine (below 1mm) roots in the same zone in site 1 decreased by 30%, and in site 2 – by 80%.

Recreation-induced change is somewhat more pronounced in the weight of fine (below 1 mm) physiologically active roots than in the weight of thicker roots (Tab. 2). This situation is most conspicuous in the forest floor.

Discussion

According to Lazareva and Morozova (1987), root content in upper soil layers is a good indicator of the degree of stand digression. This statement is confirmed by our data that a rise in recreational pressure leads to a reduction in root weight (Tab. 2). In the first run, recreation damages the forest floor. It is compacted, its components grow finer, and organic matter content decreases (Morozova and Lazareva 2002). That is why roots respond most acutely in this very horizon (Tab. 2). If however a site is used intensively, root weight decreases significantly in the mineral horizon also, due to soil compaction and loss of the forest floor under heavier pressure. This is the case with site 2, which was exposed to heavy load, and the root content throughout the studied 20-cm soil layer differed notably from control values (Tab. 2).

Forest floor compaction and degradation lead to damage and die-back of sucking roots (Lazareva and Morozova 1987, Problems of nature use optimization … 1988). A sharper reduction in the weight of roots below 1 mm in diameter compared to that of all roots below 3 mm, which is especially explicit in the forest floor (Tab. 2), is due to their greater susceptibility to mechanical damage, and to changes in hydrothermal conditions.

According to the literature, roots of a tree may extend to a distance 2-5 times exceeding the radius of its crown (Sennov 1980), and tree root systems may get interwoven: root systems of many trees may simultaneously occupy the same physical volume of soil, and perform their functions. Active root tips fill ecologically available parts of the soil, and are distributed over the area nearly independently of the distance to the tree trunk (Sennov 1980, Oja and Lykhmus 1985). Thus, the degree of damage to the entire set of root systems in a stand has hardly any relationship to the placement of the path network.

Summing up, the following can be postulated:

- a rise in recreational load leads to a reduction in root mass;

- root mass decreases most sharply in the forest floor;

- most heavily inhibited are fine (physiologically active) roots, which serve for assimilation of nutrients from the soil;

- degree of damage to the entire set of root systems in a stand is virtually independent of the placement of the path network.

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Analysis of recreational impact on living ground cover in forests on Paanajärvi National Park (Republic of Karelia, Russia)

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Abstract

The paper reports the results of research into transformation of the living ground cover in Paanajärvi NP forests exposed to heavy recreational load. Altogether, 12 camping sites of the National Park Paanajärvi located in pine forests were surveyed. Three zones were distinguished within the sites: zone of total wear-out, zone of moderate wear-out and zone of relatively slight wear-out. Transition from one zone to another is quite obvious, maximal destruction of the ground cover is around fire rings and the cover density increases with distance from them. The area of digression depends on location of access roads and elements of infrastructure in the campsite. The main changes in the living ground cover induced by increased trampling are reduction in percent cover and increase in species diversity, excepting the zone of complete wear-out.

Keywords: recreation, national park, tourism, campsite, trampling, living ground cover.

Introduction

Paanajärvi National Park (NP) was founded over 15 years ago, and is now one of the most attractive areas in Karelia with high potential for nature tourism development. Although people had settled in the area a long time ago and maintained active agriculture for over three centuries, there survived unique landscape complexes with nearly virgin expanses of predominantly spruce forest.

Owing to the NP's functional infrastructure, tourist traffic is growing every year, and this cannot but tell on the condition of the natural complexes. Recreation leads to gradual change (digression) of the forests. The components to suffer most are the living ground cover and the soil. Trampling-induced changes in their structure can be diagnosed already at early stages of digression.

One distinguishes five stages of recreation-induced digression (Polyakova et al. 1981; Dyrenkov 1983; Rysin 1983, etc.): I. Slightly disturbed state, II. Disturbed state, III. Heavily disturbed state, IV. Stand degradation, V. Total wear-out (typical forest species survive only in 5-10% of the territory). The main visual signs of digression are: worn-out land, damaged or destroyed understorey and trees, forest herbs replaced by meadow herbs and weeds.

Many researchers (e.g., Tarasov 1986) believe the threshold of forest resistance to be between the third and the fourth stages of digression. As steady and growing recreational pressure at these stages results in die-back of the understorey, the forest loses its self-regeneration capacity. At this stage of digression, lichen pine stands transform into pine stands with no field layer, cowberry pine stands – into sheep fescue pine stands, and bilberry pine stands – into herb-grass pine stands.

Species in the living ground cover show different responses to such recreational load as trampling. Mosses are more tolerant of trampling than herbaceous forest plants, and normally tolerate twice greater loads (Polyakova et al. 1981).

The parts continuously exposed to recreational pressure in the NP are forest fragments in campsites, actively used trails, as well as attractive from the recreational viewpoint areas such as Lake Paanajärvi, Mäntykoski and Kivakkakoski waterfalls, mountain tops, etc. The park has strict visitor regulations, and attempts of “wild” tourism are stopped.

The aim of our surveys was to determine the degree of change in the living ground cover in campsites within Paanajärvi NP forests, and to assess the impact of this form of recreation on the condition of the park’s forest ecosystems in general.

Material and Methods

Paanajärvi National Park (area – 104371 ha) is situated in the northwest of Republic of Karelia, near the border with Finland (66°20' N, 30°00' E). The territory falls within the north-taiga tectonic denudation hilly-ridge moderately paludified landscape with low-mountain complexes (Volkov et al. 1995; Gromtsev et al. 1995). It is the most elevated part of Karelia, with elevation marks up to 450-550 m. Some 75% of the park area is covered by forest, over 90% of which are spruce forests (Belkin et al. 1991; Gromtsev & Litinsky 2003; Shelekhov 2003).

The campsites surveyed are situated in pine stands occupying the eastern and south-eastern parts of the park within an aqueoglacial plain. Crystalline bedrock is overlain by Quaternary sediments, absolute elevations range from 130 to 235 m. The campsites are in flat areas, some of them slightly sloping towards the lake or river nearby. In addition to guesthouses or wooden decks for tent installation, each campsite must have a fire ring with benches, a lavatory, a shed with firewood, and garbage containers.

The present paper is based on the data collected in July 2007 from 12 campsites situated in clusters of 4 in three localities: a crowberry-cowberry lichen-true moss pine stand by the bridge across River Olanga; a cowberry-lichen pine stand near lakes Shärkijärvi and Jungojärvi; bilberry-cowberry pine stands on stony (sandy-bouldery) soil on the shores of Lake Paanajärvi. For each of the localities, a reference description of the living ground cover was made from sites unaffected by trampling in identical forest types with a similar topographic position.

Campsite outlines (dimensions) were determined by the degree of disturbance of the living ground cover. During visual examination, boundaries of the campsites are quite distinct, since the trampling area is limited to major facilities: fire ring – cabins and/or tents – garbage containers, etc., and hardly any damage to vegetation is observed outside them.

The area of the campsites regularly used by visitors ranges from 0.02-0.04 ha to 0.31-0.37 ha, due to differences in location with respect to access roads. Larger campsites have parking, and sometimes even maneuvering space. In other sites, where parking is nearby, a network of paths connecting it to the camp appears, considerably expanding the trampling-affected zone. There are several campsites in the park that are situated on paths and have no driveways nearby. They are 0.02-0.04 ha in area – a size close of that in some other national parks (Kangas et al. 2007). Another important factor influencing the size of trampled area is the number of buildings and distance between them.

Given the characteristics of recreation in the park (having to spend several nights in one campsite, to carry along a lot of gear, sometimes including tents; quite significant distances one has to travel by road from campsites to the start of nature trails; no road network around the park), it is quite justifiable to have parking space near campsites. When planning campsites however one has to take the location of access roads into account, namely build cabins in the immediate vicinity of existing roads.

The living ground cover of the plant communities was described using a conventional geobotanical technique (Field Geobotany 1964, 1976). Percent cover of species (shrub, herb-dwarf shrub, moss-lichen layers) was determined. Simultaneously, the living ground cover within campsite outlines was mapped (ratio of totally worn-out areas and paths, as well as surviving patches of vegetation was determined).

Scientific and Russian names of vascular plants are cited after Tzvelev (2000), of mosses – after Ignatov et al. (2006), of lichens (species composition insufficiently known) – after Fadeeva et al. (2007).

Results and Discussion

Surveys have shown the living ground cover in campsites in different forest types to be deformed unevenly. As a rule, three distinct zones can be visualized: heavy (total), medium (moderate) and slight wear-out.

1. Heavy (total) wear-out zone. Hardly any living ground cover present, 90-100% of the area is worn-out, with the litter destroyed. Recreational digression in stage V. Herb-dwarf shrub layer missing, or sole plants present. Moss-lichen cover either totally destroyed, or made up of mosses forming a thin (several mm high at most) green “carpet” in totally worn-out areas. Trees few or missing. No understorey or undergrowth. This zone may occupy 6-30% of the site area; the ground cover is heavily degraded mostly at the fire ring, as well as around guesthouses and utility buildings (Fig. 1).

Fig. 1. Zone 1 (heavy wear-out). Campsite on the left-hand bank of River Olanga by the bridge; crowberry-cowberry pine stand.

