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DETERIORATION OF FOREST GROUND COVER DURING TRAMPLING

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SELOSTE:

TALLAAMISEN VAIKUTUS METSIKÖN PINTAKASVILLISUUTEEN

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The aim of the study is to investigate the trampling tolerance of forest ground cover of the *Calluna, Vaccinium* and *Myrtillus* site types. Positive correlation was found between the site fertility and trampling tolerance of plant communities. Annual trampling at a level of about 16 000 visits per hectare decreased the biomass of the ground cover to almost half the original amount, and annual trampling of about 160 000 visits per hectare completely destroyed the forest ground cover irrespective of site fertility. Comparisons made between herb and grass dominated and forest ground cover showed that herb and grass cover is in the long run the best alternative for the management of ground cover in intensively used recreation areas.

INTRODUCTION

Deterioration of ground cover resulting from human trampling in recreation areas has been frequently reported in the ecological literature (cf. for example Bates 1935, Düggeli 1937, Burger 1940, Lutz 1945, Magill 1963, Wagar 1964, Frissel and Dungan 1965, Brooks 1966, Talhelm 1969, Goldsmith *et al.* 1970, Willard and Marr 1970, Settergren and Cole 1970, Cordell and James 1971, Burden and Randersson 1972). The phenomenon is associated with changes in the soil properties. According to LaPage (1962) soil compaction reduces the radial growth of trees and indicates damage to the root system. Thus deterioration of the ground vegetation is only one part of the total effect of recreation to which the ecological systems in recreational areas are subjected. Destruction of the ground vegetation is the first indication of the overuse of a recreation area.

The aim of the present study is to investigate the effects of short term trampling on forest ground cover communities. Special attention is paid to the changes in biomass and to the differences in trampling tolerance between different forest site types.

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MATERIAL AND METHODS

The study was carried out at the Forest Field Station of the University of Helsinki (60° 47″ N, 24° 28″ E, 150 m a.s.l.) in the years 1972 and 1973. The general climitic conditions of the study areas are as follows

- annual mean temperature −3.0 − +3.5°C,
- annual mean rainfall 550−600 mm/year and
- effective temperature sum 1100−1200 dd/year.

The field experiments were carried out in three stands representing *Myrtillus*, *Vaccinium* and *Calluna* site types (cf. CAJANDER

Table 1. Description of the study areas

Taulukko 1. Tutkimusalueiden kuvaus

Stand characteristic *Metsikön tunnus*	Study area *Tutkimusalue*			
	1	2	3	4
Soil type *Maatyyppi*	Sand, moraine, *Hietamoreeni*	Sand *Hieta*	Sand, morain *Hietamoreeni*	Sand, moraine *Hietamoreeni*
Forest site type *Metsätyyppi*	*Myrtillus* site type *Mustikkatyyppi*	*Vaccinium* site type *Puolukkatyyppi*	*Calluna* site type *Kanervatyyppi*	Natural grass area *Niittykasvillisuus*
Development class *Kehitysluokka*	Mature stand *Uudistuskypsä*	Mature stand *Uudistuskypsä*	Middle aged *Kasvatusmetsikkö*	
Tree species ratio *Puulajisuhteet*	Spruce 80 % *Kuusi* Pine 10 % Birch 10 % *Mänty* *Koivu*	Pine 100 % *Mänty*	Pine 100 % *Mänty*	
Average age of stand, yrs *Metsikön ikä*	95	85	45	
Stand density *Metsikön tiheys*	0.9	0.9	0.9	
Stand basal area, $m^2.ha^{-1}$ *Pohjapinta-ala*	22	20	8	
Average height of stand, m *Keskipituus*	22	19	9	
Stand volume, $m^3.ha^{-1}$ *Kuutiomäärä*	230	180	40	
Biomass of field layer, $g.m^{-2}$ *Kenttäkerroksen biomassa*	99	147	137	
Biomass of bottom layer $g.m^{-2}$ *Pohjakerroksen biomassa*	55	144	289	

