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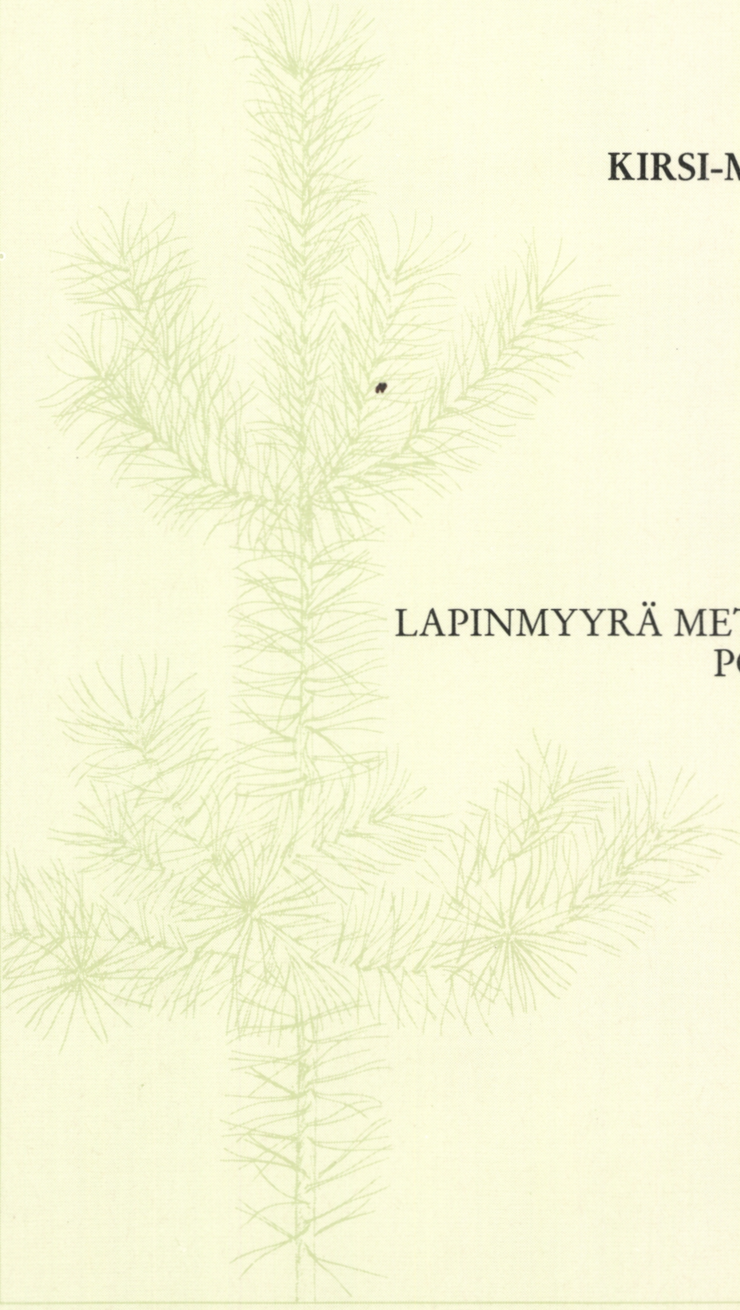
DAMAGE CAUSED BY THE ROOT VOLE (MICROTUS OECONOMUS) TO SCOTS PINE IN MAN-MADE HABITATS IN NORTHERN FINLAND

KIRSI-MARJA KORHONEN



SELOSTE

LAPINMYYRÄ METSÄTUHOLAISENA POHJOIS-SUOMESSA

HELSINKI 1987

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Cover (front & back): Scots pine (*Pinus sylvestris* L.) is the most important tree species in Finland. Pine dominated forest covers about 60 per cent of forest land and its total volume is nearly 700 mil. cu.m. The front cover shows a young Scots pine and the back cover a 30-metre-high, 140-year-old tree.

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DAMAGE CAUSED BY THE ROOT VOLE (*MICROTUS OECONOMUS*) TO SCOTS PINE IN MAN-MADE HABITATS IN NORTHERN FINLAND

Approved on 20.11.1987

Department of Environmental Conservation, University of Helsinki
To be presented, with permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public criticism in Auditorium XII on March 2nd, 1988, at 12 noon.

SELOSTE

LAPINMYYRÄ METSÄTUHOLAISENA POHJOIS-SUOMESSA

HELSINKI 1987

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Natural habitats of the root vole (*Microtus oeconomus*) in northern Finland are seasonally flooded meadows and fens. Recent changes in land-use, such as abandoning of fields, clear-cutting and draining of peatlands, have multiplied the habitats suitable for voles. The increase in root vole numbers has resulted in damage to young Scots pines (*Pinus sylvestris*).

Damage to seedlings on afforested fields was studied on 46 plots. Half of all the fields afforested during 1972—1977 suffered from root vole damage. Damaged plantations were larger than undamaged ones. Also sedges and grasses were more luxurious and the soil more fertile in damaged plantations. In ploughed fields the voles used the hollow layer inside the shoulder for nesting.

Damage in peatland forests of the young thinning stage was studied on 57 plots and in two line inventory areas. Half of the 3697 trees examined in drained areas were attacked, and 40 % of the damaged trees died within 3 years. In undrained comparison areas a total of 420 trees were examined but no vole damage was found. The luxury of the field vegetation proved to be the most important factor influencing the damage. The vegetation was classified using DECORANA and TWINSPAN analyses. Study plots were arranged according to the vegetation analyses into groups indicating the damage susceptibility. Fertilization seemed to increase the damage risk by increasing soil fertility and growth of the vegetation. Phosphorus content in the soil correlated positively with the damage degree. The damage risk also increased after heavy thinnings.

Lapinmyyrän (*Microtus oeconomus*) luontaisia elinympäristöjä ovat tulvaniityt ja aapasuot. Viimeaikaiset maankäytön muutokset, mm. peltoviljelystä luopuminen, avohakkuiden runsastuminen ja soiden ojitus, ovat moninkertaistaneet myyrille soveltuvien elinympäristöjen määrän. Lapinmyyrän runsastuminen on tehnyt siitä huomattavan männyn tuholaisen Pohjois-Suomessa.

Pienten taimien tuhoja tutkittiin metsitetyillä pelloilla 46 koealalla. Vuosina 1972-77 metsitetyistä pelloista puolella esiintyi myyrätuhoja. Tuhojen kohteeksi joutuneet taimikot olivat laajempia kuin niiltä säästyneet. Myös sarat ja heinät olivat ensinmainituissa rehevämpiä ja maaperä ravinteisempi. Auratuilla pelloilla myyrät kaivoivat pesäkolonsa palteen sisään jäävään löyhään kerrokseen.

Turvemaiden harvennusmetsien tuhoja tutkittiin 57 alalla ja kahdella linja-arviointialueella. Puolet ojitusaloilla tarkastetuista männyistä (n= 3697) oli myyrän jyrsimiä ja niistä 40 % kuoli 3 vuoden kuluessa. Ojittamattomilla vertailualoilla tarkastettiin 420 mäntyä, joista yhdestäkään ei tavattu myyrän jyrsintäjälkiä. Pintakasvillisuuden rehevyys osoittautui tärkeimmäksi tuhoalttiutta kuvaavaksi tekijäksi. Kasvillisuus luokiteltiin DECORANA- ja TWINSPAN-analyysien avulla. Näytealat ryhmiteltiin kasvillisuusanalyysien perusteella tuhoalttiudeltaan erilaisiksi ryhmiksi. Lannoitus näytti lisäävän tuhoalttiutta lisäämällä maan ravinteisuutta ja rehevöittämällä pintakasvillisuutta. Tuhojen ankaruus oli suoraan verrannollinen maaperän fosforipitoisuuteen. Tuhoriski kasvoi myös voimakkaiden harvennushakkuiden jälkeen.

Keywords: vole damage, pests, damage risk
ODC 451.2+845.4+(480.99)+149.32 *Microtus oeconomus*

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To Seppo

PREFACE

This study was carried out in the Department of Forest Protection, Finnish Forest Research Institute. The study is based on the author's master's and licentiate theses submitted to the Department of Environmental Conservation, University of Helsinki (Korhonen 1981, Korhonen 1985). A report on the distribution of the root vole damage (Korhonen et al. 1983) has been published earlier.

Dr. Terttu Teivainen from the Finnish Forest Research Institute and Prof. Pekka Nuorteva from the Dept. of Environmental Conservation, University of Helsinki, provided valuable encouragement and advice during the years of this study. I extend my sincere thanks to them. I greatly appreciate the stimulating discussions with Prof. Erkki Annila, Mr. Asko Kaikusalo, Mr. Jouni Kitti, Dir. Erkki Numminen and many others. During the field work I have been assisted by Jaana Hiltunen, Aino Kananen and Eeva Kuhlman, and during the data handling by many helpful and patient friends in the Forest Research Institute. Katriina Huttunen, Auli Immonen, Lasse Kärnä, Pasi Pekkinen and Annikki Viitanen assisted with the typing and drawing of figures.

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My research has been financed by the Finnish Forest Research Institute and the Academy of Finland. The Committee for Scientific-technical Cooperation between Finland and the Soviet Union supported financially my stay in the Soviet Union during 24.10.—18.12. 1983. Veitsiluoto Co. and the Department of Peatland Forestry kindly allowed the use of their plantations and research areas, and made the data on silvicultural methods available.

I would also like to thank Dr. Kari Heliövaara and Mr. Markku Ropo who commented on the manuscript and Mr. John Derome who corrected my English. I extend my sincere thanks to all who have cooperated in the completion of this study.

Vantaa, December 1987

Kirsi-Marja Korhonen

1. INTRODUCTION

The increase in forest cultivation has brought about several new forest pest problems. Among the most harmful pests in forest plantations are the voles. They gnaw the bark of the seedlings and cause great economical losses to forestry during their population peak years. Vole species which are important pests in forestry in Finland are the field vole (*Microtus agrestis* L.), the water vole (*Arvicola terrestris* L.), the bank vole (*Clethrionomys glareolus* Schr.) and the root vole (*Microtus oeconomus* Pallas). This study deals with the damage caused by the root vole in northern Finland. The damage caused by root vole is of special concern because besides in young plantations, it also occurred in forests at the young thinning stage.

The root vole is a species which is distributed over the whole northern part of Eurasia, stretching from northern Scandinavia and Germany to the Pacific Ocean, and in North America, the whole of Alaska and the western part of Canada. In addition to this continuous area, it also occurs in the Netherlands, Austria, Hungary and southern Scandinavia (Tast 1972). In Czechoslovakia the species is known as a very rare relict (Sladek and Mosansky 1985). In Finland the southern edge of the distribution area of the root vole is considered to be slightly south of the Arctic Circle (Siivonen 1967). In addition, the species has been reported on some islands of the Gulf of Bothnia (Kostian 1970). In Karelia the species occurs from north to south at least to the northern shore of lake Ladoga (61°30′N) (Ivanter 1986, Ivanter and Ivanter 1986).

The natural habitats of root voles in Finland are of two main types: the open, watery fens occurring widely throughout northern Finland, and the seasonally flooded meadows on the shores of rivers, brooks and lakes (Tast 1966). In fens the root voles occupy the wet parts in summer and the drier hummocks in winter. In flood meadows they live within the flood range in summer and beyond it during the winter (Tast 1968a). In spite of the differences in soil and vegetation, the ecological conditions associated with flooding are so uniform in these areas, that the dominant small rodent species in both is the root vole (Tast 1966).