2. Medium (moderate) wear-out zone. Fringes zone 1 and has a dense network of paths; 30-80% of the area is worn-out. Disturbance of the living ground cover corresponds to the digression stage III or IV. Ground cover flattened. It is worn out on paths, but survives around the trunks of isolated trees and in vegetation patches separated by paths. The patches vary in size from 0.5×0.5 m to 3.0×3.0 m and more. This zone occupies an average of 25% of the site area (Fig. 2).

Fig. 2. Zone 2 (moderate wear-out). Campsite of the left-hand bank of River Olanga by the bridge; crowberry-cowberry pine stand.

3. Relatively slight wear-out zone. Found in the campsite periphery, and may occupy up to 30-50% of the site area. The network of paths is sparse. The paths are moderately worn out, moss-overgrown. Altogether, less than 30% of the surface area is worn out. Living ground cover retained in most of the area, but locally strongly flattened. Stage II-III of recreational digression (Fig. 3).

Fig. 3. Fragment of zone 3 (slight wear-out). Dwarf shrub (bilberry, cowberry, crowberry) shoots deformed (“skeletonized”), lichen thalli crushed.

In fact, these zones represent different path densities, from few or rare (zone 3) to confluent and forming one worn-out area (zone 1). To a certain extent, they can be distinguished in every campsite.

As recreational pressure grows, overall percent ground cover decreases, and species demonstrate different resistance to trampling. All detected species were arranged into 8 groups depending on response to trampling: a) forest dwarf shrubs (*Vaccinium vitis-idaea*, *V. myrtillus*, *Calluna vulgaris*, etc.), b) grasses, c) forest herbs, d) synanthropic herb species, e) lichens, f) forest mosses (except for genus *Dicranum*), g) *Dicranum* mosses, h) mosses pertinent to disturbed habitats and barren rock,.

Response of the plant cover to trampling is measured through various parameters, the most illustrative ones being percent cover (Table 1) and species diversity (Table 2).

Table 1. Percent cover (%) of species in the living ground cover in campsites and reference plots in Paanajärvi NP (see text for explanations and notations)

Forest types within campsites	Trampling zones and reference plots	Herb-dwarf shrub layer				Moss-lichen layer			
		Groups of species by resistance to trampling							
		a	b	c	d	e	f	g	h
Sites in crowberry -cowberry pine stands	Zone 1	+	+	2	+	-	+	7	12
	Zone 2	35	+	+	+	15	51	12	2
	Zone 3	63	+	+	+	38	54	4	2
	Reference	63	+	-	-	40	59	+	-
Sites in cowberry-lichen pine stand	Zone 1	+	+	+	+	+	+	2	+
	Zone 2	32	+	+	+	21	30	6	+
	Zone 3	35	-	-	-	52	36	4	+
	Reference	25	-	-	-	80	15	5	-
Sites in cowberry-bilberry pine stand	Zone 1	+	+	13	3	-	+	+	5
	Zone 2	34	6	3	+	9	19	11	7
	Zone 3	60	2	2	-	+	93	2	+
	Reference	60	3	+	-	30	63	+	+

Forest mosses, mainly *Pleurozium schreberi* and *Hylocomium splendens*, as well as fruticose *Cladonia* lichens, are the dominants in the ground cover of forests in the park, and suffer most from trampling in campsites. The lichen cover is destroyed more dramatically and much faster – even at low pressure (zone 3), lichens are replaced by more resistant forest mosses. As one moves from the campsite periphery to the fireplace, the moss cover grows nearly totally transformed, and the forest floor becomes compacted and/or stripped off, with exposed sand areas forming.

Where human impact is heavy (zone 2 and, especially, zone 1), the moss cover shrinks abruptly, and the ratio of mosses of different groups changes (Tab. 2). The contribution of genus *Dicranum* and moss species pertinent to disturbed habitats (*Pohlia nutans*, *Ceratodon purpureus*, *Polytrichum juniperinum*, etc.) increases notably in zone 2. In contrast to typical forest mosses, their stems are not branched, leaves are closely set, and the size is relatively small, making these species much more resistant to recreational impact. Species of this group have the greatest percent cover in zone 1. In worn-out areas, genus *Dicranum* is represented by the same species as in the surrounding forest, but moss plants there are much smaller (less than 1 cm). Exposed rocks in the campsite on Lake Paanajärvi are inhabited by *Bucklandiella* (*Racomitrium*) *microcarpon*.

The slight and moderate wear-out zones (3 & 2) retain patches of natural moss cover separated by paths bearing trampling-resistant species, and moss diversity in these zones is the highest. Where the pressure is more intensive, forest-dwelling moss species disappear, the composition of the moss flora becomes poorer and differs significantly from that in the surrounding forest.

Table 2. Number of species in the living ground cover in campsites and reference plots in Paanajärvi NP

Forest types within campsites	Trampling zones and reference plots	Herbs and dwarf shrubs		Mosses	
		Total no of species	Mean no of species in a site	Total no of species	Mean no of species in a site
Sites in crowberry -cowberry pine stands	Zone 1	17	11	6	3
	Zone 2	16	9	14	7
	Zone 3	16	9	14	7
	Reference	6	6	6	6
Sites in cowberry-lichen pine stand	Zone 1	12	5	10	4
	Zone 2	22	8	11	6
	Zone 3	4	3	9	6
	Reference	4	4	4	4
Sites in cowberry-bilberry pine stand	Zone 1	24	13	9	5
	Zone 2	24	14	14	9
	Zone 3	11	11	6	6
	Reference	14	14	8	8

Thus, compared to reference plots, nearly all campsites, irrespective of the forest type, had a higher species diversity of mosses owing to settlement of anthropophilous species in worn-out areas (Fig. 4, 5, 6).

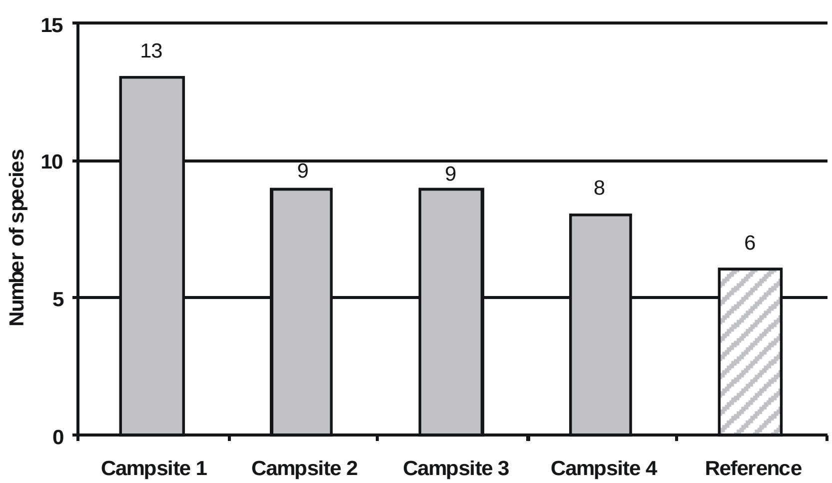

Fig. 4. Number of moss species in the campsites and the reference plot in crowberry-cowberry pine stands

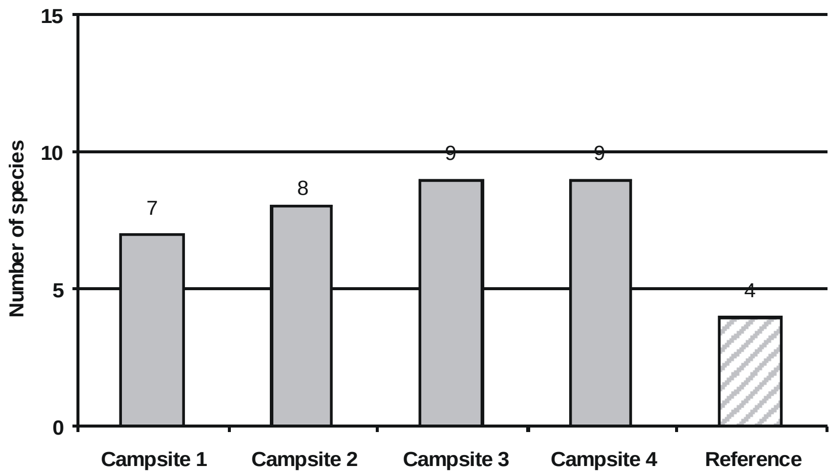

Fig. 5. Number of moss species in the campsites and the reference plot in cowberry-lichen and lichen pine stands

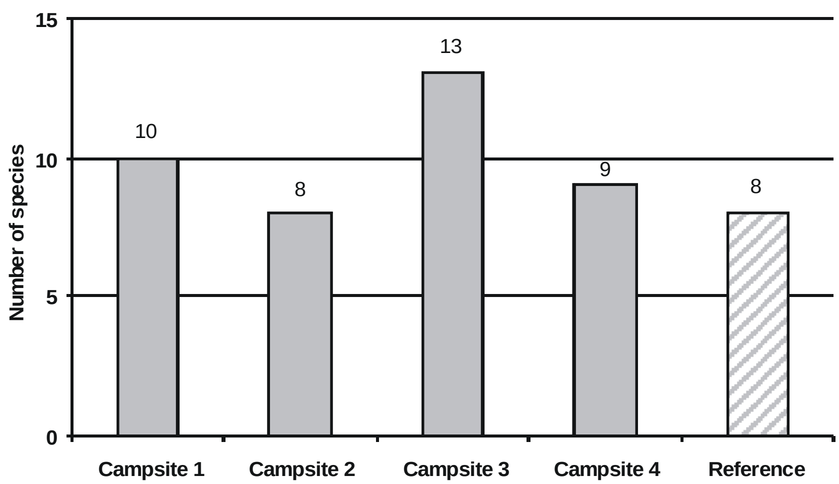

Fig. 6. Number of moss species in the campsites and the reference plot in bilberry-cowberry pine stands

Similar changes take place in the herb-dwarf shrub layer. Dwarf shrubs, which are dominants in undisturbed forest, retain their percent cover under slight pressure in zone 3, but are strongly affected as the pressure increases and a greater area is damaged. E.g., after two years of exploitation of a campsite, the only thing left of the herb-dwarf shrub layer there was skelotonized shoots of bilberry and cowberry. Typical forest herbs (*Luzula pilosa*, *Solidago virgaurea*, Melampyrum *pratense*, etc.) occurring in reference plots survive also in disturbed parts of the campsites, nearly disappearing only from heavily worn-out zones.