Table 2. Ground vegetation of the forested study areas

Taulukko 2. Metsäisten tutkimusalueiden pintakasvillisuus

Species or group of species *Laji tai lajiryhmä*	Coverage % *Peittävyys %*		
	Study area 1 *Tutkimusalue 1*	Study area 2 *Tutkimusalue 2*	Study area 3 *Tutkimusalue 3*
DWARF SHRUBS — *VARVUT*			
Vaccinium myrtillus	42.8 ± 25.3	0.4 ± 0.6	
Vaccinium vitis-idaea	3.8 ± 4.3	15.6 ± 11.7	10.5 ± 7.4
Calluna vulgaris		15.1 ± 17.8	12.2 ± 12.5
Empetrum nigrum		6.1 ± 7.6	1.2 ± 4.5
Linnea borealis	2.1 ± 4.3		
GRASSES — *HEINÄT*			
Deschampsia flexuosa	2.2 ± 4.3		
Luzula pilosa	0.2 ± 0.6		
HERBS — *RUOHOT*			
Melampyrum sp.	0.6 ± 2.5		
Maianthemum bifolium	3.1 ± 2.9		
Goodyera repens	0.6 ± 1.7		
Trientalis europaea	0.2 ± 1.3		
Oxalis acetosella	0.1 ± 0.8		
MOSSES — *SAMMALEET*			
Hylocomium splendends	11.0 ± 19.4	1.7 ± 6.4	
Pleurozium schreberi	47.1 ± 35.4	55.3 ± 35.3	44.5 ± 33.1
Dicranum sp.	24.0 ± 30.1	31.4 ± 33.9	0.1 ± 0.1
Other mosses *Muut sammaleet*	0.1	0.3 ± 1.2	
LICHENS — *JÄKÄLÄT*			
Cladonia sp.		0.1	39.3 ± 29.4
Cladina sp.			0.1

1949). Some charecteristics of the trees and ground vegetation in these stands are presented in Tables 1 and 2. In addition, comparisions with grass and herb dominated vegetation characterized by *Poa sp.*, *Pleum pratence*, *Alchemilla vulgaris*, *Vicia cracca*, *Rhinanthus sp.*, *Trifolium repens*, *Taraxacum officinals*, *Prunella vulgaris*, *Ranunculus acer*, *Plantago major*, *Achillea millefolium*, *Rumex acetosella*, *Rumex acelosa* and *Hypericum maculatum* were carried out.

The ground vegetation was trampled by walking along the study trails once a week, altogether seven times during the period June 15 to July 31 during 1972 and 1973. The study trails were 0.4 × 10.0 m in size, and were trampled by the same person each time. The pressure applied to the vegetation was 270 g/cm²/tramp. The rates of treatment were 0, 4, 16, 32 and 64 tramps/trail/week with eight replications. The layout of the treatment was completely randomized.

The deterioration of the ground cover

was monitored by following changes in the biomass. One sampling plot, 40 × 40 cm in size, was randomly selected from each trampling trail and its biomass determined. The vegetation in the field layer was cut at the level of the bottom layer. Only the green part of the mosses, and the parts of the lichens lying above the humus layer were taken into account. The grass and herbs in the reference area were cut 5 cm above ground level. The samples were dried (24 hours at 105° C) and then weighed to an accuracy of 0.1 g. The sampling procedure was carried out one week after the last trampling treatment.

RESULTS

Changes in biomass

The biomass of the vegetation growing on the treated and untreated trails was compared. The values for the ratio between the treated and untreated trails are presented as a function of the treatment rate in Figs. 1—4. It is evident, that the rate of destruction of the vegetation of the *Calluna* site type is the greatest. The trampling tolerance of the bottom layer is exceptionally low, and very little of the original vegetation has survived by the end of the trampling period. In the case of the *Myrtillus* site type the relationship between the field and bottom layers is reversed. The trampling tolerance of the field and bottom layers seems to be at its greatest in the *Vaccinium* site type. As a whole there appears to be positive correlation between site fertility and trampling tolerance of a plant community as reported earlier by Brooks (1968), Kardell (1975) and Kellomäki and Saastamoinen (1975). In particular, the predominance of mosses and lichens on poor sites reduces the trampling tolerance (cf. Holmström 1970, Hoogesteger 1976). This phenomenon is closely associated with the environmental conditions prevailing in the ground cover. The moisture content of the moss and lichen carpets is very important and determines the trampling tolerance of bryophytes. Further consideration of these facts falls, however, outside the scope of the present study.