Most of the studies carried out on the natural biotopes of the root vole have been published in the Soviet Union. The root vole is known there as the dominating small mammal throughout wide zones of the southern tundra and northern forest-tundra (Pjastolova 1971). In the forest zone the species occupies moist and swampy habitats ranging from the western border to the Kamchatka Peninsula (Dinesman 1961). In western Siberia the optimum zone of the species is considered to be the southern taiga, although it is common in all the zones ranging from the northern taiga to the southern forest-steppe, and even occurs in subalpine meadows above an altitude of 3000 m (Ravkin, J.S., Biological Institute, Siberian Dept., AN SSSR, unpubl.). The most favourable biotopes in western Siberia are moist meadows, river valleys and the edges of open bogs (Maksimov 1978). Often the species is dominating in numbers and occupies all the main biotopes: peatlands, fields with forest islands, clear-cuts (Maksimov 1978, 1981, Maksimov and Erdakov 1985). The root vole is the most numerous species of small mammals also in the vast flooded valleys of the river Ob (Erdakov 1981a). In northern Kazakstan the root vole occurs sporadically, but the numbers can be very high especially along the shores of lakes and large rivers (Pjastolova 1966).

The root vole occupies an area unevenly. In the forest zone the species may spread out over vast areas and form large mosaic communities, while in the forest-steppe zone it occurs in small mosaic communities like separate islands (Litvin 1975). According to Šilov et al. (1977), the mosaically distributed habitats of the root vole occur in moist thickets consisting of hygrophilic plants. In eastern Siberia the species has a wide range of important habitats in the forest-steppe and taiga zones: grass and herb-rich spruce forests, moss-covered pine forests in lowlands, birch-aspen forests, thickets, meadows or bush and herb-rich bogs (Fetisov 1958). According to the data combined from the Soviet authors (Fetisov 1958, Karaseva et al. 1960, Lavrov and Zonov 1963, Očirov 1966, Pjastolova 1974a, Maksimov 1978, Agipaev 1979), the root vole occurs most numerously in river valleys, moist forests, meadows, open fens and in rural buildings.

Summer habitats of the root vole are characterized by excess moisture and luxurious vegetation dominated by sedges and grasses. The denser and higher the sedge cover, the better is the habitat. Root voles also occur more frequently in habitats with some sedges than in those without. Besides food the vegetation also has to provide shelter. Thus the root voles do not occur in pure stands of *Trichophorum cespitosum* (L.) Hartman, although this plant species is favoured by them as food. Besides large-sized sedges, grasses such as *Poa* spp., *Deschampsia cespitosa* (L.) Beauv., *Milium effusum* L., *Phragmites australis* (Cav.) Trin. Steudel, *Calamagrostis* spp. and *Molinia caerulea* (L.) Moench can also serve as the main food source of the root vole and can provide shelter, too (Tast 1966).

Wintering sites of the root vole are considerably drier than its habitats during the breeding season. In peatlands the root vole prefers hummocks since it can eat the underground parts of *Carex aquatilis* Wahlenb., *C. rostrata* Stokes and *Eriophorum angustifolium* Honck. (Tast 1966). The root vole digs tunnels through the peat in the hummocks until they become completely hollowed out. On mineral soils the wintering sites of the root vole are situated above the flood range, along rivers, lakes and streamsides, where the underground parts of grasses and sedges are available. The runways lie above ground and the voles dig small holes to reach the roots of the plants, e.g. *Deschampsia cespitosa* and *Calamagrostis* spp.

The summer food of the root vole is the green parts of sedges, cotton-grasses and grasses (Tast 1966). According to Grodziński (1971) the species also feeds on berries and tree seeds. Tast (1974) has found that 57 % of the food eaten by the root vole during February-November is monocotyledons, 23 % dicotyledons, 19 % *Equisetum* spp. and 1 % mosses. In eastern Kazakstan the root vole eats more vegetative parts of plants during the breeding season than *Clethrionomys rutilus* Pallas and *Cl. rufocanus* Sund. (Agipaev 1979). According to Karaseva et al. (1957), sedges and grasses represent more than half of the food of the root vole during the snowless period, but in April one third of the food still consists of willow bark. Fetisov (1958) has studied the food of the root voles by examining the contents of their guts and food stores in their tunnels (Appendix 1). In eastern Siberia the main food of the species in summer are the leaves and stems of forest, meadow, peatland and subalpine plants.

The winter food of the root vole is different from that of any other small rodent in Finland. According to Tast (1974), the winter food of root voles in Finnish Lapland consists almost exclusively of the underground parts of monocotyledons, especially *Eriophorum angustifolium.* Of all the mammal species occurring in Lapland, only reindeer (*Rangifer tarandus* L.) sometimes consumes similar food. However, during population peak years root voles also consume other plant species. Thus, in winter 1964 the root voles had eaten bark of *Salix phylicifolia* L. and *S. myrsinites* L. (Tast 1966).

The winter diet of the root vole depends on the local conditions. In the Jaroslav region, Karaseva et al. (1957) found that 79 % of the guts examined in winter contained green grass (preserved in tunnels), more than 30 % had bark of woody plants and 20 % also seeds. In eastern Siberia the root vole eats in wintertime the remains of herbs, fallen tree leaves, bark from bushes, shrubs and fallen branches under the snow cover, and also its food reserves which consist of the rhizomes and roots of *Carex* spp., *Calamagrostis* spp., *Parnassia palustris, Polygonum* spp., *Dentaria* spp., *Eranthis sibirica,* and *Phlomis tuberosa* (Fetisov 1958). Underground parts of sedges and grasses are the main part of the winter reserves of the root vole in the Selenga river valley. In addition to these reserves, willow bark is also common in its winter diet in the area (Švecov 1970).

Zonov (1962) found, near Irkutsk, that the species especially favours forest openings with flattened grass and hummocks where green shoots still emerge late in the autumn. The most common plants in the root vole diet in the Irkutsk area are *Carex cespitosa* L., *Deschampsia cespitosa* and *Poa* spp. (Zonov 1962). Since the natural habitats of the root vole are diverse, so too are its main food and lifestyle. Erdakov (1984) found that the root voles living in flooded valleys of the Ob river and eating vegetative parts of plants have a very different daily activity rhythm than those living in the river banks and eating more concentrated food.

In feeding experiments the root vole has eaten the bark of the following plant species:

Pinus sylvestris	(Fetisov 1958, Tast 1974)
Pinus cembra	(Fetisov 1958)
Betula spp.	(Tast 1974, Teivainen 1978)
Alnus spp.	(Teivainen 1978)
Populus spp.	(Fetisov 1958, Teivainen 1978)
Salix spp.	(Karaseva et al. 1957, Fetisov 1958, Teivainen 1978)
Vaccinium myrtillus	(Fetisov 1958)

A high reproductive potential is typical of the root voles in northern regions. The fecundity of females is exceptionally high, the offspring grow fast and reach sexual maturity at an early age. The females become pregnant immediately after parturition and can reproduce throughout the whole summer (Švarc et al. 1969, Pjastolova 1971, 1974b). When the population density reaches a certain level, young animals disperse out of the normal reproduction centers (Pjastolova and Jaskin 1975).

Mobile life-style, great reproductive potential, wide choice of food and good adaptability are natural factors which provide a significant potential for this species to take over new man-made habitats. In northern Finland the root vole has occupied afforested fields and pine-dominated drained peatlands. As a consequence, it has developed into a pest that damages pine seedlings in afforested fields and older pine stands on drained peatlands.

The aim of this study is to describe and analyze damage caused by the root vole to forestry. Since such damage has earlier been almost unknown, considerable emphasis has been placed on a descriptive study of the damaged areas. Finally, this study describes, analyzes and discusses the importance of anthropogenic factors on the history of the root vole, ranging from its natural habitats to afforested fields and eventually to drained peatland forests.

The study is divided into two parts. The first part deals with the damage caused by the root vole in afforested fields, and the second part the damage in Scots pine stands on drained peatlands. The two types of damage differ from each other in the age of the damaged stands. In afforested fields the damage occurs in small seedling stands (dominant height < 1.3 m) and on drained peatlands mainly in young thinning stands (a stage which produces primarily pulp wood). The definitions of development stages are the same that have been used in the Finnish national forest inventory (Kuusela et al. 1986).

The differences between undamaged and damaged afforested fields are analyzed by means of a comparison study. Line inventory methods are used to ascertain the intensity of the damage in peatland forests, and to compare the suitability of drained and undrained peatlands as habitats of the root vole. The factors affecting the susceptibility of different types of forest stands to root vole damage are investigated. Analyses are made of the field layer vegetation, the soil and the forest stand in damaged areas, and the results are compared to those of undamaged areas. The effect of forest cultivation methods, such as soil preparation, draining, thinnings, herbicide treatment etc. on the incidence of vole damage are studied both in afforested fields and peatland forests.

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2. ROOT VOLE DAMAGE IN AFFORESTED FIELDS

21. Introduction

The history of the root vole in Lapland is closely connected to the settlement of Lapland by the Finns, and the development of their agriculture. The Lapps have been living in these areas for a fairly long time, but their way of life has been based on reindeer herding, fishing and hunting, all practices which did not change the environment (Siuruainen 1982, Massa 1983). The Finnish settlers occupied the same habitats as the root voles: the shores of rivers and lakes (Siuruainen 1978, Vahtola 1982).

Farming started in Lapland in the 16th century, but the gathering of hay in flooded meadows originates from the late 18th century and became a common practice early in the 19th century (Itkonen 1948a, 1948b). The Finns extended the flooded meadows and collected the hay for cattle fodder (Fig. 1). The first economic damage caused by the root vole took place in these meadows. Paulaharju (1939) describes in an ethnological book the problems of meadow cultivation in Lapland:

"Karjan eloiksi suovat rakennettiin, vaikka metsien hiiret luulivat, että heinät oli kasattu heidän eloikseen. Ja he tulivat, söivät kohta koko suovan silppuläjäksi ja tyytyväisinä lepäilivät silpuissa".

(Hay was gathered on stacks for the cattle, but the small mice from the woods thought the hay stacks were theirs. And they came, ate all the hay and rested happily among the chopped straw.)

The increase in the field area has been rapid in Lapland: in 1910 the total field area was less than 15 000 ha, in 1950 almost 50 000 ha and in 1969 at its greatest 87 500 ha (Fig. 2) (Lapin... 1981, 1986). Along with the expanding effect of man on nature, the root vole numbers slowly increased and the species now occupies the road banks, pasture lands and hay fields. In northern Lapland it has taken the role of the rat and lives in middens, cattle sheds, barns and houses (Tast 1968a). In eastern Siberia, too, the root vole lives in yards, dumps, buildings and under granaries (Fetisov 1958). The root vole primarily migrates in the autumn when it can move many kilometers to winter quarters using paths for orienteering (Tast 1966, 1968a).

The growth of the field area in the 20th century in Lapland has taken place through the establishment of new farms and the clearing of river valleys, bogs and peatland forests for fields. The law which freed small tenant farmers in the 1920's was the incitement for 10 % of the farms present in Lapland today, while 13 % of the farms originated from settlement laws passed in 1922 and 1936 (Varjo 1967, Jaatinen 1982). During 1917—1945 the clearing of land for agricultural purposes was active in Lapland (Fig. 2).

After World War II there was a need to replace the field area lost in Petsamo and eastern Finland by clearing forests for fields. New laws were passed: in 1940 laws covering the settling of evacuees and soldiers, and in 1944—1945 the laws covering land acquisition. This doubled the number of farms in Lapland up until the beginning of 1965. In Lapland there were very few fields to be redistributed and thus almost all of the new farms were established on peatland and forestland. During 1945—1964 a total of 11 000 ha of new field was cleared on these new farms (Varjo 1967). Most of the new fields were cleared in southern and central Lapland (Rovaniemi, Salla, Ranua, Sodankylä, Kittilä), primarily in peatlands, the natural biotopes of the root vole. The total area drained for fields in Lapland was 165 100 hectares during 1920—1965, 78 % of it in southern Lapland (Varjo 1967). Unlike the old villages along the sides of the rivers, the new farms were isolated in vast "aapa"-fen regions.