Being more resistant to trampling, grasses, on the contrary, cover a certain percent of the surface of worn-out areas, and even dominate in the most heavily disturbed zone in the locality with fertile soils on Lake Paanajärvi shore (*Deschampsia cespitosa*, *Agrostis capillaris*, *Poa annua*, etc.).

In the heavy wear-out zone (1), dwarf shrubs are only present as sole suppressed plants near tree trunks. Worn-out areas around buildings are inhabited by synanthropic herb species, but the percent cover of this layer in general is very low. On Lake Paanajärvi shore, where soils are more fertile, campsites that are used most intensively and for the longest time gain typical weed species such as *Amoria repens*, *Plantago major*, *Stellaria media*, etc., occupying up to 8% of the cover.

Surveys of the localities (campsites and reference plots) yielded a total of 63 vascular plant and 25 moss species. Reference plots contained 16 and 12 species, campsites – 61 and 25 species, respectively. Among vascular plants, only two species were not found in disturbed habitats (*Goodyera repens* and *Geranium sylvaticum*), whereas a majority – 47 species, on the contrary, were detected in disturbed areas only. Regarding mosses, all species known from undisturbed habitats occurred also in campsites, and 13 species found in campsites were quite logically absent from reference plots.

The species diversity of the herb-dwarf shrub layer reaches a maximum in zones 2 and 1, owing to survival, although with a lower percent cover, of forest dwarf shrubs and herbs, coupled with arrival of synanthropic species not typical of the park's undisturbed forests.

Depending on the forest type and habitat conditions, the number of vascular plant species in campsites may differ sharply from that in reference plots (Fig. 7, 8, 9).

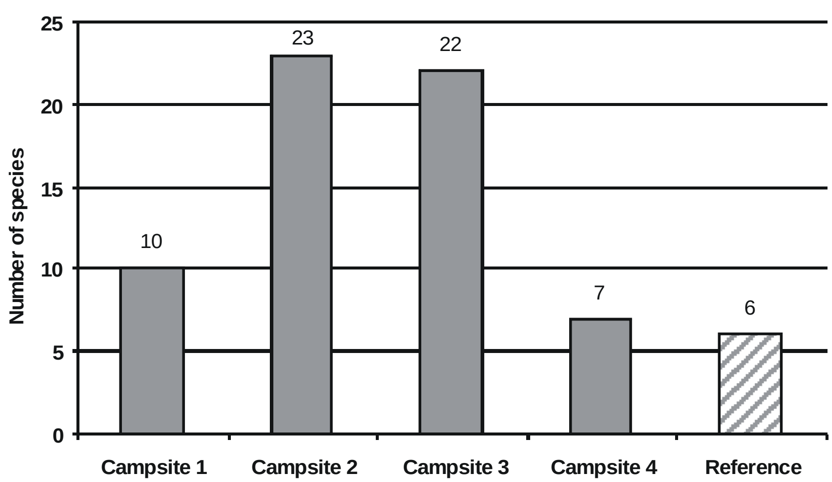

Fig. 7. Number of species in the herb-dwarf shrub layer in the campsites and the reference plot in crowberry-cowberry pine stands

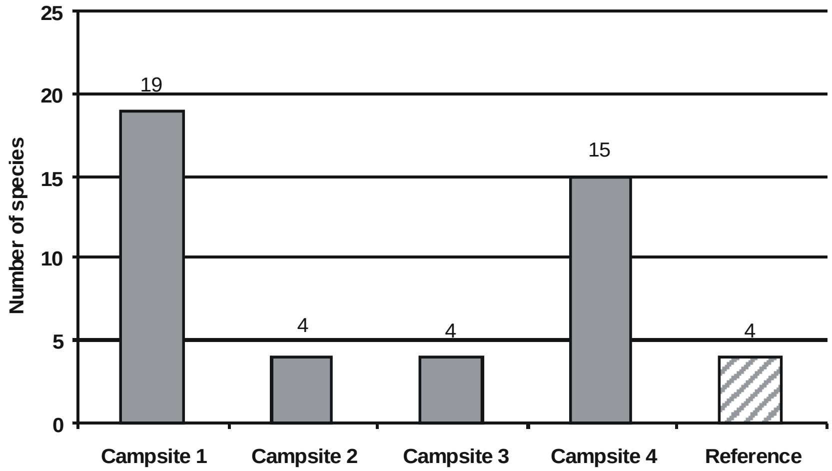

Fig. 8. Number of species in the herb-dwarf shrub layer in the campsites and the reference plot in cowberry-lichen and lichen pine stands

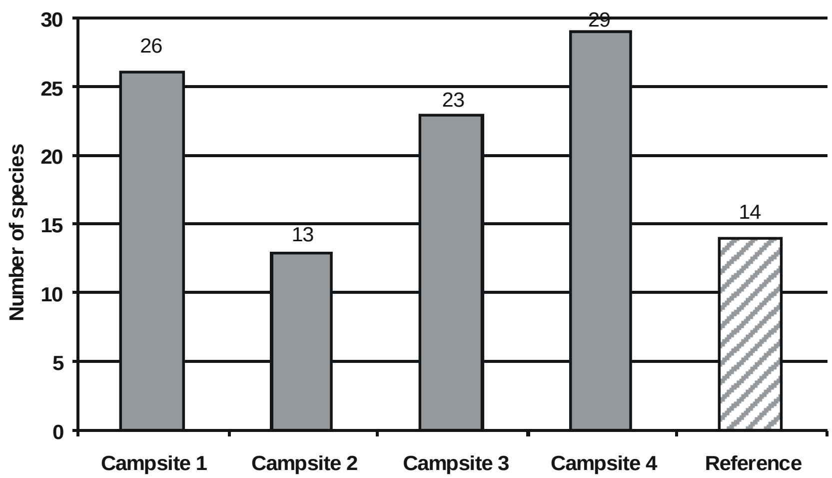

Fig. 9. Number of species in the herb-dwarf shrub layer in the campsites and the reference plot in bilberry-cowberry pine stands

Thus, the species diversity in different stand layers within campsites depends on the forest type and degree of disturbance. The greatest number of species, both in the reference plot and in campsites, was found on Lake Paanajärvi shore, near a bedrock outcrop, in a bilberry-cowberry pine forest over stony soil. Species diversity in campsites in the crowberry-cowberry lichen-true moss pine forest was somewhat lower, with a clear upward tendency (owing to arrival of human-tolerant species) as trampling damage increased. The number of species was the lowest in the campsites and the reference plot in the cowberry-lichen pine forest, but the species richness there, too, was higher in trampled areas than in reference plots, both on average and in total.

When recreational impact intensifies, the percent cover of the field layer decreases and the species richness, vice versa, grows, decreasing only in the total wear-out zone, as confirmed by quite a number of other authors (Liddle 1997). The living ground cover would be heavily degraded only within campsite outlines. Hardly any disturbances can be found in the ground cover just several metres away from the campsite boundary. This is achieved through availability in each campsite and wise siting of all the facilities visitors need (fire rings, cabins, garbage containers, etc.). Irrespective of the duration of exploitation, all campsites surveyed have similar characteristics of the ground cover disturbance. Nearly all of them have heavy, moderate and slight wear-out zones. The area affected depends on the location of access motor roads and siting of facilities (fire ring, garbage containers, etc.) within the campsites. If current regulations and loading are maintained in the future, there will be no significant increase in the proportion of affected areas within the campsites. Further potential changes in the species composition of the campsites' plant cover are likely to be due to introduction of meadow and weed species.

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Assesment of recreational degression of woody vegetation in Paanajärvi National Park

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Abstract

Results of assessment of human-induced disturbances in woody vegetation in Paanajärvi NP ecosystems are reported. Recommendations on conservation of the ecosystems are given.