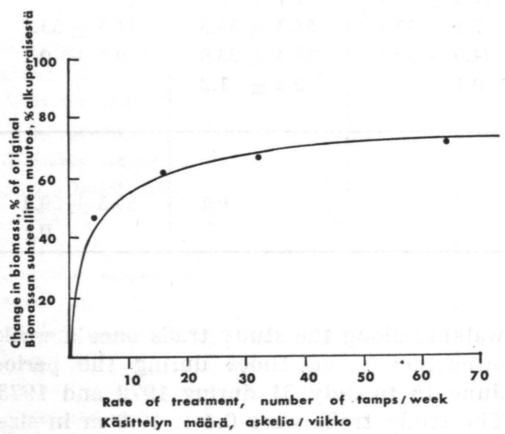

Fig. 1. Change in biomass of ground cover as a function of trampling for *Calluna* site type. Solid line is field layer and dotted line is bottom layer.

Kuva 1. Kanervatyypin pintakasvillisuuden biomassan muutos tallauksen funktiona. Yhtenäinen viiva tarkoittaa kenttäkerrosta ja katkoviiva pohjakerrosta.

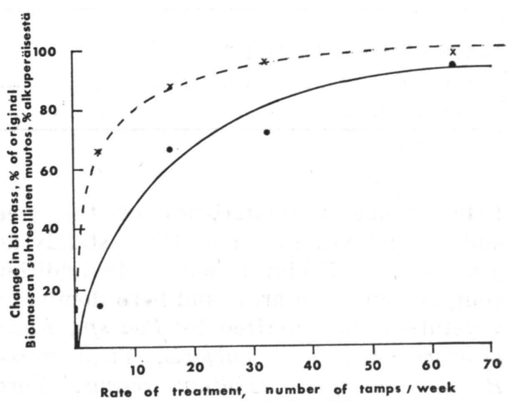

Fig. 2. Same as in Fig. 1 but for *Vaccinium* site type.

Kuva 2. Kuvaa 1 vastaavat tiedot puolukkatyypille.

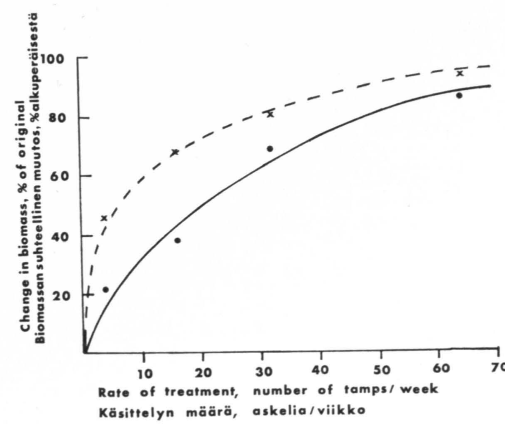

Fig. 3. Same as in Fig. 1 but *Myrtillus* site type.

Kuva 3. Kuvaa 1 vastaavat tiedot mustikkatyypille.

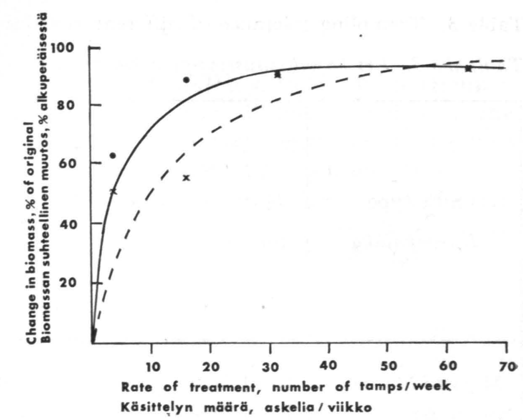

Fig. 4. Same as in Fig. 1 but for herb and grass dominated ground cover.

Kuva 4. Kuvaa 1 vastaavat tiedot niittykasvillisuudelle.

As was expected the grass and herb dominated vegetation had the highest trampling tolerance. However, trampling did have some effect on this kind of ground vegetation. Even the lowest rate of treatment lowered the biomass by such an amount that its significance cannot be ignored.

In forest stands, the same rate of trampling had a more pronounced effect and in the *Calluna* site type only one half of the original vegetation survived by the end of the trampling period. If the rate of treatment is converted into annual visits per hectare, it is evident that annual visits of about 16 000 per hectare results in considerable deterioration in the ground cover of all the types studies. Such a trampling level is evidently fairly normal in camping sites. In other recreation areas such a trampling level is uncommon in Finnish conditions expect for the most popular areas and trails. On the other hand, the forest ground cover cannot withstand annual trampling levels of about 160 000 persons per hectare. With such a trampling level only one half of the grass and herb dominated vegetation is destroyed. Thus, this kind of vegetation should be introduced in areas where heavy trampling is likely to occur, such as in camping sites (cf. for example Bates 1935, LaPage 1967, Holmström 1970, Kellomäki and Saastamoinen 1975).