The new farms turned out to be too small, under-productive and remote in the long run, and already in the 1950's the number of farm workers began to diminish: there were 28 300 farm workers in Lapland in 1950, but only 12 700 in 1970 (Lapin... 1975, 1986). The climate sets limits on

Fig. 1. Habitats where the root vole caused economical losses for the first time were flooded meadows. Voles chopped the hay on drying frames.
Kuva 1. Tulvaniityt olivat ensimmäinen ihmisen muovaama biotooppi, missä lapinmyyrä osoittautui vahingolliseksi. Myyrät silppusivat heinän haasioissa.

farming in Lapland. Hay is produced on 60 % of the fields. In addition, more than half of the field area in southern and central Lapland is situated on peatlands. The root vole which, unlike other voles in Finland, changes its home range after every litter, has been able to occupy these hay fields and adapt to the yearly harvest.

The real boom in the optimal habitats of the root vole has occurred since the 1960's when the abandonment of fields began (Fig. 3). In 1969 a law of field reservation was passed, which provided the farmers living on their farms with a grant for not cultivating their fields. In Lapland 17 % of the field area had come within this system by 1975 (Tutkimus... 1975, Jaatinen and Alalammi 1978, Varjo 1978). During the 1970's and 1980's migration from the countryside to industrial towns in southern Finland and Sweden has reduced the cultivated field area even more (Fig. 2) (Lapin... 1981, Häkkilä 1984). The farms are kept as summer

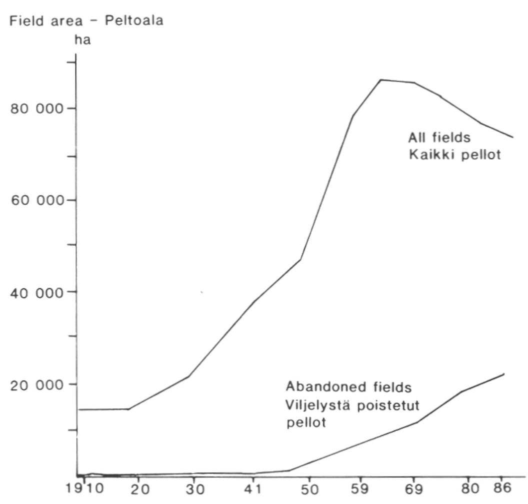


Fig. 2. Total field area and abandoned field area in Lapland during 1910—1985 (Lapin... 1981, Lapin... 1986).
Kuva 2. Kokonaispeltoala ja viljelystä poistettu peltoala Lapin läänissä Lapin maatilatalouden kehittämisneuvottelukunnan ja Lapin seutukaavaliiton tilastojen mukaan (Lapin... 1981, Lapin... 1986).

Fig. 3. An abandoned field, a typical man-made habitat, is a most suitable habitat for the root vole.
Kuva 3. Viljelystä poistettu pelto, tyypillinen ihmistoiminnan muovaama kasvupaikka, on lapinmyyrälle mitä suotuisin elinympäristö.

cottages or sold to forestry companies which afforest the fields.

According to the vole damage questionnaire and inventory results (Teivainen 1979, 1984, Korhonen unpubl.), it appears that the voles and the damage they cause in forest plantations have increased during the last few decades in northern Finland. A similar development has been observed since the late 1950's in Sweden and Norway (Larsson 1973, Christiansen 1975, Hansson and Larsson 1980) and in the Soviet Union, e.g. in the Krasnojarsk region (Švecova 1980). The highest population density peak was recorded in northern Finland during 1977—1978, when most of the damage investigated in this study took place.

22. Material and methods

The studies on root vole damage to small seedling stands were performed in 1978—1979 in fields forested by Veitsiluoto company in northern Finland (Fig. 4). The root voles affected these plantations during the winter 1977—1978. In spring 1978 the company's foresters inventoried the vole damage on all afforested fields, totalling 87 (491.3 ha). Vole damage was observed on 34 fields (263 ha). For the study purposes the fields were divided into 40 vole damage areas (263 ha) and 68 undamaged ones (228 ha). 95 % of the seedlings which had been planted on these fields were Scots pine, but also lodgepole pine (*Pinus contorta* Douglas ex Loudon), Siberian larch (*Larix sibirica* Ledeb.) and birch (*Betula pendula* Roth) had been planted. The average planting density was about 2000 seedlings/ha.

Data about the management methods used on the fields was collected from the forest management files of Veitsiluoto forestry division and analyzed with a VAX 11/785 computer using conventional statistical methods.

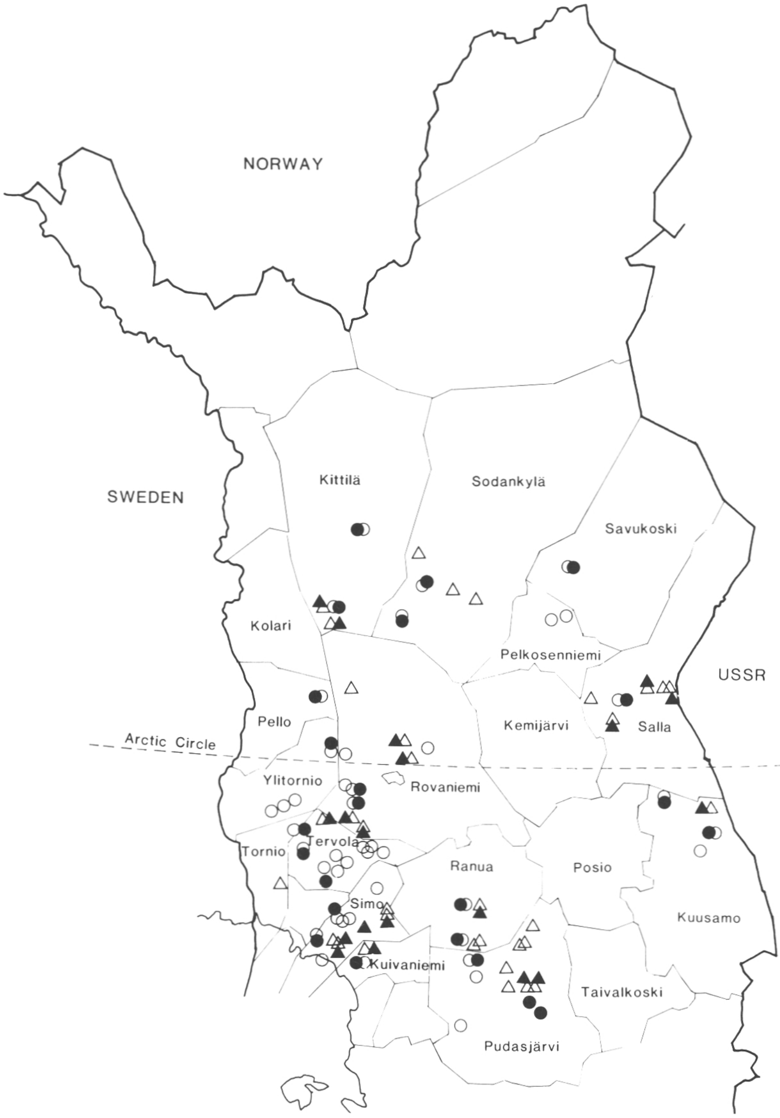


Fig. 4. Location of the fields afforested by Veitsiluoto Co. during 1972—1977. Plantations with vole damage are indicated with (△) and undamaged with (○). Study plots in vole-damaged plantations are marked with (▲) and in undamaged plantations with (●).

Kuva 4. Veitsiluoto Oy:n vuosina 1972–77 metsittämien peltojen sijainti. Myyrien vahingoittamat taimikot on merkitty (△), vahingoittumattomat (○). Myyrätutkimuksen koealat on merkitty vastaavasti: myyrätuhoalat (▲), vahingoittumattomat vertailualat (●).

A more detailed study was performed on 23 plots (a total of 148 ha) which were picked randomly from among the affected afforested fields. In addition, the nearest possible field area without damage was chosen for each of these damage areas, i.e. 23 comparison plots (111 ha) (Fig. 4). Seedlings were examined with a line inventory method to determine the proportion of damaged seedlings. Vegetation analysis was made along two lines on each plot using ten systematic sample squares of 1 m^2 each. The frequency of plant species and the height of the vegetation, as well as the height of the seedlings were determined on these squares.

Nomenclature of the plant species is according to Hämet-Ahti et al. (1984). The vegetation data were analyzed by ordination, classification and diversity methods. The ordination method used was a detrended correspondence analysis DECORANA (Gauch 1982). In the cluster ordination produced by means of DECORANA the point value of each plot is the average of the species existing at that point, and the point value of each species is the average of those points where the species exists (Gauch 1982, Mikkola and Jukola-Sulonen 1984).

Classification analyses were used for numerical clustering of the data by arranging the observations or variables according to special equality criteria in a data matrix. The different classification methods were tested using agglomerative, hierarchic clustering (CLUSTAN) and a dividing, hierarchic method (TWINSPAN = two-way indicator species analysis) (Mikkola and Jukola-Sulonen 1984). The diversity of the plant communities on the plots has been estimated numerically using different diversity indices. The species diversity has been calculated for each sample plot as follows:

1. Total number of species in the sample (S)
2. Simpson's (1949) diversity index $D = 1 - \sum_{i=1}^{s} p_i^2$
3. Shannon's (Shannon and Weaver 1949) diversity index $H' = -\sum_{i=1}^{s} p_i \ln p_i$
4. Kempton and Taylor's (1976) diversity index $Q = S/2 \ln (R_2/R_1)$
5. Pielou's (1966) diversity index $J' = H'/\ln S$

where S is the number of species, p_i is the coverage of the i:th species divided by the total coverage, and R_1 and R_2 are the lower and upper quartiles in the species abundance distribution.

Ordination, classification and diversity analyses, as well as output of the vegetation data matrix, were performed on a VAX 11/785 computer using special programmes developed for vegetation ecological studies (Mikkola and Jukola-Sulonen 1984, Mikkola, Kari, the Finnish Forest Research Institute, unpubl.).

Peat samples were taken on the vegetation sample plots, a bulked, volumetric sample (> 1 l) being made of the ten subsamples from each plot. The samples were taken from the peat surface down to a depth of 20 cm. The samples were analyzed by Viljavuuspalvelu Co. (a soil testing service). The following analyses were performed: soil type, acidity, exchangeable calcium and potassium, easily soluble phosphorus and nitrate nitrogen. The results were expressed per unit volume of the dry milled or sieved sample (mg/l). The methods and terminology are described in Kurki et al. (1965) and Kurki (1982). The results were analyzed using conventional statistical methods.

Vole trapping was carried out using snaptraps, 100 traps usually being systematically set out on a plot on a single night (100 trap nights per plot). Trapping was done on a total of 961 trap nights in the vole damage areas in 1978. Trapping was not done in 1979 on the comparison plots because the vole density peak had already collapsed and the vole population was very low. The species, sex and maturity were determined. Identification of the species was checked from their teeth.

23. Results

231. Vole catches

A total of 112 voles were caught in trappings performed on the damaged areas. 83 % of them were root voles and 17 % field voles (Table 1). All the field voles were caught in the southernmost part of the root vole range. The trapped root voles weighed 12—82 g ($\bar{x}$ = 31.6 g) and the field voles 12—58 g ($\bar{x}$ = 30.6 g). Of the 88 root voles examined, 42 were females and 46 males.

Table 1. Number of voles caught with snap traps in July 1978 on afforested fields in different localities.
Taulukko 1. Heinäkuussa 1978 pellonmetsitysaloilla suoritettujen myyränpyyntien tulokset kunnittain.