Introduction

The world now observes an upward tendency in recreational nature use, i.e. utilization of natural resources and settings for rest, restoration of physical, spiritual and mental powers, health and working capacity people have spent at work.

Among the main aims behind designation of national parks are preservation of the integrity of natural landscapes, establishment of conditions for controlled tourism and recreation, development and introduction of scientifically grounded methods for conservation of natural complexes exposed to recreational impact.

Recreational use of forests cannot but disturb the ecosystems. Reaching a balance between recreational forest use on the one hand and minimization of ecosystem disturbance on the other is a crucial task, which cannot be achieved unless a set of well-reasoned measures for organization of orderly recreational activities is introduced. The first step in working out such measures is assessment of the condition of natural complexes, which we consider in the present paper.

Material and methods

The aim of the study was to assess the state of components of forest communities (tree stand, understorey, undergrowth), and to determine the degree of recreational digression of forest ecosystems with regard to the condition of the ground cover and forest floor.

The study objects were sites with greatest visitor concentrations – relatively small tourist stopover sites bearing the highest human load in the context of the nearly "reference" values of human impact in the rest of the park.

Since the sites ranged widely on the parameters assessed, they we divided into zones depending on intactness of the living field layer and forest floor. The following zones were singled out:

- total trampling damage: total absence of living ground cover, heavy compaction and wear of the forest floor (thickness reduced to 3 cm);
- low recreational impact zone, where no trampled areas are present;
- intermediate damage zone.

Zoning was carried out through expert review of the above parameters, and only where the zones appeared to be sufficiently big for human impact parameters to be determined.

After than, woody vegetation was described for each zone using conventional techniques (Anuchin 1960, Natural Complexes of Valaam… 1983). Inventory (forest type, composition, tree stand age, understorey composition and density) and morphological parameters describing the degree of recreational digression (tree stand, undergrowth, understorey damage, tree health categories) were determined.

The degree of recreational digression was determined on a five-point scale depending on the above-listed parameters and with regard to the condition of the field layer and forest floor (Tab. 1).

Table 1 Indicators of recreational digression stages

Digression stage	Condition	
	field layer and forest floor	tree stand, understorey, undergrowth
I	Field layer intact and corresponds to the forest type. Forest floor intact.	Understorey and undergrowth correspond to the site conditions, and remain intact.
II	Field layer slightly disturbed. The cover is distinctly layered.	Understorey and undergrowth satisfactory or good. Trees of good and satisfactory health status prevail in the tree stand (75-90%)
III	Field layer is disturbed; the proportion of forest and forest-meadow herbs is reduced. Weeds or meadow herbs atypical of the habitat are present. The cover is still somewhat layered.	Surviving understorey little differentiated. Hardly any saplings of primary stand-forming species.
IV	Field layer growing degraded. Biomass and abundance of weeds and meadow plants sharply increasing. Forest floor degradation underway.	Peculiar coenosis structure: alternation of clumps of undergrowth and poorly viable understorey bound to gaps and paths.
V	Field layer typical of the habitat conditions has degraded. Weeds and meadow plants have much higher cover and biomass than forest plants, which survive at tree bases only. Forest floor totally degraded.	Hardly any undergrowth or understorey. Illumination beneath the canopy is very high. Trees show mechanical damage and are declining. Roots of many trees are exposed.

When assessing recreational impact, the resistance threshold of various forest communities should be determined. This threshold depends on the capacity for self-regeneration under recreational pressure. Permissible recreational load corresponds to changes in forest ecosystems ranging from barely noticeable signs of degradation to the upper limit of the second degree of digression. In this case, the natural complex can tolerate a rise in recreational load without losing the self-regeneration capacity. The load corresponding to the upper limit of the second degree of digression is considered to be optimal. Maximum permissible recreational load corresponds to the upper limit of the third degree of digression, when forest ecosystems still retain the self-regeneration capacity, but lose some minor components or links (sparser upper canopy and understorey; poorer typical species composition in the field layer) (Gensiruk, Nizhnik and Voznyak 1987).

Proceeding from the results of the assessment, measures for conservation of the communities are suggested.

Results

Table 2 shows various parameters reflecting the degree of anthropogenic change in woody vegetation in each site.

Tree canopy. The fact that trampling down of the ground cover, soil compaction and heavy desiccation of the forest floor deteriorate the conditions for tree growth is well known. In sites used for recreation in all forest types, the proportion of trees with good and satisfactory growth notably decreases and, vice versa, the proportion of suppressed, declining and dead standing trees increases. Core samples taken for age determination show a clear downward tendency in annual increment. Recreational use of tree stands results in growing number of trees with mechanical damage. The damage is mostly torn bark. The proportion of trees damaged by people is rather high, but the scope and type of damage would only weaken some specimens. In general, the tree canopy copes quite well with recreational pressure.

Understorey and undergrowth. Recreational pressure significantly affects understorey and undergrowth. A clear tendency for a reduction in the amount of coniferous understorey under the impact of recreation is observed in all forest types. Understorey occurrence may differ 3-fold or more between the moderate impact and slight impact zones. The brightest example is site 2 – understorey abundance in its zone 2 is 2000 plants/ha, and in zone 3 – 6200 plants/ha. Furthermore, recreational load changes the ratio of pine and spruce in the understorey in favour of the latter. This happens because pine in the understorey is more vulnerable. In intensive recreation zones, the proportion of larger plants in the understorey increases, and the plants become suppressed. Damage has also been found in the understorey (broken trunks). Understorey is the component where anthropogenic impact elicits most vivid consequences. It is virtually missing from zones with intensive recreational impact, and much reduced in amount in zones with moderate impact. Hence, forest cannot regenerate naturally. In the foreseeable future, as recreational pressure grows, these manifestations will become even more pronounced and dynamic.

Recreation notably reduces the amount of undergrowth and its species diversity. Its abundance in recreation sites is usually lower than in the control, or it may sometimes be totally absent. In a heavily broken terrain however, undergrowth remains nearly undisturbed, since tourist traffic is well organized by specific natural conditions. The main kind of undergrowth damage is breakage, either for some utilitarian purposes or as tourists move across the area.

Discussion

Thus, the sites surveyed are at various stages of recreational digression. Most heavily affected by human impact (stage IV) are small-sized (30-50 m2) tourist stopover sites, where tourists spend most of the time (facilities around campfires, lunch tables, etc.). Most of the coenoses investigated are at stage III of recreational digression, i.e. the optimal recreational load at which forest ecosystems are still capable of self-regeneration is somewhat exceeded.

According to national park regulations, tourists can only stay in specially appointed sites. Owing to that, the rest of the park territory has hardly any human impact, and recreation-induced digression there is at stage I.

Management of the Paanajärvi NP in general has led to optimal fulfillment of conservation, recreation and education functions, secured conservation of unique natural, historical and cultural complexes of northwestern Karelia, which are of high environmental, historical and esthetic value. Recreational impact has no significant effect on the state of natural complexes and biodiversity in general. Some negative effects of recreational impact occur at the local level. They can be amended by changing functional zonation of tourist campgrounds to redistribute recreational load maximums over the area, as well as by closer control of visitors to prevent damage to components of the tree stand.

Acknowledgements

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Table 2. Parameters of human impact on forest vegetation

Site	Forest type	Composition by storeys	Age, yrs.	Understorey	Undergrowth	Note	Degree of recreational digression
Site 1 Zone 1	Crowberry-cowberry pine forest	10P	90 few 160	None	singular coppice birch	no ground cover; buttress flares; several impaired, the rest - satisfactory; 2 stumps, dead standing trees, torn bark.	**IV**
Zone 2	Crowberry-cowberry pine forest	10P	90	S 2-3.5 m, few P 0.5 m, 600 plants/ha, unreliable	singular coppice birch, singular juniper	ground cover around trunks; buttress flares; 1 - dead standing, 2 - declining, the rest - satisfactory	**III**
Zone 3	Crowberry-cowberry pine forest	10P	120 few 190	7P3S 0.3-5 m, uneven, 3000 plants/ha, ca. 50% unreliable	birch, aspen, juniper; few rowan, willow; uneven, medium density	ground cover partially damaged, with gaps; no buttress flares; satisfactory condition 2 dead standing old spruce trees	**II**
Site 2 Zone 1						no woody vegetation	**IV**
Zone 2	Crowberry-cowberry pine forest	1st storey 10P few B 2nd storey 10S	100-160	2S3P 0.7-2.5 m, uneven, 2000 plants/ha, only spruce unreliable	aspen, rowan, birch, uneven, medium density	ground cover around trunks; buttress flares; 3 declining trees, the rest satisfactory; torn bark - 2 plants, 1 broken plant in understorey	**III**