Trampling tolerance

The change in biomass gives only a rough estimate of the differences in trampling tolerance between different plant communities and quantitative comparisons are difficult. However, this can be done by applying the method presented by Kellomäki (1973) to the actual material. Let y be the biomass of the vegetation after trampling, x the original biomass of the vegetation and j the rate of trampling, then

(1) $$y = P^j \cdot x + e,$$

where P is a parameter to be estimated and e the uncontrolled variance. The value of parameter P is characteristic for each plant species and is dependent on its anatomical, morphological and organological structure and the ability of the plant species to exploit the available environmental resources. The trampling tolerance expressed with parameter P, determined for both field and bottom layers of each site type, is presented in Table 3. A more detailed discussion on the present method is given by Kellomäki and Saastamoinen (1975).

As was expected the bottom layer of the *Calluna* site type received the lowest P value. On the other hand, the field layer of the *Vaccinium* site type had the highest

Table 3. Trampling tolerance of different vegetation types

Taulukko 3. Eri kasvillisuustyyppien kulutuskestävyys

Site type *Kasvupaikka*	Horizontal layer *Kerrososakasvusto*	Values for parameter P *Parametri P:n arvot*			
		Present material *Tämä aineisto*	Reference material[1] *Vertailu-aineisto*	Mean per layer[2] *Keskiarvo kerroksittain*	Mean for all vegetation *Keskiarvo koko kasvustolle*
Myrtillus site type *Mustikkatyyppi*	Field layer *Kenttäkerros*	.790	.992	.891	.924
	Bottom layer *Pohjakerros*	.919	.993	.956	
Vaccinium site type *Puolukkatyyppi*	Field layer *Kenttäkerros*	.967	.994	.981	.965
	Bottom layer *Pohjakerros*	.924	.975	.950	
Calluna site type *Kanervatyyppi*	Field layer *Kenttäkerros*	.950	.930	.940	.879
	Bottom layer *Pohjakerros*	.773	.865	.819	
Herbs and grasses — *Niittykasvillisuus*		.955	.740	.848	.848

1) Material by KELLOMÄKI and SAASTAMOINEN (1975) — KELLOMÄEN *ja* SAASTAMOISEN *(1975) aineisto*
2) Mean for present and reference material — *Tämän ja vertailuaineiston perusteella laskettu keskiarvo*

trampling tolerance as reported earlier by KELLOMÄKI and SAASTAMOINEN (1975). The results of this study differ from those of the earlier one in two respects. Firstly, the field layer of the *Myrtillus* site type received in the present material a considerably lower value than earlier. Secondly, in herb and grass dominated ground cover the comparison gives an opposite result, and in the present material this type of ground cover receives a considerably higher trampling tolerance than earlier. The comparison emphasizes the difference between the trampling method used in this study and the simulated trampling carried out by KELLOMÄKI and SAASTAMOINEN (1975) with which the comparisons are made. However, it can be considered that combining these two materials gives a sufficiently precise estimate for the trampling tolerance of ground cover. These figures show that the relationship between trampling tolerance and forest site fertility is unlinear as reported earlier by KELLOMÄKI and SAASTAMOINEN (1975).

DISCUSSION

The model (1) applied for the estimation of values for trampling tolerance agrees rather well with the basic pattern of the deterioration process as far as the forest ground cover is concerned (cf. Figs. 1—4). As indicated by parameter P the trampling tolerance of herb and grass dominated vegetation in relation to forest ground cover was lower than that reported in the relevant literature (cf. for example HOLMSTRÖM 1970). Fig. 4 shows that during the initial stage of trampling, the deterioration agrees well with the basic assumptions. At higher trampling levels the discrepancy between the actual model and the real process is evident. In the case of herb and grass dominated ground cover the regrowth should be taken into consideration in modelling the deterioration process. (cf. for example BATES 1935). The annual production of forest ground cover is negligible in relation to the rate of deterioration and hence omitting regrowth does not give rise to any inaccuracies in modelling as in the case of herb and grass dominated ground cover. Comparisons made between different types of cover on the basis of changes in the biomass show that the present material also indicates that the real trampling tolerance of herb and grass dominated ground cover is greater than that of forest ground cover.