Locality *Kunta*	Trap nights *Loukku-vrk*	Voles/100 trap nights *Myyriä/100 loukku-vrk*	
		M. oeconomus	*M. agrestis*
Simo	301	7	6.3
Kuivaniemi	60	11.7	—
Ranua	100	7	—
Tervola	100	12	—
Kolari	100	29	—
Salla	100	16	—
Kittilä*			
$\bar{x}$/100 trap nights $\bar{x}$*/100 loukku-vrk*		13.8	1.0
SD		8.2	2.6
Total — *Yhteensä*	761	93	19

* In Kittilä 1 ex. *M. oeconomus* was caught during trapping of two hours with two traps.
Kittilässä pyydettiin kahdella loukulla kaksi tuntia ja saatiin yksi lapinmyyrä.

Half of the females were mature and half immature, but of the males only 28 % were mature and 72 % immature. Of the field voles 47 % were mature, and the female: male ratio was 10:9. The vole peak collapsed before the following summer and only trial trappings with no catches were carried out in the undamaged areas.

232. Description of the damage

Voles had attacked 55 % of all the Scots pine seedlings growing on the damage plots. The damage on these seedlings (1—5 years of age) was most frequently located in the lower parts of the stem (Table 2). Often the voles had gnawed the upper parts of the stem and top, too. In addition, they had dug holes in the peat around the tree and eaten the roots. The smallest seedlings were completely destroyed, only the hard pith being left (Fig. 5).

Besides Scots pine, also lodgepole pine and Siberian larch, both of which are species exotic to Finland, had been attacked despite their small plantation area. Birch had been planted on a few fields only, but 94 % of the birches had been damaged by voles. Norway spruce (*Picea abies* (L.) Karsten) had not been planted at all on the study plots. Compared to pine, spruce is known to be damaged by voles quite seldom (Bärring 1963, Teivainen 1979). However, spruce seedlings were found to have suffered from root vole damage in Kolari on the largest of the forested fields in Lapland (Fig. 6).

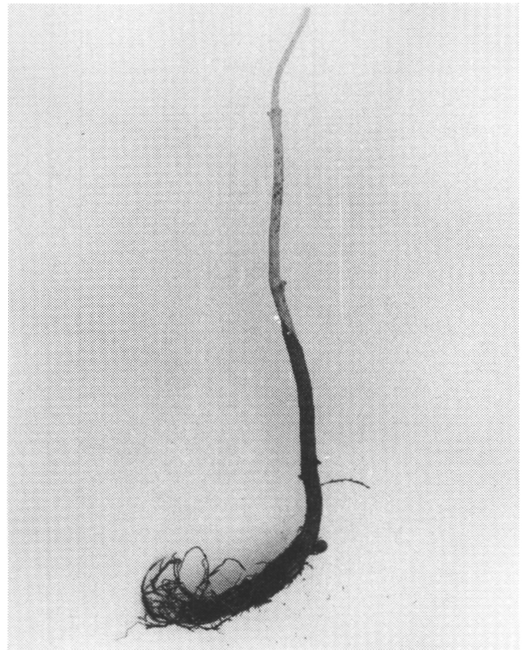


Fig. 5. The root vole often gnaws the whole pine seedling apart from the hard pith.
Kuva 5. Lapinmyyrä jyrsii pienet männyn taimet tikkukasaksi, vain kova ydinpuu jää pystyyn törröttämään.

Table 2. Location of root vole damage in seedlings planted during 1972—77 and damaged in 1977—78.
Taulukko 2. Lapinmyyrän jyrsintäjälkien sijainti vuosina 1972-77 istutetuissa ja talvella 1977-78 jyrsityissä taimissa.

Location of the damage *Vioituksen sijainti*	Number of seedlings damaged *Jyrsittyjen taimien lukumäärä*	Proportion of damaged seedlings, % *Jyrsittyjen osuus, %*
Top *Latva*	22680	7.6
Top + butt *Latva + rungon alaosa*	36610	12.2
Butt *Rungon alaosa*	148130	49.6
Butt + root *Rungon alaosa + juuri*	41640	13.9
Root *Juuri*	9260	3.1
Whole seedling *Koko taimi*	40600	13.6
Total *Yhteensä*	298920	100

The mean height of the seedlings on the affected afforested fields was 45.3 cm (SD = 3.22). Three quarters of the damaged seedlings were less than 50 cm in height. However, trees 170 cm tall had also been attacked. 65 % of the plantations established 1—3 years before the vole peak were damaged, but only 33 % of those planted 4—6 years before.

233. Comparison of damaged and undamaged plantations

2331. Plantation characteristics

Root vole damage occurred on 37 % of all the fields afforested by Veitsiluoto Co. during 1972—1977. This was equivalent to

Fig. 6. Norway spruce *(Picea abies)* can also be attacked by root voles. Spruce seedlings with roots debarked by root voles were common in an afforested field in Kolari.
Kuva 6. Lapinmyyrä jyrsii toisinaan myös kuusen taimia. Pellolle istutetun kuusen juuret on kuorittu paljaaksi (Teuravuoma, Kolari).

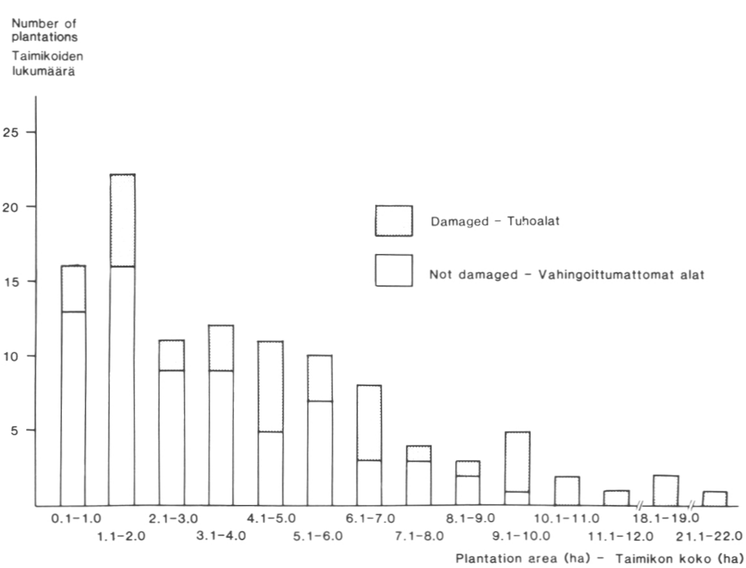


Fig. 7. Occurrence of the vole damage on afforested fields in accordance to the size of the plantation.
Kuva 7. Myyrätuhojen esiintyminen pinta-alaltaan erikokoisissa, pelloille istutetuissa taimikoissa.

Table 3. Fields afforested by Veitsiluoto Co. during 1972—77 in different localities, and the proportion of root vole damage in these areas in 1978.
Taulukko 3. Veitsiluoto Oy:n vuosina 1972–77 metsittämät pellot kunnittain ja myyrätuhojen esiintyminen niillä v. 1978.

Locality *Kunta*	Afforested fields *Metsitysalat* No. *Kpl*	ha *ha*	Vole damaged areas *Tuhoalat* No. *Kpl*	ha *ha*	Proportion of damaged areas *Tuhoalojen osuus* %
Lapland region *Lapin lääni*					
Salla	7	77.1	6	74.0	96.0
Ranua	5	36.9	3	27.4	74.3
Simo	10	59.3	5	27.1	45.7
Rovaniemi	10	39.2	5	25.8	65.8
Sodankylä	5	31.8	3	20.5	64.5
Kittilä	4	29.8	2	18.7	62.8
Tervola	11	56.1	1	10.0	17.8
Tornio	1	6.5	1	6.5	100.0
Ylitornio	4	22.5	0	—	—
Pelkosenniemi	2	8.0	0	—	—
Savukoski	1	4.3	0	—	—
Pello	1	3.5	0	—	—
Kemijärvi	1	3.1	0	—	—
Total — *Yht.*	62	378.1	26	210.0	55.5
Oulu region *Oulun lääni*					
Pudasjärvi	10	56.9	6	42.8	75.2
Kuivaniemi	3	15.6	1	10.0	64.1
Kuusamo	11	39.2	1	0.5	1.3
Taivalkoski	1	1.5	0	—	—
Total — *Yht.*	25	113.2	8	53.3	47.1
Grand total *Kaikki yhteensä*	87	491.3	34	263.3	53.6

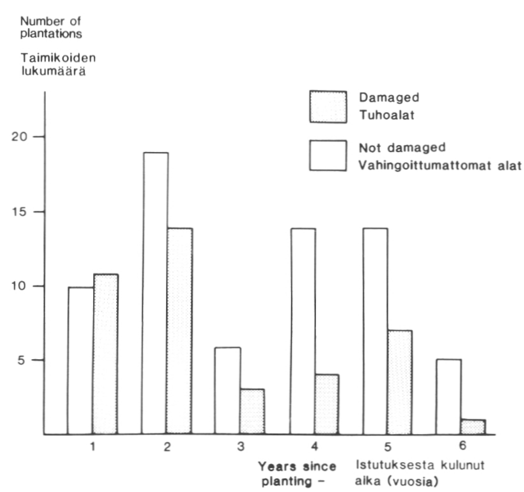


Fig. 8. Occurrence of vole damage on afforested fields according to the age of the plantation.
Kuva 8. Myyrätuhojen esiintyminen eri-ikäisissä, pelloille istutetuissa taimikoissa.

53.6 % of the total afforested field area (Table 3). Damaged plantations were larger than undamaged ones, the difference being highly significant ($t = 3.70$, $df = 49.9$, $P < 0.001$) (Fig. 7). The same result was obtained also when using the Kruskal—Wallis test ($H = 13.55$, $P < 0.001$). Both the frequency and the severity of damage were higher in larger fields.

The age of the plantations proved to be a factor depicting the damage susceptibility. The average age of the trees was 8.5 months younger in the damaged plantations than in the undamaged ones. The average time which had elapsed since planting in the damaged areas differed significantly from that of undamaged ones ($t = 2.05$, $df = 83.7$, $P < 0.05$ and $H = 4.10$, $P < 0.05$) (Fig. 8). Some supplementary planting had been done in both areas. Since all of the afforested fields had been planted, it was not possible to study the significance of different regeneration methods. A greater amount of the seedlings in undamaged areas had been planted in pots (as opposed to bare-rooted seedlings) than in damaged areas ($H = 4.68$, $P < 0.05$). No difference was found between the origin of seedlings in the damaged and undamaged plantations, equal numbers of local and transferred provenances growing in both groups ($H = 0.13$, $P > 0.05$).

2332. Silvicultural methods

The growth of grasses was heavy on nearly all of the afforested fields. However, herbicide treatment carried out less than three years before the damage appeared was more common in undamaged than in damaged plantations ($H = 2.70$, $P < 0.1$). Furthermore, the chemical control of willow bushes had been done more often in undamaged than in damaged plantations ($H = 3.06$, $P < 0.1$). Soil preparation did not differ significantly in the damaged and undamaged plantations ($H = 2.29$, $P > 0.1$). Ploughing with a field plough was a common method that had been used in the undamaged areas but not in damaged ones. Ploughing with a forest plough was the prevailing method in both cases, although even more common in damaged areas. Plantations established on peatlands had been fertilized at the time of afforestation. These early fertilization treatments had no effect on the damage susceptibility of the plantations ($H = 0.24$, $P > 0.1$).