Zone 3	Crowberry-cowberry pine forest	10P few B	120-160, few over 250	6S4P 0.3-4 m, uneven, 6200 plants/ha, unreliable	aspen, rowan, birch, juniper, uneven, medium density	some small gaps in the ground cover; 2 old declining trees, 1 dead standing, the rest satisfactory.	**II**
Site 3 Zone 1						no woody vegetation	**IV**
Zone 2	Crowberry-cowberry pine forest	10P few B	120-200 few over 250	9S8P 1-5 m, in clumps, 6800 plants/ha, only pine unreliable	birch, rowan, few juniper, uneven, medium density	ground cover within tree clumps only; 3 old declining trees, the rest impaired; torn bark and fire scars on most trees.	**III**
Zone 3	Crowberry-cowberry pine forest	10P few B	120 few ca. 300-350	9P1S 0.5-3 m, uneven, 6600 plants/ha, reliable	juniper, birch, rowan, aspen, uneven, medium density	ground cover throughout, trees in satisfactory condition; 3 old dead standing trees, fire scars, littered.	**II**
Site 4	Cowberry pine forest	10P few B, S	120-300	10P few S 0.5-3 m, 2000 plants/ha, unreliable	juniper, birch, uneven, sparse	most trees impaired, old dead standing trees, torn bark, bark damage on birch.	**III**
Site 5	Lichen pine forest	10P few S	120-140	8P2S 0.3-5 m, 1600 plants/ha unreliable, zone 3 - 4100 plants/ha reliable	birch, willow, uneven, sparse	overall stand condition satisfactory; old dead standing trees; torn bark, broken dead standing trees, fire scars.	**III**

Site 6	Lichen pine forest	10P few S	120, 250	10P few S 0.3-5 m, 2000 plants/ha unsatisfactory, zone 3 - 8000 plants/ha reliable	singular	overall stand condition satisfactory; dead standing, old stumps, understorey broken and damaged, torn bark, littered, blazes along roads.	**III**
Site 7	Herbaceous birch forest	7B2As1S	40-110	10S 0.2-0.5 m, reliable, 400 plants/ha	aspen, juniper, speckled alder, willow, rowan, uneven, sparse	ground cover relatively undisturbed; overall stand condition satisfactory, signs of suppression along paths, old dead standing birch, trunk rot on birch; bark damage on birch, some broken understorey.	**III**
Site 8	-	-	15-25	-	rowan, aspen, willow, even, dense	site surrounded by overstocked deciduous and pine-deciduous clumps; no obvious damage found.	**II**
Site 9	Bilberry-cowberry pine forest	1st storey 10P 2nd storey 10B	80-140 20-50	9S1P 0.2-5 m, 800 plants/ha, uneven density, mostly reliable	rowan, aspen, willow, speckled alder, uneven, medium density	stand condition satisfactory, fire scars	**III**
Site 10	Bilberry-cowberry pine forest	1st storey 10P 2nd storey 10B	80-140 20-50	9S1P 0.3-5 m, 800 plants/ha, uneven density, mostly reliable	rowan, aspen, willow, speckled alder, uneven, medium density	stand condition satisfactory, fire scars	**III**
Site 11	Bilberry-cowberry pine forest	10P+B	100-140	9S1P 0.2-1 m, 800 plants/ha, uneven density, mostly reliable	rowan, willow, birch, uneven, sparse	ground cover little disturbed; overall stand condition satisfactory, 1 dead standing, 2 declining	**III**

Control plot	Crowberry-cowberry pine forest	1st storey 10P few S, B 2nd storey 7S3P	110-300	6S4P 0.5-2 m, 4200 plants/ha, reliable	juniper, aspen, birch, willow, even, medium density	uneven-aged, older generation with inhibited growth, the rest satisfactory, old declining trees	**I**

Limits of acceptable change as a tool for protected area management – Oulanka National Park as an example

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Abstract

National parks have become important tourist attractions and tools for regional development which challenges the management of national parks in a new way. To assure a balanced development between nature protection and tourism, several management and planning frameworks have been developed worldwide. This paper reports the results on an assessment of sustainability of nature-oriented tourism and recreation in Oulanka National Park. The goal of assessment is to ascertain sustainability in the future as it is a prerequisite for use of the national parks and for continuity of nature-oriented tourism. In general, the aim of the study is to evaluate the Limits of Acceptable Change (LAC) framework used by Metsähallitus. We give several recommendations for the future park management.

Introduction

Nature-based tourism has become an instrument for regional development in the northern peripheral areas of Finland as the role of primary production has decreased steadily (Saarinen, 2005, 2007). National parks have become more dynamic and innovative; co-ordinating conservation and the utilization of nature are seen as advantageous for both conservation and regional development (Fennell & Weaver, 2005; Hammer *et al*., 2007; Zachrisson *et al*. 2006). The current aim of parks is to integrate socio-economic goals of nature-based tourism with ecological goals of conservation by implementing principles of sustainability (Puhakka, 2008). Thus, national parks increasingly function as intermediaries between local and national or international interests in both nature protection and regional development issues (Saarinen, 2007). Statistics by Metsähallitus, the manager of the state-owned land and water areas in Finland, indicate that the average number of visits to Finnish national parks doubled in the 1990s with continual growth in the 2000s. In 2007, there were 1.7 million visits to 35 national parks in Finland (Metsähallitus, 2008).

Nature protection is, however, the most important goal of Finnish protected areas (Heinonen, 2007) which have been internationally rated as well managed and with some exceptions, to achieve their aims of conserving biodiversity (Gilligan *et al*., 2005; Hockings *et al*., 2006). To assure a balanced development between nature protection and tourism, several management and planning frameworks have been developed worldwide. The development of management frameworks for protected areas initiated with a search of certain carrying capacities. However, as the limitations of the concept of carrying capacity were becoming increasingly apparent, the question was directed from the use numbers to appropriate or acceptable conditions of tourism destinations (e.g. McCool & Lime 2001). Because of the failures to find carrying capacities, a variety of new planning frameworks have been developed to address the issues of visitor impacts. These new planning frameworks include Recreation Opportunity Spectrum (ROS; Clark & Stankey 1979, Brown et al. 1978)), a Process for Visitor Impact Management (VIM, Graefe et al 1990), Visitor Experience and Resource Protection (VERP, National Park Service 1997, Manning 2001) and Limits of Acceptable Change (LAC, Stankey et al. 1985). These all are based on protecting certain conditions rather than finding numerical carrying capacities. These frameworks share several common themes and issues, and indeed the basic steps of the management and planning process are quite similar in each of the frameworks (Fig. 1) even though the terminologies they use vary considerably. Basically, the wilderness mandates are transformed into objectives that can be implemented and evaluated with standards. Limits of acceptable conditions are defined by the standards that are monitored with the selected social and environmental indicators. If standards are exceeded, appropriate and effective management interventions are evaluated by a problem analysis.

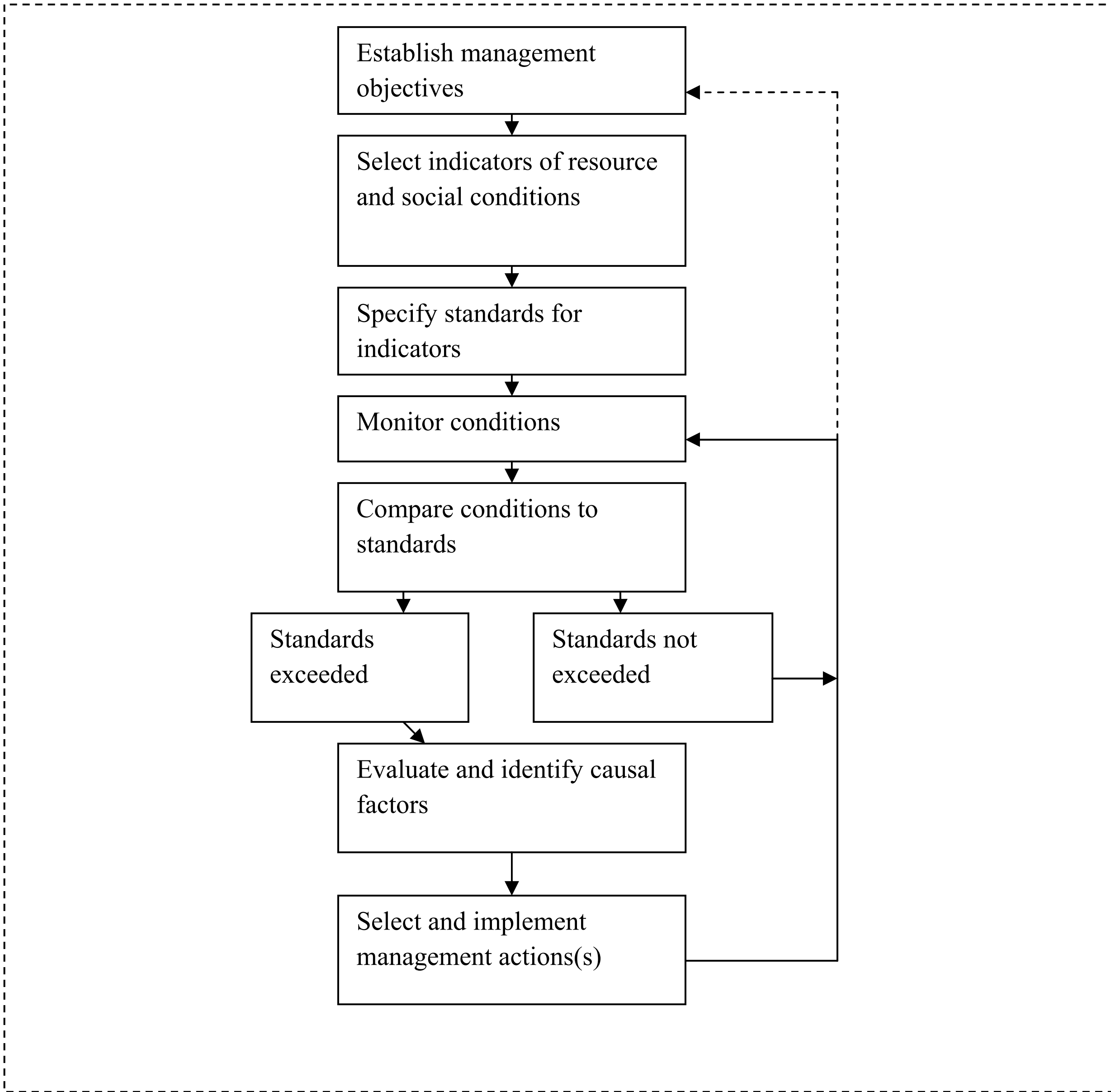

Figure 1. A diagram illustrating the basic stages of management planning frameworks (modified from Leung and Marion 2000)