The results of the present study concerning the trampling tolerance of plant communities are based on only one year's trampling. According to LaPAGE (1967) the destruction of vegetation is greatest at the initial stage of trampling. Later on the secondary vegetation invades the trampled areas. Herb and grass dominated vegetation is in the long run especially resistant to trampling (cf. BATES 1936) as indicated also by the present material. In forest vegetation the share of the secondary vegetation may not be as pronounced as in grass and herb dominated vegetation (cf. HOLMSTRÖM 1976, HOOGESTEGER 1976). KARDELL (1975) has, however, reported the rapid recovery of grass and herb cover after short trampling periods on fertile sites. However, it is evident, that the species number in the secondary vegetation of a forest stand remains lower than that in herb and grass dominated vegetation (cf. LaPAGE 1976). In particular, on poor sites the difference between the original and secondary vegetation may prove to be exceptionally pronounced. It is also evident that the coverage of vegetation remains under 30—40 %, which is considered by BEARDSLEY and WAGAR (1971) to be esthetically satisfactory.

The present method gives rise to some objections. Above all, the trampling was carried out by the same person throughout the trampling period. Although carried out as objectively as possible the effect of the trampler's behaviour may have some effect on the results. Secondly, the trampling intensity was the same each time. This reduces the reliability of the results as far as their application to the management of recreation areas is concerned. However, it is evident that the present estimates for the trampling tolerance of different plant communities are more reliable than those produced by simulated trampling (cf. KELLOMÄKI and SAASTAMOINEN 1975). In particular, the effect of the uneveness of the sampling plots on the results is considerably smaller than earlier. The basic pattern of the trampling tolerance of the ground vegetation is, however, the same as found earlier, and the results agree well with earlier findings on the low trampling tolerance of boreal vegetation (HOLMSTRÖM 1970, KELLOMÄKI 1973, KARDELL 1975, KELLOMÄKI and SAASTAMOINEN 1975, HOOGESTEGER 1976).

There appears to be a positive correlation between the site fertility and trampling tolerance of a plant community. This result emphasizes the role of water and nutrient supply in the management of recreation areas. In addition, all measures which increase the productivity of the ground cover, such as thinning the tree cover, increase the trampling tolerance of a site. These measures also favour herbs and grasses at the expense of dwarf shrubs and mosses and thus increase the trampling tolerance of the ground cover (cf. WAGAR 1964, HOLMSTRÖM 1970, KELLOMÄKI and SAASTAMOINEN 1975). Moreover, in planning the use of recreation areas an attempt should be made to restrict trampling to the most fertile sites.

The present approach is based on the assumption that the trampling is evenly distributed all over the area used for recreational activities. This is only possible in homogenous environment where every natural element has equal attractiveness. In a forest stand this assumption is not valid but the trampling pattern is changed by differences in attractiveness of natural elements. In addition, tree stems, stones and such objects will effect on recreational activities in such a way that trails will appear in terrain. Since recreationists prefer trails, it is evident, that a forest stand may endure trampling much greater than reported now. For a planner the present figures gives, however, the minimum level which the ground cover can be expected to endure in short term trampling.

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SELOSTE:

TALLAAMISEN VAIKUTUS METSIKÖN PINTAKASVILLISUUTEEN

Tutkimuksen tarkoituksena on ollut selvittää lyhytaikaisen kulutuksen vaikutuksia kanerva-, puolukka- ja mustikkatyypin pintakasvillisuuteen, jota on kuvattu kenttä- ja pohjakerrokseen kohdistunein biomassamittauksin. Kasvupaikan ravinteisuuden ja kulutuskestävyyden välinen positiivinen riippuvuus oli ilmeinen. Vuotuinen kulutus, joka vastasi noin 16 000 käyntiä hehtaaria kohti, vähensi kasvillisuuden biomassaa kaikilla metsätyypeillä noin puoleen alkuperäisestä, ja noin 160 000 käyntiä vastaava kulutus tuhosi kasvipeitteet yhden kesän aikana kasvupaikan laadusta riippumatta. Vertailu niittykasvillisuuteen osoitti, että ruoho- ja heinävaltainen kasvillisuus on pitemmällä tähtäimellä paras ratkaisu alueilla, joihin kohdistuu voimakas kulutus.