2333. Vegetation

A rich coverage of grasses was typical of the young plantations on afforested arable land. In damaged plantations, where the voles had eaten the grass during winter, the proportion of withered grass ranged from a few per cent up to 90 %. Some bare ground still occurred in plots that had recently been

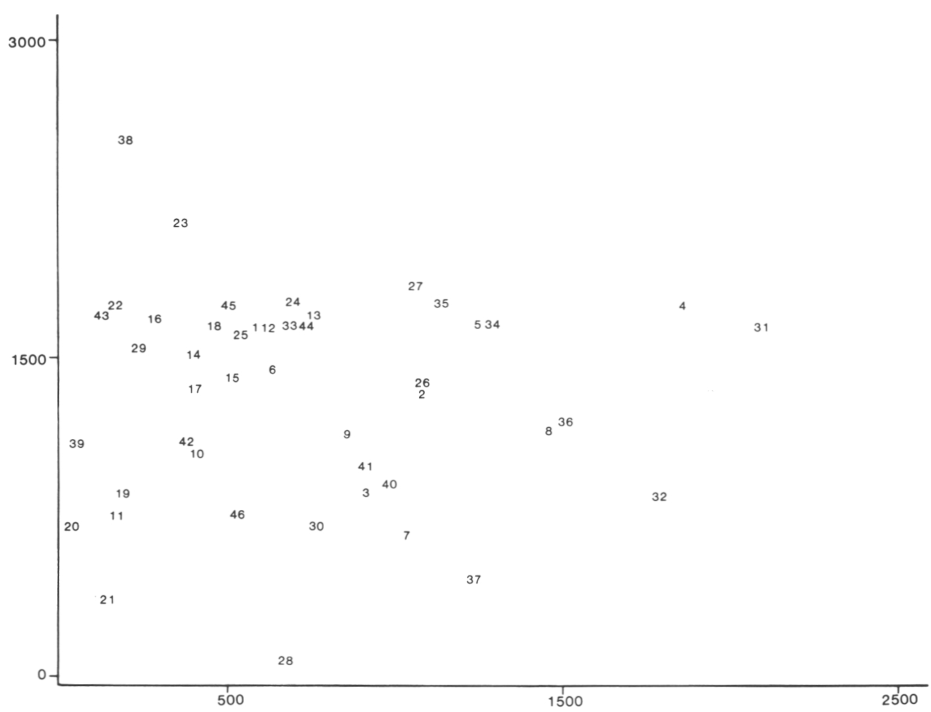


Fig. 9. DECORANA ordination analysis of the field vegetation in forested fields. Vole damage plots are numbered from 1 to 23, and undamaged plots from 24 to 46.

Kuva 9. Pellonmetsitysalojen pintakasvillisuuden DECORANA-ordinaatioanalyysi. Myyrätuhoalat on numeroitu 1–23 ja vahingoittumattomat alat 24–46.

ploughed. The bottom of the furrow was in many cases under water. Elsewhere the field vegetation cover was complete, but the bottom layer was incomplete or missing. The field layer consisted mainly of grasses, with a few herbs and occasional dwarf shrubs. The most common plant species on the damaged and undamaged areas were *Deschampsia cespitosa, Epilobium angustifolium* L. and *Agrostis capillaris* L. (Appendix 2).

The frequency of mosses in the vole damage areas was 40 %, and in the undamaged areas 80 %. Only a few plant species occurred more often on the damaged plots than on the undamaged ones, such as *Poa pratensis* coll. and *Viola epipsila* Ledeb., *Calamagrostis arundinacea* (L.) Roth, *C. lapponica* (Wahlenb.) Hartman, *Agrostis stolonifera* L., *Poa trivialis* L. and *Carex aquatilis* occurred only in the damaged areas.

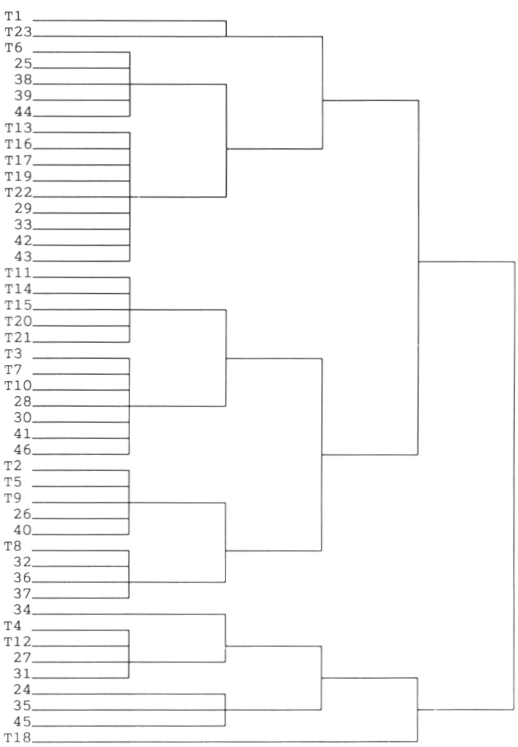


Fig. 10. Classification dendrogram of the vegetation in afforested field areas obtained using TWINSPAN analysis. The plots with vole damage are marked with a T next to the plot number.

Kuva 10. TWINSPAN-luokitteluanalyysin avulla muodostettu pellonmetsitysalojen pintakasvillisuuden luokitteludendrogrammi. Myyrätuhoalat on merkitty T-kirjaimella alanumerojen edessä.

Species more common in the undamaged areas included *Carex canescens* L., *C. magellanica* Lam., *C. nigra* (L.) Reichard, *Calamagrostis purpurea* Trin., *Elymus repens* (L.) Gould, *Luzula* spp., *Galeopsis bifida* Boenn. and *G. speciosa* Miller. These species were typical of drier fields. All the species of dwarf shrubs were found more often on the undamaged than the damaged plots. Surprisingly, the cotton grasses, *Eriophorum* spp. and *Trichophorum cespitosum,* on which root voles feed in nature, occurred somewhat more frequently in the undamaged plantations than in the damaged ones. This is most likely due to the fact that the root voles had eaten all the cotton grasses in the damaged areas. At least half of the plant species were typical of wet and moist habitats on 43 % of the undamaged and 57 % of the damaged plots.

The study plots and plant species were organized, using DECORANA ordination analysis, on two axes based on the species frequencies. No clear difference was found in the main gradients between the vegetation in the damaged and undamaged plantations (Fig. 9).

TWINSPAN clustering analysis was used for the phytosociological classification of the sample plots (Fig. 10). Abundance of grasses and *Epilobium angustifolium* was common to all groups. Three clusters were formed on the basis of the frequency values of the plant species:

I. Herb-rich plots, which were characterized by an abundance of herbs and *Equisetum palustre* L. Typical plants on these plots were *Rubus arcticus* L., *Viola epipsila, Galeopsis bifida* and *Filipendula ulmaria* (L.) Maxim. The group consists of eight damaged plots and eight undamaged ones.

II. Sedge-rich plots, in which *Carex magellanica, C. canescens* and *Eriophorum angustifolium* were common. Of the plots in this group twelve were damaged and nine undamaged. This vegetation type is characteristic of plantations susceptible to root vole damage.

III. Forest vegetation plots which were characterized by forest plant species. *Vaccinium myrtillus, V. vitis-idaea* L., *Deschampsia flexuosa* (L.) Trin., *Melampyrum sylvaticum* L. and *Leontodon autumnalis* L. were common. The group consisted of three damaged plots and six undamaged ones. This vegetation type could indicate those plantations which are least susceptible to vole damage.

Table 4. Diversity analysis of the field layer vegetation on the afforested fields. Plot numbers 1—23 damaged by voles, numbers 24—46 undamaged. See indices on page 14.
Taulukko 4. Pellonmetsitysalojen pintakasvillisuuden diversiteettianalyysi. Näytealanumerot 1-23 myyrätuhoaloja, 24-46 vahingoittumattomia aloja. Indeksien selostus sivulla 14.

Sample *Näyteala*	Species number *Lajiluku*	Simpson index D	Shannon index H'	Kempton index Q	Pielou index J'
1	20	0.920	1.195	20.959	0.919
2	9	0.810	0.811	10.052	0.850
3	18	0.907	1.133	14.949	0.903
4	19	0.922	1.182	25.129	0.924
5	21	0.917	1.182	16.610	0.894
6	31	0.950	1.377	22.891	0.923
7	24	0.920	1.210	25.151	0.877
8	16	0.888	1.052	16.767	0.873
9	20	0.921	1.179	14.307	0.906
10	18	0.902	1.105	10.650	0.880
11	20	0.907	1.138	16.610	0.875
12	13	0.887	1.007	12.575	0.904
13	17	0.896	1.066	9.466	0.867
14	14	0.891	1.032	10.716	0.900
15	15	0.892	1.039	9.466	0.883
16	28	0.945	1.334	20.029	0.922
17	27	0.936	1.318	46.507	0.921
18	33	0.947	1.389	33.534	0.914
19	22	0.927	1.224	18.271	0.912
20	19	0.913	1.153	14.307	0.901
21	32	0.950	1.383	22.891	0.919
22	27	0.944	1.330	23.253	0.929
23	20	0.924	1.197	16.610	0.920
24	42	0.962	1.509	34.880	0.929
25	24	0.931	1.263	25.151	0.915
26	14	0.890	1.038	17.591	0.906
27	16	0.896	1.066	11.445	0.886
28	24	0.934	1.262	30.155	0.914
29	29	0.944	1.338	20.029	0.915
30	26	0.941	1.305	27.247	0.922
31	24	0.925	1.223	17.168	0.886
32	17	0.912	1.129	13.288	0.918
33	25	0.933	1.265	17.168	0.905
34	21	0.925	1.204	25.129	0.911
35	33	0.945	1.370	26.575	0.902
36	20	0.903	1.144	20.959	0.879
37	25	0.931	1.255	17.168	0.898
38	24	0.940	1.278	22.056	0.926
39	29	0.949	1.364	20.029	0.933
40	19	0.913	1.153	16.610	0.901
41	23	0.933	1.244	15.421	0.913
42	30	0.948	1.363	24.914	0.923
43	37	0.961	1.485	37.726	0.947
44	17	0.888	1.062	16.767	0.864
45	34	0.953	1.415	28.236	0.924
46	27	0.947	1.335	29.343	0.932

The classification of afforested plots was also made by means of CLUSTER analysis, but no clear groups were formed. Comparison of the diversity indices of the damaged and undamaged study plots gave no significant differences explaining the damage (Table 4).

2334. Soil

According to Veitsiluoto management files the root vole damage in afforested fields occurred as often on peat as on mineral soil. On the basis of the soil analysis, almost 3/4 of the area of damaged plots was peat soil

Table 5. Calsium, potassium and phosphorus contents of the soil in the study plots on afforested fields and the regional averages in cultivated fields.
Taulukko 5. Maaperän kalsium-, kalium- ja fosforipitoisuudet metsitetyillä pelloilla ja Lapin maatalousseuran sekä Perä-Pohjolan maanviljelysseuran alueiden viljellyillä pelloilla keskimäärin.

	Afforested fields *Metsitetyt pellot*		All fields *Kaikki pellot*	
	Damaged areas *Tuhoalat* mg/l	Not damaged areas *Vertailualat* mg/l	Northern Lapland region *Lapin maatalous-seuran alue* mg/l	Southern Lapland region *Perä-Pohjolan maan-vilj.seuran alue* mg/l
Calsium (Ca) *Kalsium* (exchangeable *vaihtuva*)	965	556	755	994
Potassium (K) *Kalium* (exchangeable *vaihtuva*)	47	25	92	88
Phosphorus (P) *Fosfori* (easily-soluble *helppoliukoinen*)	5.6	1.6	9.3	9.0

and 1/4 mineral soil. The corresponding values for the undamaged plots were 1/2 and 1/2. According to soil fertility tests carried out in 1955—1970, half of the fields in the region where damage occurred were mineral soil, and half peat soil (Lapin... 1975). The most common soil type was *Sphagnum*-sedge peat (SCt), which occurred on half of the area of damaged plots and 40 % of the undamaged ones, but only on 10 % of all the fields in the region.