Here we report the results on an assessment of sustainability of nature-oriented tourism and recreation in Oulanka National Park (hereafter Oulanka NP). The goal of assessment is to ascertain sustainability in the future as it is a prerequisite for use of the national parks and for continuity of nature-oriented tourism. In general, the aim of the study is to evaluate the Limits of Acceptable Change (LAC) framework used by Metsähallitus. More specifically we focused on the developed indicators, standards and actions of the modified LAC framework.

This report comprises a summary on the results from the assessment of socio-economic and ecological sustainability of nature-oriented tourism and recreation in Oulanka National Park. The assessment was made as a part of the Interrreg-project "Oulanka-Paanajärvi – wilderness, experiences and well-being". Oulanka Research Station / "Sustainable nature-based tourism" - research group led by Dr. Pirkko Siikamäki has been responsible for the implementation of this activity. The overall objective of the project is to secure and strengthen the status of Oulanka-Paanajärvi twinpark as the most important national and international attraction and resource for nature-oriented tourism in the region. In relation to the objectives of the present subproject it is expected that the project contributes towards the following long-term impacts:

- Nature-oriented tourism and recreation in Oulanka and Paanajärvi National Parks is sustainable in ecological and socio-economic sense and executed in an environmentally responsible manner.
- Visitor use of National Parks and nature sites in the surrounding region is not deteriorating biological diversity, as visitor use is oriented in such a manner that it does not lead to overcrowding of individual sites and that the visitor expectations are met. This ensures the continuous appeal of the area for visitors thus safeguarding existing employment in nature-oriented tourism and recreation.

The aim of this activity has been an assessment of sustainability of nature-oriented tourism and recreation in Oulanka National Park in order to ascertain sustainability in the future as it is a prerequisite for use of the national parks and for continuity of nature-oriented tourism.

Tools for management

Limits of Acceptable Change (LAC)

"The Limits of Acceptable Change (LAC) System for Wilderness Planning" was initially developed to deal with recreational carrying capacity in wilderness Stankey et al. (1985). LAC is a process where the managers of the protected area have to decide what kind of wilderness conditions are acceptable and then determine what actions need to be implemented in order to protect or achieve these conditions. Indicators are specific variables that are used as indicatives of the condition of the desired future condition (Stankey et al., 1985). Standards state the minimum acceptable conditions and the values stand for absolute limits (Cole & Stankey, 1998). The limit values may be based on present values. Target values represent future goals.

LAC by Metsähallitus

Metsähallitus is using a modified version of LAC framework for the management of sustainable nature tourism in protected area in Finland. The LAC process that Metsähallitus uses includes general principles with all themes of sustainable tourism. The principles are divided into different desired future conditions that specify the problems that are dealt with (Box 1.). The principles are intended to guide the operations of Metsähallitus in protected areas. LAC process serves a tool for the evaluation of the environmental and socio-economical effects and sustainability of nature-oriented tourism. The approach has been used when defining the principles, desired conditions and indicators for sustainable nature tourism as well as for use and management plans. When planning and developing a management tool for Metsähallitus, the LAC-method was find to be especially useful approach as it uses limit values based on decisions – not on some certain exact numbers. Therefore, the LAC-method can be developed further on the basis of changed situations and circumstances.

When developing the LAC-method, the following steps were executed at a general level in pilot areas:

- The essential questions concerning the environmental and socio-economic effects of nature tourism were specified generally for all protected areas of Metsähallitus
- The desired future conditions regarding nature tourism and its effects were specified for each general principle
- A list as extensive as possible of useful indicators and measuring modes was made

The following steps were executed in pilot areas in order to evaluate the sustainability at local scale.

- The previous values of the indicators as well as the present situation were established
- Target values and limit values were determined
- Contemplating by what actions the desired future conditions of sustainable nature tourism is achieved and maintained

Metsähallitus selected the indicators to be used in protected areas based on experience, literature and results from field testing. A variety of indicators was tested in six pilot areas, mainly national parks. The pilot areas had the choice of testing the indicators that were significant and promising in their specific area. They also had the opportunity to develop existing indicators or create new ones. Metsähallitus had previously collected data from the national parks in the form of standardised visitor surveys and the quantification of waste left in the area due to nature tourism. These, among other information regularly collected from the areas, were modified into indicators (Kajala, et al., 2004).

Box 1. Principles for Sustainable Nature Tourism by Metsähallitus

1. Natural values are preserved and all activities promote nature conservation.

- Nature is an important reason for visits.
- Visitors can learn about nature and conservation.
- Tourism does not disturb nature; not all areas are suited to tourism.
- Groups are small, and use marked trails wherever possible.
- Tourism is channelled into areas with suitable facilities.
- Facilities are designed to fit in with the surroundings; the most beautiful natural areas are left undeveloped.
- Erosion and other impacts are monitored, with corrective measures taken as needed.

2. The environment is subjected to as little pressure as possible.

- Nature comes first; every effort is taken to avoid damage or disturbance.
- Visitors leave no trace behind them.
- Firewood is used sparingly.
- Emissions of all kinds are minimised, and renewable energy sources preferred.
- Metsähallitus and other organisations set good examples on environmental protection.

3. Local traditions and cultures are respected.

- Visitors are encouraged to learn about local cultures.
- Local cultures are suitably considered in the provision of information and activities.
- Guides are familiar with local conditions.

4. Visitors increase their understanding and appreciation of nature and cultures.

- Information is available for visitors before they come.
- Information is easily available and attractively presented.
- Visitors can contribute to the management of the area.
- Guides are well trained.

5. Improved recreational facilities are provided for visitors.

- The needs of all visitors are considered.
- Facilities suit local demand and conditions.
- Visitors can enjoy peace and quiet, as well as guided activities.
- Facilities and services are developed in co-operation with local firms.

6. Visitors are encouraged to enjoy both mental and physical recreation.

- Visitors are encouraged to move under their own steam.
- Facilities are provided for hikers and other visitors.
- Easy and demanding routes are available.
- Opportunities exist for a variety of activities in natural surroundings.
- All trails and other facilities are safe.

7. Local economies and employment are promoted.

- Local firms' products and services are used where possible.
- Employment is given to local people where possible, although outsiders may also contribute valuable ideas to help promote local development.

8. Publicity materials are produced responsibly and carefully.

- Information is reliable and up-to-date.
- Publicity work is conducted openly and interactively.
- Publicity does not work against nature conservation.

9. Activities are planned and organised co-operatively.

- Visitors' opinions are very important.
- Training is organised together with local firms.
- All interested parties may participate in planning.

Defining the ideal indicators for sustainable tourism in protected areas

Because the LAC-method modified by Metsähallitus seems to serve a proper framework for the sustainability analysis, we will not evaluate generally the rationale of the used framework. Yet, in some cases we discuss the relationships between the principles and desired conditions. Instead, in this report we put the emphasis on the analysis of indicators because the effectiveness of LAC method in measuring the sustainability of nature-based tourism and recreation is largely based on the use of indicator system. In general, indicators are meant to quantify and communicate complex phenomena in a simple manner (Bibby 1999). For indicators to be effective at a general level they must meet a number of scientific and practical criteria (Table 1). They should be scientifically credible, sensitive to change, linked to drivers, clarity of message, affordability and easy to update. Indicators are, however, always compromises. The purpose of indicators is to help decision-makers formulate policy and then to continue to review it in response to changes in the indicator.

From the general attributes of effective indicators we suggest that for purposes of LAC process the most important qualities are:

1) relevancy,

2) easiness to understand,

3) sensitivity,

4) availability of data and cost-efficiency of data collection, and

5) amenable to management.

In an indicator system, complementary indicators should be also taken into account in the planning process. We suggest that complementary of indicator should be used as one criterion for the addition of new indicators to the indicator system. Traditionally this has not been mentioned as key attribute of an indicator but we will use it as one criterion in our analysis to focus also to the whole indicator system, not only to single components of system. The easiness of data collection might lead to situation where new indicators are added to system without assessment their complementary and added value for the whole indicator system. This could lead to collection of redundant data and further to inefficient use of limited resources for monitoring.

Table 1. Key attributes of effective indicators (collected and modified from Cole & McCool, 1998, Gregory et al. 2005, Siikamäki 2008).

Attribute	Details	Importance for sustainability analysis[1]
Relevant	Measures and indicates the desired issues	++
Easily understood	Non-experts from policy—makers to members of the public (NGOs) must be able to understand the issues to have an ownership	+
Simplifying information	Transparent, easy to interpret and visually attractive	+
Immediate	Capable of regular update	+
Quantitative and statistically representative	Accurate measurement with assessment of error. Shows trends over time, measures a rate of change and changes in the rate	++
Sensitive	Allows rapid identification of trends – an early warning of issues	++
Realistic to collect	Quantitative data are available or can be collected readily. Does not require excessive or unrealistic financial resources.	++
Reflect appropriate scales	The appropriate scale are taken into account -	+
User driven	Developed in response to the need of stakeholders	
Policy relevant	Indicators aim to provide signals to policy	+
Comparability	Allows comparisons e.g. between regions or countries	+
Amenable to management	Responsive to management	++

Methods and results

Study area

Oulanka NP is located in north-eastern Finland in Municipalities of Kuusamo and Salla adjacent to the Russian border and close by the Arctic Circle (Fig. 2). Oulanka NP has been founded 1956 and expanded twice in 1986 and 1989. Eastern part of the park ends to Russian border, where it joins to Paanajärvi National Park in Russia established in 1992. Oulanka NP was established to protect the nationally unique river habitats, and rare and endangered species and habitat types. Other main functions of the park are to offer versatile nature and recreation experiences for visitors, and possibilities for education and research (Metsähallitus 2003). The total area of national park is approximately 28 000 hectares. Park is divided into zones; core zone 16 900 ha (approximately 61% of the total park area), wilderness zone 7 800 ha (28%), three restricted areas 800 ha (3 %), border

[1] ++ = very important, + = important

zones 2 200 ha. The zoning is based on goals of ensuring the nature protection and research, distribution of visitor use, and attainability and features of the nature in the area (Metsähallitus 2003). Oulanka NP is managed by Metsähallitus. It is one of the most popular national parks in Finland, with over 180 000 visitors per year (Metsähallitus 2007). Park area provides possibilities for variety of recreation activities, which include e.g.; hiking, commercial horse riding, canoeing, skiing, snowshoeing, hunting and fishing. In 2003 Metsähallitus established a management plan for the park area, in which one of the main objectives is to balance the nature conservation and the increasing pressure of nature tourism within national park.

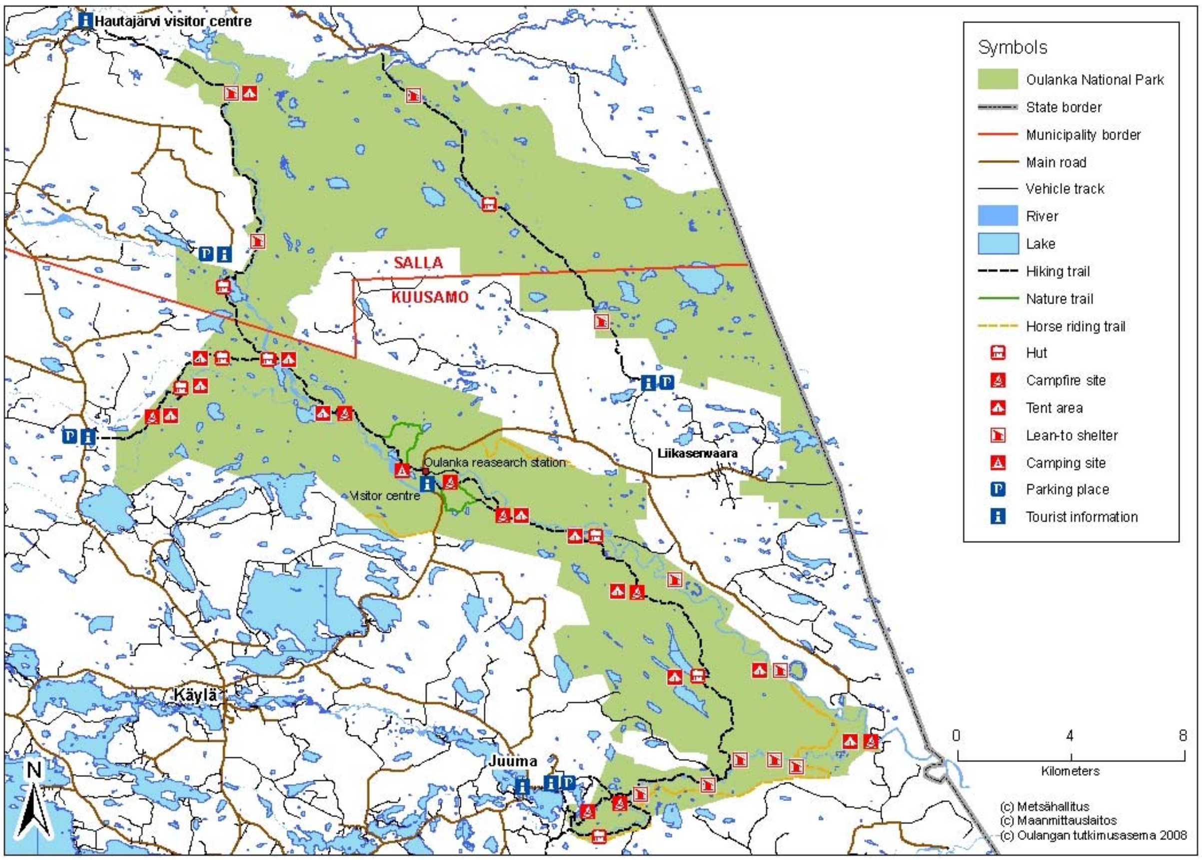

Figure 2. A map on Oulanka National Park in Kuusamo and Salla municipalities with main park facilitites.

Our main goal of this study was to examine the ecological sustainability of the nature tourism in the whole park area. For this landscape level of approach we used ArcGIS (version 9.2) –program (Ormsby et al 2004). The aim was to examine how the recreation areas are distributed in relation to occurrences of endangered plant, moss and lichen species, sensitive habitat types and nest of certain birds of prey. Further goals were to provide information for evaluation of current indicators of ecological sustainability of the national park as well as for constructing new indicators.

Endangered plant, moss and lichen species

In this part we first used known occurrences of endangered plant, moss and lichen species to survey how big proportion of each endangered species is located in proximity of recreational routes compared to whole park area. Secondly, we used species occurrences to examine how are the important habitats for endangered species (areas with high number of endangered species) situated in relation to recreational areas. The coordinates for the species occurrences observed in different parts of the national park, were obtained from the Environmental Information System (HERTTA) of The Finnish environmental administration. Only the species that were endangered according to the Finnish Red List (Rassi et al. 2001) were chosen for the study. Six different categories of threatened species were defined according to the classification by the Finnish Environmental Centre. The states were "critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), locally endangered or the species with monitoring responsibility given to Metsähallitus. The most accurate coordinates consisted of seven digit numbers. Only coordinates with a precision of at least five digits (i.e. accuracy of 1 ha) were included in the analyses. Some of the species had only a few observations and an accuracy of 1 km2, which means that these species were excluded from the analyses. In addition the species occurrences that had been observed in the area a long time ago but not in recent surveys were not included. The analyses were made with ArcGIS –programme.

To study the proportion of each endangered species situated in proximity of recreational routes the coordinates of the species were layered onto the base map of the national park using the ArcMap-programme. The hiking routes Karhunkierros and Keroharju, two horse trails and few additional trail managed by Metsähallitus were digitized by hand onto the base map. Hiidenlampi and Rytilampi nature trails and the trails to the beauty spots of Oulangan kanjoni were not included in the analysis. We created 100 m wide buffers for both sides of each route, from which all the species observations situated within the buffers were counted separately for each species as well as for all the species added together. We further calculated the percentage of the observations of each species situated within 100 m of the trails in relation to the total park area. As the location data of threatened species is not public information the results on map are not shown here. Thus, to summarise the main results, in total the proportions of all occurrences of threatened species located within 100 m buffer were 13 %, 22 % and 31 % for vascular plants, mosses and lichens, respectively.

To survey how the recreational routes are situated in relation to areas with high density of occurrences of endangered plant, moss and lichen species we used kernel density analysis, with 1007 meter search radius (ArcGIS). Results of the density analysis show that many of the high-use recreational areas like Kiutaköngäs, Oulangan kanjoni and Taivalköngäs are located in important habitats for endangered plants i.e. hotspots.

Birds of prey

In this part we examined the location of recreational routes in relation to nesting of certain birds of prey. We used known nesting sites of osprey (Pandion haliaetus), golden eagle (Aquila chrysaetos), goshawk (Accipiter gentilis) and honey buzzard (Pernis apivorus) inside the Oulanka NP. Nest site data were provided by Metsähallitus. Similar 100 meter buffers were created in both sides of hiking routes as presented above and number of nests inside the buffers were calculated. As the disturbance caused by recreation can have negative impacts of bird of prey even from longer distances, we also used 1000 m wide buffers for each side of the hiking trails. Inside the 100 meter buffers there is located one nest of Osprey. Indeed, the southern horse trail passes nest of osprey approximately less than 50 meters distance. Inside the 1000 m buffers there are one nest of golden eagle, two nests of honey buzzard and two nests of osprey.