The soil in both the damaged and undamaged plantations was more acid than the regional averages would indicate. The pH in the damaged areas was 5.0 and in undamaged ones 4.7 ($t = 2.88$, $df = 45$, $P < 0.01$), while in Kittilä, Simo and Tervola the regional average was 5.41—5.55, in Tornio, Rovaniemi and Ranua 5.26—5.40 and in Salla 5.2 (Lapin... 1975). The nutrient contents of the soil in the study plots were below the regional averages, only calcium in the damaged areas being slightly higher. The calcium content was higher in the damaged plots than in the undamaged ones ($t = 2.28$, $df = 43.8$, $P < 0.05$). This was also the case with the potassium content ($t = 4.59$, $df = 30.3$, $P < 0.001$) and phosphorus content ($t = 4.72$, $df = 24.6$, $P < 0.001$) (Table 5).

24. Discussion

Land use in northern Finland has gone through prominent changes during the last decades. Rapid changes have been typical of the development in agriculture: clearing of forest after World War II and the abandoning of fields in the 1970's. Afforested fields are a new biotope which appeared to be very suitable for root voles and thus the damage to seedlings in afforested fields has been severe.

The probability of a certain stand suffering from root vole damage is not very high in general, but in the case of afforested fields and other stands with a luxurious field vegetation the damage risk is high. This study revealed that of all the fields afforested by Veitsiluoto Co. during 1972—1977, 54 % suffered from root vole damage.

The damage risk seems to increase with increasing size of the forested plot. One explanation for this could be that, in large abandoned fields, the root voles can change their home ranges inside the preferable habitat, and thus the density of the vole population may increase to exceptionally high level. In addition to artificial forestation of former fields, natural regeneration has also taken place widely. Natural afforestation of fields leads to the formation of deciduous stands rich in grasses and herbs (Järvinen et al. 1977), which are very favourable for voles. Luxurious vegetation is the main factor which makes the abandoned fields optimal habitats for voles. This was also indicated by the results of the soil analysis: damaged fields had higher nutrient contents than undamaged ones.

In the afforested field areas, the damage occurred most often in fields that had been ploughed with forest machines. This is the prevailing method in the afforestation of fields (Paavilainen 1970, 1977). During this study the root voles were found to have used the hollow layer inside the ploughing shoulder as their nesting sites. The furrows served as runways for voles. The microclimate in the furrows also favours voles: temperature changes are smaller and the snow drifts build up faster. Švecova (1984) found that in furrowed areas in western Siberia 92 % of the damaged pine seedlings were growing in furrows. In addition to afforested fields, ploughing is the predominant method used in soil preparation on forest land in northern Finland (Pohtila 1979). Forest ploughing is mostly done on mineral soil sites, which means that the vole damage risk is mainly apparent in moist areas with a rich field vegetation.

Of the other soil preparation methods, prescribed burning is the least favourable to voles but its effects are not long lasting (Larsson 1975, 1976). Similar temporary falls in vole numbers can be achieved by herbicide treatment (Sviridenko 1953, Larsson 1975, Švecova 1984, Teivainen et al. 1986). This was also the case in some of the afforested field areas in this study. On the other hand, Larsson and Hansson (1976) found that treatment with grass herbicides seemed to increase bark consumption of the voles present in the treated areas.

3. ROOT VOLE DAMAGE IN PEATLAND FORESTS

31. Introduction

The economic utilization of forests began at the same time as the development of farming in Lapland. Due to the remoteness and the harsh climate of Lapland, forests in earlier times were utilized on a very small scale. The first water-powered sawmills were established at the end of the 18th century. Up until the 1870's northern water sawmills consumed altogether only 50 000 logs/year (Ahvenainen 1982). New steam saws were more effective and, with the development of river floating, larger areas were used for industrial forestry. Still in the 1930's two thirds of the number of trees felled in SW Lapland were sawtimber; this means that selective cutting was the prevailing method. The forests were in a poor condition after these cuttings.

After World War II the forest industry grew rapidly in Lapland (Ahvenainen 1982, Raumolin 1982, Massa 1983) and the methods used in forestry went through a complete change during 1955—1970. In the 1950's the so-called "zero border" (the maximum distance of economic wood transport) set limits on the expansion of clearcutting in Lapland. Already at the end of the decade, however, the amount of wood removed from northern forests was 45 % larger than the planned target (Kuusela 1979). Since then, clearcutting has been carried out in Lapland on a vast scale and, unlike in southern Finland, the total drain from forests has exceeded the recommendations of balanced forestry almost every year in Lapland. Industrial wood consumption in Lapland has increased 4-fold since the beginning of the 1950's (Hokajärvi 1982). The rapid increase in clearcutting and plantations has provided more and more favourable habitats for voles.

Since the start of industrial forest usage was late in Lapland, the proportion of forest stands older than 100 years was 65 % in northern Finland still in the 1920's. The rapid development of silvicultural and forest improvement methods, coupled with the growing forest industry, has caused a change in the age structure. The proportion of young stands has increased strongly, and in 1977—1980 the proportion of treeless areas was 4 %, under 20-year-old stands 11 %, 21 to 40-year-old stands 12 %, 41 to 60-year-old stands 16 %, 61 to 80-year-old stands 13 %, 81 to 100-year-old stands 8 % and over 100-year-old stands 37 % of the forest land (Metsätilastollinen... 1986).

Among the changes which have favoured voles, the most prominent has been the increase in commercial fellings, which in the area of root vole damage (in NE Finland and Lapland Forestry Board Districts) occurred on 78 357 hectares in 1977 and on 88 626 hectares in 1984 (Metsätilastollinen... 1979, 1986). This has led to the situation where, in the most acute root vole damage area, small-seedling stands cover 3409 km^2, 30 km^2 of which are afforested fields (Kuusela et al. 1986, Mattila 1986). The advanced seedling stands and young thinning stands cover 44 % of the forest land, totalling 20 059 km^2 (Table 6) (Mattila 1986).

The greatest increase in the forest area in northern Finland has taken place through draining of peatlands, which started in the 1950's and reached a maximum in the late 1960's (Heikurainen 1980). By the end of 1984 the total forest drainage area was 8682 km^2 in the districts of the NE Finland Forestry Board and the southern part of the Lapland Forestry Board (Kuusela et al. 1986), i.e. the main area where root vole damage occurred. The increase in the area drained has been rapid throughout the whole of Lapland: from 2432 km^2 in 1967 to 8902 km^2 in 1985 (Fig. 11) (Metsätilastollinen... 1968—1986).

The proposed future drainage area given by Kuusela et al. (1986) for NE Finland and southern Lapland is 5837 km^2 of primary drainage of swamps and paludified mineral soil sites, and 1340 km^2 of supplementary drainage and cleaning of ditches. Fertilization of peatlands is closely associated with drainage. Fertilization, which started in the 1960's, was done during 1974—1984 on a

Table 6. Proportion of the different development classes of the forest land area in Lapland (Mattila 1986).
Taulukko 6. Nuorten kehitysluokkien osuudet metsämaan alasta Lapin läänissä Mattilan (1986) mukaan.

		Western Lapland *Lapin metsälautakunnan eteläosa*	Eastern Lapland *Koillis-Suomen metsälautakunta*	Total *Koko alue*	Kittilä	Sodankylä	Kolari	Rovaniemi mlk
Forest land area, ha *Metsämaan ala, ha*		28490	17267	45756	4724	7037	1795	5422
Proportion of peatlands on forest land *Soita metsämaasta*	%	20	16	19	10	10	20	23
	ha	5712	2761	8474	472	704	359	1247
Area of development classes on forest land *Eri kehitysluokkia metsämaan alasta*								
1 — Open *Aukea*	%	5	7	6	5	7	8	6
2 — Small seedling stand *Pieni taimikko*	%	7	9	7	5	6	12	8
1 + 2	%	12	16	14	9	12	20	14
	ha	3430	2784	6214	440	867	359	737
3 — Advanced seedling stand *Varttunut taimikko*	%	19	20	20	15	12	19	22
4 — Young thinning stand *Nuori kasvatusmetsikkö*	%	28	18	24	27	25	36	28
3 + 4	%	47	38	44	41	38	55	51
	ha	13490	6567	20059	1948	2643	981	2748

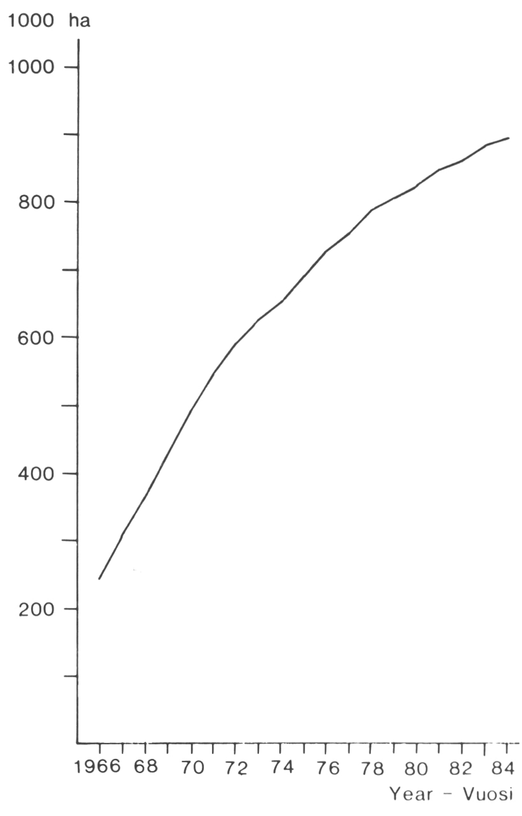


Fig. 11. Increase in the total area drained for forestry purposes in Lapland during 1966—1985 (Metsätilastollinen... 1968—1986).
Kuva 11. Soiden kokonaisojitusalan kasvu Lapin ja Koillis-Suomen metsälautakuntien alueilla vuosina 1966-85 (Metsätilastollinen... 1968-1986).

total of 94 000 ha of peatlands in the area susceptible to root vole damage.

The maximum area of forest stands susceptible to root vole damage could include nearly all pine-dominant, small-seedling stands (3000 km^2) and pine-dominant, advanced seedling and young thinning stands on peatlands (more than 6000 km^2) in southern and central Lapland.

The aim of this part of the study is to determine the effect of drainage, fertilization and other forest improvement and silvicultural methods on the root vole damage in young thinning stands of Scots pine. Habitat changes are studied in relation to root vole damage. The vole damage dealt with in this study originated from winter 1977—1978, the time when there was an exceptionally high vole peak in Lapland. In 1981—1982 the vole densities had again become rather high, and some of the damage originated from that winter.

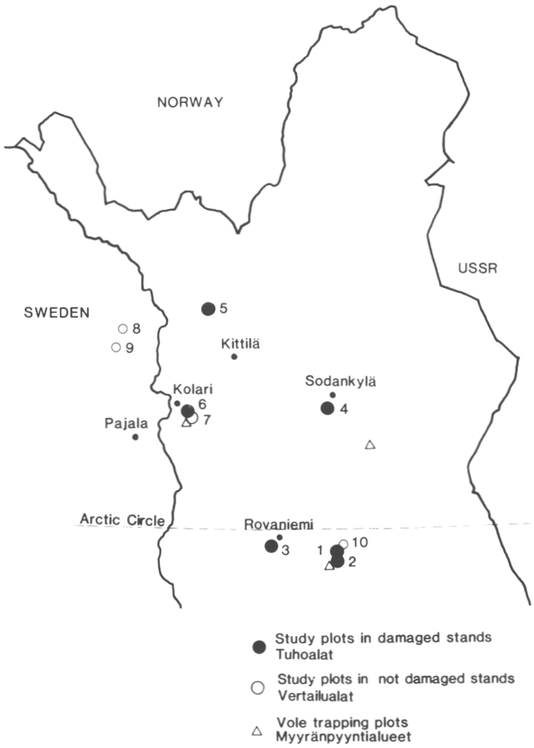


Fig. 12. Research areas in peatland forests. 1 = Sattasuo, 2 = Alajärvensuo, 3 = Imari, 4 = Suolomaapa, 5 = Verkkolahdenjänkä, 6 = Teuravuoma, 7 = Pohjasenvaara, 8 = Muotkavuoma, 9 = Juolamaa, 10 = Silva.