Total length of recreation routes and total area under disturbance

The total lengths of maintained official hiking trails and horse riding trails were measured with the ArcGIS –program. The lengths of the different routes are presented in table 2. "Other trails" include here trails that are not "official" trails but are maintained by Metsähallitus (personal communication R. Koramo, Metsähallitus 12.11.2006). However, here are not considered the numerous unofficial trails, which represent the offsite use in the park area. This is probably biggest problem at Kitkajoki area were fishers make and use new unofficial trails, which are not under any monitoring or management. All these offsite use also increase the total area under wear and disturbance. Other "critical" places of offsite use are the important beauty spots in the park, like Kiutaköngäs, Oulangan kanjoni and Ristikallio, with high use pressure.

Table 2. The lengths of hiking trails and horse trails in Oulanka NP.

Route	Km
Karhunkierros	62,8
Nature trails	7,9
Keroharju trail	14,4
Horse trails	30,1
Other trails	4,2
Total	119,4

In order to calculate the percentage of terrain that is under the influence of visitors, buffers zones of 1 m and 100 m were set on both sides of the trails using ArcMap. The 1 m buffer for studying the area under most intensive disturbance is probably relevant scale for the vascular plants, mosses and lichens as they are mostly affected by direct trampling. The area of the buffer zones was calculated and compared to the total area of the national park. With one meter buffer 0.09% of the total national park area is under disturbance, and with 100 meters 8,6%. However, here we have only used the recreational trails as a source of disturbance and the camping sites, roads and the numerous unofficial trails e.g. used by fishers are not considered here. Thus, the total area under disturbance is in reality more extensive in all the studied scales. Furthermore, also the consideration of using 1000 m buffer might be reasonable for example for the birds of prey or for large carnivores as they have large home ranges. Indeed, the disturbance caused by recreation is known to affect e.g. nesting success even from the 1000 meters distance (Swenson 1979, 1991).

Tolerance of vegetation types to disturbance

The degree of sensitivity of different vegetation types towards trampling was estimated based on the literature. The vegetation types were ranked from more tolerant types to sensitive types. The ranking is based mainly on the classification made by Kaakinen and Ryynänen (1982), but also on other studies concerning the trampling tolerance of vegetation types in Finland (Aho 2005, Emanuelson 1984, Hoogester 1976, Kellomäki and Saastamoinen 1975, Pesonen 2003 and Tervo 2003). Results of the review are presented in table 3.

Based on the review the most suitable vegetation types in Oulanka area for recreational activities, e.g. for camping are the meadows and flooded meadows and the least suitable types are the stands on rocky terrain. However, many of the "high-use" recreational areas in Oulanka NP are located in areas with rocky terrain, e.g. Ristikallio, Taivalköngäs, Oulangan kanjoni and Kiutaköngäs. In addition to being very sensitive to trampling calcareous rocky terrains are one of the most important habitat types for endangered plant, moss and lichen species, which should be considered in managing and channelling the recreational use of these areas. The table of trampling tolerance can be used also in planning the recreational use in the whole park area.

Table 3. Trampling tolerance of different vegetation types.

Tolerance	Vegetation type	Kasvillisuustyyppi
good	meadow, grounds	niitty, pihamaa
rather good	flooded meadow	tulvaniitty
moderate	mesic forest	tuore kangas
	semi-dry forest	kuivahko kangas
	dry forest	kuiva kangas
rather poor	pine mire, spruce mire	räme, korpi
poor	fen	letto
very poor	flark fen	rimpineva
highly poor	spring (fen), barren forest, stands on rocky terrain	lähteet, lähdesuot, karukkokangas, kalliokasvillisuus

Conclusions and recommendations

To conclude, the current LAC modification by Metsähallitus seems to form a sound basis for the management of sustainable nature tourism in protected area in Finland. One major challenge of the LAC method is the incorporation of different dimensions and elements of LAC to form an integrated analysis. Additionally, due to uncertainties both in the development of recreation and nature-based tourism and in our knowledge of ecosystems and ecological processes, adaptability and ability to react according to feedback and enhanced knowledge are crucial characters for a sound management framework. However, as the used LAC-method is outside of the main scope of this assessment, in the following we give our recommendations that are mainly related to the used indicator system.

General recommendations

We recommend that the following factors and issues should be taken into account in the development of further LAC framework:

- Scale mismatch: The scale of currently used indicators measuring nature values is mainly local and spatially restricted and impacts of tourism to ecological processes acting at the ecosystem and landscape levels are not included to analysis. When a hierarchical and resource-based approach is used and single indicators are focused one by one temporal, spatial and functional scales of ecological entities (i.e., ecosystems, habitats, landscapes) are quite easily neglected, and ecological entities are often seen only as resources for recreation. This viewpoint has lead to situation where management and monitoring are emphasized on the direct impacts of recreation and nature-based tourism on resources, and the monitoring and indicators are stressed on visible impacts on soils, vegetation, trails and campsites which all are relatively easy to measure. When the complexity, interconnectedness and dynamic characteristics of ecological systems are neglected in the monitoring, the worst scenario will be that gradually the capacity of the ecosystems to provide ecosystem services is diminished and ecological processes are changed without any alarming signals delivered by the LAC. To cope with this problem of scale mismatch we suggest at least the following complementary indicators to be included to in the further LAC process:

- o The total length of trails and the total area / proportion of protected area under recreational use with direct and indirect impacts could serve as new indicators, which give new information concerning the landscape level disturbance, connectivity and the distribution of use within the park. Current values for the trails in Oulanka NP are presented in the table 2. The total impacted area of Oulanka NP is **0.09%** and **8,6%** when calculated with one meter and with 100 meters buffers, respectively**.**
- o Birds of prey and large carnivores do not only have large home ranges but also they have key roles in the ecosystems which make them suitable indicator organisms. In the current LAC method the Golden Eagle is already included, but as it is very rare with only few breeding pairs in the park, we recommend also the osprey to serve as an additional indicator species.

- Overlapping indicators: In the current LAC method there are several overlapping indicators measuring almost the same issue (erosion and trampling impacts of visitors; trash). When having those multiple indicators, measuring effort is not optimally allocated. Instead of having several indicators measured a relatively low sample size, it would be better to have few indicators with adequate sample size.
- Biodiversity hotspot areas: should be taken into account in the large-scale planning. If new trails or other service infrastructure is planned, areas with simultaneously high species richness and vulnerable habitats should be avoided.
- Visitor flow: The data on the spatial distribution and the amount of visitors and their activities within the national park are lacking. These data are needed for several management purposes because the total number of visits do not alone help in the planning and channelling of the future use within the parks. We recommend a more precise survey for determining the distribution and intensity of recreational use in the whole national park area. More exact knowledge about the number of visits in different parts of the park enables a reliable examination of many measures and indicators of sustainability as they can be related to recreational pressure of in a given area. Survey of the spatial distribution of visitation pressure also provides information for management and planning the future recreational use in the park. The survey could be done at five-year intervals, possibly in the same year as trail monitoring.
- Off-site use: The amount and spatial distribution of use and user groups outside the managed trails and campsites are currently unknown, and thus not under the control of manager.
  - o Analysis of user groups and the potential problematic areas / places where this off-site use overlaps with nature values would give valuable information and further promote conservation of nature values over the whole park.
- Setting the limits of acceptable change: When setting the limits of acceptable change and desired condition the evaluation should not be based too much on the current value of a given indicator. Thus, the current situation should not affect and direct the selection of standards but the selection should be based on as objective evaluation as possible.

Additional recommendations to Oulanka NP

A special biological value of the Oulanka NP is the very rich flora with tens of endangered and rare vascular plant, moss and lichen species. The protection of these species and their habitats can thus be seen as a major objective of the Oulanka NP. However, within the Oulanka NP there are several areas where high biodiversity, vulnerable habitat types (rocks, cliffs) and high pressure of tourist and recreation use overlaps. These beauty spots are attractive to tourists mainly due to beautiful sceneries at deep cliffs close to the Oulankajoki river but there are also some charismatic and interesting bird and plant species occurring at these highly visited sites. Due to high visitor pressure severe visible erosion and trampling impacts have already occurred. We recommend that the erosion and deterioration process within these high-use sites should be restricted/prevented by constructing new, protective structures and by channelling the use more carefully. The priority list with a need of management and restoration actions is as following: Kiutaköngäs falls, Oulangan kanjoni, Taivalköngäs, Ristikallio and Juuma. Also some restoration actions should be planned to restore already deteriorated occurrences of rare and endangered plant, lichen and moss species inhabiting calcareous rocky cliffs.

In addition to above mentioned general recommendations, we suggest the following indicators as complementary or alternative ones for LAC process in Oulanka NP:

- Use of rare and threatened plant species as indicators (principle 1)
- Breeding success of Golden Eagle as indicator (principle 1)
- The state of the cultural environments and traditional rural biotopes (principle 1 and/or 3)
- Water quality in high use area (principle 2)
- Number of offences by visitors (principle 8)

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