Kuva 12. Tutkimusalueet turvemaiden metsissä. 1 = Sattasuo, 2 = Alajärvensuo, 3 = Imari, 4 = Suolomaapa, 5 = Verkkolahdenjänkä, 6 = Teuravuoma, 7 = Pohjasenvaara, 8 = Muotkavuoma, 9 = Juolamaa, 10 = Silva.

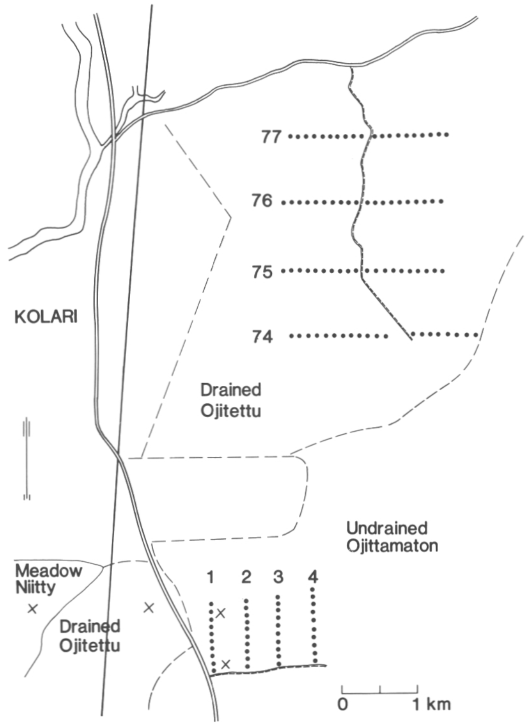


Fig. 13. The line inventory areas in drained Teuravuoma bog (lines 74—77) and undrained Pohjasenvaara bog (lines 1—4). Vole trapping plots are marked with an X.

Kuva 13. Linja-arviointialueet ojitetulla Teuravuoman suolla (linjat 74–77) ja ojittamattomalla Pohjasenvaaran suolla (linjat 1–4). Myyränpyyntialueet on merkitty X:llä.

32. Study areas

Root vole damage in advanced seedling and young thinning stands was studied in several study areas in southern and central Lapland. The effect of draining on vole damage, as well as on the distribution and severity of the damage, was studied in Kolari, Teuravuoma (67° 20′ N, 23° 60′ E) with the line inventory method (Fig. 12). The inventory was carried out in a drained peatland area and in a neighbouring natural, undrained peatland area, Pohjasenvaara (67° 17′ N, 23° 55′ E). Four parallel study lines, each 2000 m long, were surveyed in the drained area (Fig. 13). The distance between the lines was 1 km, and between plots on the same line 100 m. The study plots consisted of the five trees lying closest (less than 20 m) to the centre of the plot. A total of 361 trees in an area of 6 km^2 were examined on the 20 plots along each of the four lines. Four 1000 m-long lines were surveyed in the natural comparison area (Pohjasenvaara), the distance between the lines being 500 m (Fig. 13). The study plots were located 100 m apart, and were similar to those at Teuravuoma. A total of 150 trees were examined over an area of 1.5 km^2 in Pohjasenvaara.

There was a wide range of mire site types in the area: pine bogs, small spruce swamps, almost treeless fens etc. The state of the undrained comparison area, which is protected by the Finnish Forest Research Institute as a forest reserve, was analogous to the original state of the drained peatland.

It is difficult to find natural peatlands comparable to drained peatlands in northern

Finland. The Teuravuoma peatland area extends into Sweden. In Sweden there are plenty of suitable comparison areas because forest draining has not been performed this far north at all. Thus one 1000 m-long line, with plots every 50 m was surveyed in Pajala, Juolamaa bog (67° 19′ N, 23° 12′ E) and one 400 m-long line in Pajala, Muotkavuoma bog (67° 22′ N, 23° 10′ E) (Fig. 12). A total of 132 trees were examined in Pajala.

The studies concerning the effect of fertilization, field vegetation and other factors on vole damage were carried out in five fertilization research areas of the Department of Peatland Forestry, the Finnish Forest Research Institute (Appendix 3). The areas, typical of vole damage biotopes, were situated in central Lapland, earlier known as the most severely affected damage region (Korhonen et al. 1983). Three of the study areas were located near Rovaniemi: Alajärvensuo (66° 26′ N, 26° 42′ E), Sattasuo (66° 27′ N, 26° 44′ E) and Imari (66° 29′ N, 25° 31′ E) (Fig. 12). One of the study areas was in Sodankylä, Suoloma-aapa (67° 21′ N, 26° 32′ E) and one in Kittilä, Verkkolahdenjänkä (68° 00′ N, 24° 19′ E) (Fig. 12).

In 1978, the tree stand in Alajärvensuo consisted of 42-year-old Scots pine. The stand was dense, about 1900 trees/ha, because it had not been thinned. The most common mire site type was tall-sedge pine fen (VSR) which covered 10 study plots. Four of the plots were of the herb-rich sedge birch-pine fen type (RhSR). All plots were in the 'transforming' stage. In Alajärvensuo fourteen study plots, 0.04 ha in size, were chosen along a line using systematic sampling in 1981 and 4 plots in 1982 (Fig. 14). A total of 1124 trees were examined in Alajärvensuo in 1981 and 364 trees in 1982.

The tree stand in Sattasuo was not as dense as that in Alajärvensuo, about 1500 trees/ha. 40-year-old Scots pines with a few older spruces covered most of the area. Some damage by *Tomicus* bark beetles had occurred in the area after thinnings (Etholen and Saarnio 1977). Six study plots, 24 m x 40 m in size, were chosen systematically (Fig. 15), and a total of 859 trees were examined in 1981. The whole area was a herb-rich sedge birch-pine fen (RhSR) in the 'transforming' stage. In addition, one study plot was chosen for comparison purposes from the nearby Silva natural mire area, and a total of 138 trees were examined there.

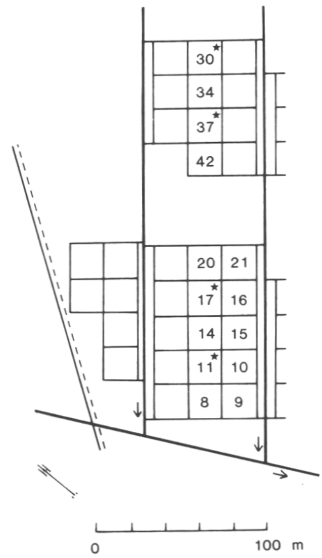


Fig. 14. The fertilization study area in Alajärvensuo and the vole damage study plots. The plots examined in 1981 are numbered as in the original fertilization experiment. The plots examined in 1982 are marked with an asterisk (★). Fertilization data is given in App. 3.

Kuva 14. Alajärvensuon lannoituskoealue ja myyrätuhotutkimuksen näytealat. Vuonna 1981 tutkitut alat on numeroitu kuten alkuperäisessä lannoituskokeessa. Vuonna 1982 tutkitut alat on merkitty tähdellä (★). Lannoitustiedot liitteessä 3.

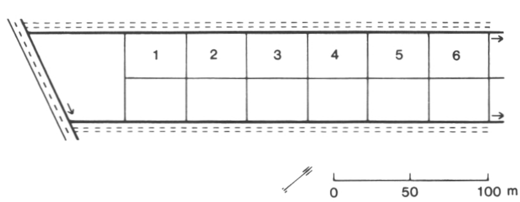


Fig. 15. The fertilization study area in Sattasuo and the sample plots of the vole damage study carried out in 1981. Fertilization data is given in App. 3.

Kuva 15. Sattasuon lannoituskoealue ja myyrätuhotutkimuksen näytealat vuonna 1981. Lannoitustiedot liitteessä 3.

In Rovaniemi, Imari, the dominating stand was 20-year-old Scots pine with an admixture of birch undergrowth and some larger spruces and birches. The stand was thinned in 1973 to a density of 1600 pines/ha. The six study plots, 0.04 ha in size, were chosen beforehand from a map in order to ensure that each fertilized sector had two plots (Fig. 16). A total of 394 trees were examined in Imari. The mire site types in Imari were rather mixed: two of the study

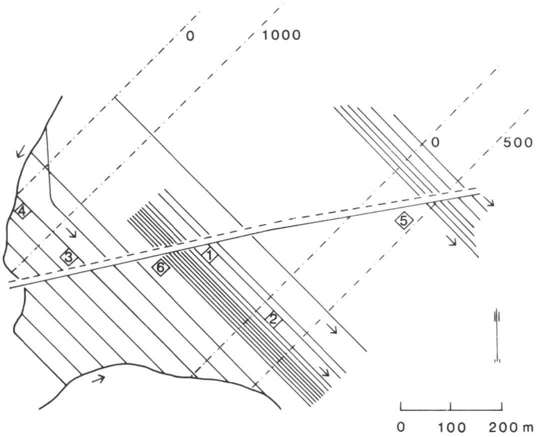


Fig. 16. The fertilization study area in Imari and the vole damage sample plots in 1981. Fertilization with PK was given in sectors 0 kg/ha, 500 kg/ha and 1000 kg/ha (numbers 0, 500, 1000 in the picture) (see also App. 3).

Kuva 16. Imarin lannoituskoealue ja myyrätuhonäytealat v. 1981. PK-lannoitus tehtiin kaistoittain 0 kg/ha, 500 kg/ha ja 1000 kg/ha (kuvassa 0, 500 ja 1000) (katso myös liite 3).

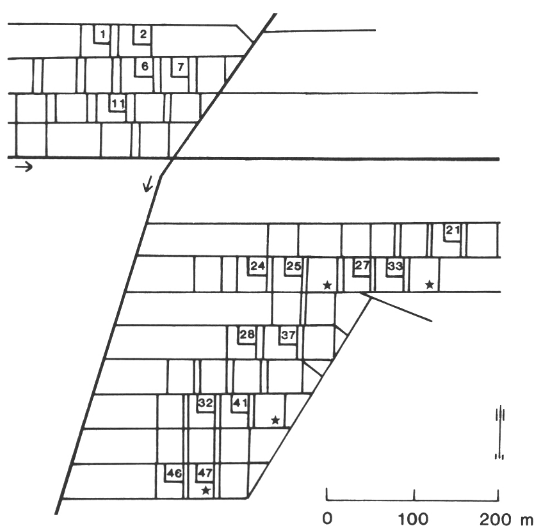


Fig. 17. The fertilization study area in Suoloma-aapa and the vole damage study plots. Plots examined in 1981 are marked with the original numbers of the fertilization experiment, and the plots of 1982 with an asterisk (★). Fertilization data are given in App. 3.

Kuva 17. Suoloma-aavan lannoituskoealue ja myyrätuhonäytealat. Vuonna 1981 tutkitut alat on merkitty alkuperäisen lannoituskokeen numeroin ja vuoden 1982 alat tähdellä (★). Lannoitustiedot liitteessä 3.

plots were *Carex globularis* spruce-pine swamps (PsKR), two *C. globularis* pine swamps (PsR), one herb-rich sedge birch-pine fen (RhSR) and one *C. globularis* spruce swamp (PsK). All plots were in the 'ditched' stage.

Most of the Suoloma-aapa study area in Sodankylä was covered with 38-year-old Scots pine in 1978. The density was only 800 trees/ha since it had recently been thinned. A smaller section in the northern part consisted of different-aged pines and some spruces. The most common mire site type was tall-sedge pine fen (VSR), and in the northern part tall-sedge pine fen with *Sphagnum*-hummocks (VSR ram). In addition, plots 2, 6 and 12 were *C. globularis* pine swamps with hummocks (PsR ram), plot 13 a cottongrass pine bog (TR ram) and plots 7 and 8 *Sphagnum fuscum* pine bogs (RaR) (see Paavilainen 1978). Sixteen study plots, 20 m x 20 m in size, were chosen systematically. Thus three of each fertilization combination and one plot fertilized with nitrogen alone were chosen in 1981, and four of these plots again in 1982 (Fig. 17). A total of 522 trees were examined in Suoloma-aapa in 1981 and 143 in 1982.

In Kittilä, Verkkolahdenjänkä, the vole damage had occurred in 1981—1982. At that time the pure Scots pine stand was 3 m tall on the average, and 15 years old. The stand density was about 1100 trees/ha, but the density in the northeastern part especially was much lower. The proportions of different mire site types on all the study plots were as follows: herb-rich sedge birch-pine fen (RhSR) 4.8 %, tall-sedge pine fen (VSR) 47.6 %, *S. fuscum* pine bog (RaR) 23.8 %, eutrophic flark fen (RiL) 19.0 % and herb-rich sedge fen (RhSN) 4.8 %. The peat thickness varied between 80—100 cm and all the plots were in the 'ditched' stage. In 1982 twelve vole damage study plots, 0.04 ha in size, were chosen systematically along three lines in order to give two plots for each fertilization combination (Fig. 18). Plot number 100 had no trees and thus number 93 was chosen instead. However, no damage was found on 93. A total of 437 trees were examined in Verkkolahdenjänkä.

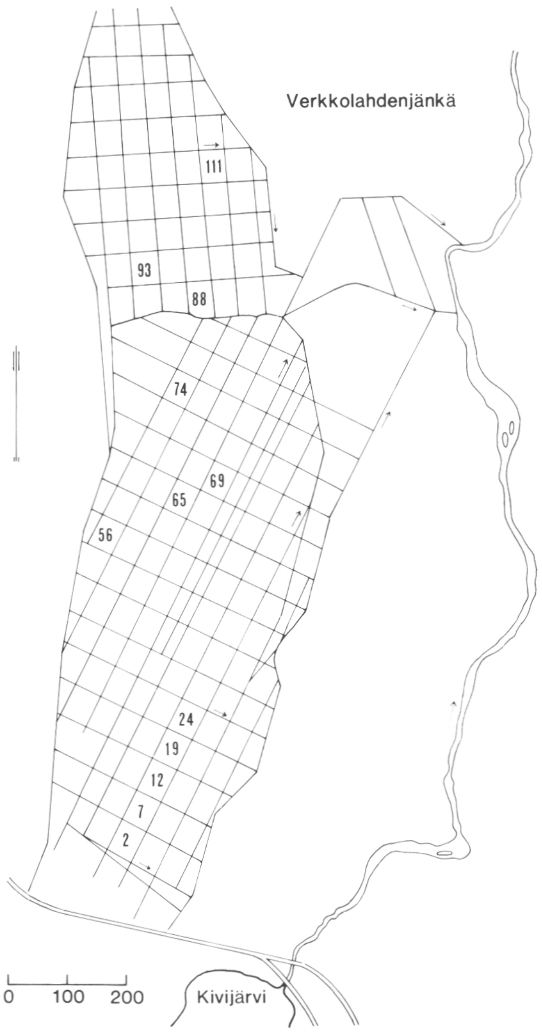


Fig. 18. The fertilization study area in Verkkolahdenjänkä and the root vole damage study plots (numbered). Fertilization data are given in App. 3.

Kuva 18. Verkkolahdenjängän lannoituskoealue ja myyrätuhotutkimuksen näytealat (numeroitu). Lannoitustiedot liitteessä 3.

33. Material and methods

The studies were carried out in 1981 in Alajärvensuo, Sattasuo, Imari and Suolomaaapa. Some of the plots in these areas were re-examined in 1982. The studies in Verkkolahdenjänkä were performed in 1982, and reexamined in 1983 and 1986. The line inventories were done during 1983—1985 in the Teuravuoma, Pohjasenvaara and Pajala areas. Vole trappings were performed in 1977—78 and on a small-scale in 1981.

A total of 3697 trees were examined on drained areas and 420 trees on undrained ones. The height and diameter at breast height of each tree growing on the study plots were measured. All of the trees were examined by exposing the butt, root neck and a part of the root system in order to detect any gnawing signs of root voles. Damage signs on the butt of the mire pines of development class 3 and 4 are clearly visible for many years. Recent root damage is also easy to recognize after some digging, but earlier damage to the roots is not so easy to detect. In contrast to the situation above the peat surface, the resin does not dry out and turn white. It is easy to see that these trees are suffering, but the damaging agent may be difficult to detect.

The trees on the study plots were classified into two groups: 1) trees gnawed by voles and 2) ungnawed trees. The gnawed trees were further divided into two subgroups: 1a) trees killed by voles and 1b) trees damaged by voles. Trees under 1 m tall were excluded from the study. The proportion (%) of gnawed trees out of all the trees on a plot is referred to further on in the text using the expression "damage degree".

In this study the mire site types of the drained plots were determined according to their original site type because the plots were in the 'ditched' or 'transforming' stages, but not yet 'transformed'. This is typical in Lapland where the development of drained swamps toward mineral soil forest types is slow: of all the drained peatlands 39.7 % are in the ditched stage, 54.6 % transforming and only 5.7 % transformed (Kuusela et al. 1986).

The vegetation and soil analyses were done with the same methods as for the afforested fields, although only five 1 m x 1 m squares were used on each 20 m x 20 m plot. In addition to the species frequency, the coverage percentage was also determined. Analyses were performed on all fertilization study plots in 1981, and in 1985 on four plots in the drained Teuravuoma line inventory area and on eight plots in the natural Pohjasenvaara. Two vegetation analysis plots were also chosen from natural peatlands in Pajala, Sweden (Fig. 12). The mire and forest site types were determined on the basis of the field-layer vegetation (Kujala 1979, Heikurainen 1986). In cases where the mire type had been determined earlier by the

Dept. of Peatland Forestry, their results were used as an aid in the determinations. English terminology is according to Laine et al. (1986).

Recovery of the trees after vole attack was studied in Verkkolahdenjänkä. 23 pines suffering from vole damage were marked in 1982. These trees had all been attacked by voles during the previous winter, but at the time of marking they appeared healthy. The height, diameter at breast height and the proportion of the butt circumference gnawed were measured. The recovery capacity was estimated in 1983, and the trees examined and measured again in 1986.

The trees on the line inventory plots were examined in order to detect any signs of vole attack. The severity of the damage to a tree was estimated as the proportion of the circumference gnawed at the butt or root neck of the tree.

Vole trapping was done with snap traps using the same methods as in afforested fields. Voles were trapped during a total of 1590 trap nights from September 1977 to September 1978. Trappings were performed by Mr. Asko Kaikusalo in Kolari, Sodankylä, Muonio and Rovaniemi (Fig. 12).

The data were analyzed on a VAX 11/785 computer using conventional statistical analyses and special vegetation analysis programs (Jukola-Sulonen 1983, Mikkola and Jukola-Sulonen 1984).

34. Results

341. Vole catches

A total of 493 voles were caught during 1590 trap nights. 48.5 % of them were root voles, 2.0 % field voles, 40.6 % bank voles, 0.4 % grey-sided voles and 8.5 % lemmings (*Lemmus lemmus* L.). The root vole was the most numerous species in all regions (Table 7). In drained pine bogs it was the dominant species, although bank voles were also caught there. In natural peatlands, a few field voles and lemmings were caught in addition to root voles and bank voles. The bank vole was the dominant species in spruce forests on mineral soil, although root voles and a few lemmings and grey-sided voles were also caught there. No water voles were caught in any of the biotopes, no traces of them being found at all.

In Kolari trapping was done in the line inventory areas on drained and undrained peatlands. Only root voles were caught in the Teuravuoma drained pine fen in September, 1977 (Table 7). The root vole population density had increased throughout the summer and autumn of 1977. A great number of voles survived winter 1978, causing damage. The root vole density in Teuravuoma was high also during summer 1978, but bank voles were caught then, too. In Pohjasenvaara undrained pine bog the root vole numbers were lower especially in autumn 1977 (Table 7).

342. Description of the damage

Vole damage occurred on half of the Scots pine trees growing in the study areas in drained peatlands, 40 % of the gnawed trees being dead three years after the damage. The damage degree of the study plots in young thinning stands varied from 16 % to 85 %. The voles had gnawed the thick bark at the butt of the pines (Fig. 19), and debarked the upper parts of the roots (Fig. 20). Of the 568 affected pines examined in 1982, 33 % had root damage only, 52 % stem damage only and 15 % both. The results of this re-examination indicated that some of the trees with only root damage had not been noticed in the studies of 2899 trees performed in 1981. The proportion of trees with damage on both the root and stem may have been higher, because the roots of trees with clearly visible stem injury were not examined thoroughly. This assumption was supported by the results of the inventory done on the Teuravuoma drained peatland in 1985. The corresponding values for Teuravuoma (243 damaged pines) were 54 %, 11 % and 35 %, respectively. Trees with roots damaged by voles had become susceptible to wind damage (Fig. 21).

The root vole had attacked, in addition to pines, only two spruces on the plots in young thinning stands and advanced seedling stands. A fallen spruce, with roots badly damaged by voles, was also found outside the study plot area. Although the root vole is known to feed on older deciduous trees (Kaikusalo, Asko, the Finnish Forest Research Institute,

Table 7. Number of voles caught with snap traps during the period July 1977 to September 1978 in older Scots pine stands in Lapland.
Taulukko 7. Myyränpyyntien tulokset heinäkuun 1977 ja syyskuun 1978 välisenä aikana mäntyä kasvavilla aloilla Lapissa.

Locality *Kunta*	Month, year *Kk, vuosi*	Biotope *Biotooppi*	Trap nights *Loukku-vrk*	Voles/100 trap nights — *Myyriä/100 loukku-vrk*				
				Microtus oeconomus	*Microtus agrestis*	*Clethrionomys glareolus*	*Lemmus lemmus*	*Clethrionomys rufocanus*
Kolari Teuravuoma	9.77	Abandoned field *Pakettipelto*	100	32	—	—	—	—
	9.78	Abandoned field *Pakettipelto*	100	18	—	—	—	—
	9.77	Drained pine bog *Ojitettu räme*	80	13.8	—	—	—	—
	9.78	Drained pine bog *Ojitettu räme*	50	24	—	8	—	—
Kolari Pohjasen-vaara	9.77	Dwarf shrub pine bog/ open bog *IR/neva*	80	5	—	2.5	—	—
	9.78	Dwarf shrub pine bog/ open bog *IR/neva*	100	19	4	5	—	—
	9.77	*Vaccinium myrtillus* type spruce forest *MT-kuusikko*	80	1.3	—	26.25	—	—
	9.78	*Vaccinium myrtillus* type spruce forest *MT-kuusikko*	100	3	—	51	—	—
Sodankylä	9.77	Pine bog/spruce swamp *Räme/korpi*	100	11	2	4	—	—
	7.78	Pine bog/spruce swamp *Räme/korpi*	100	29	3	9	—	—
	9.78	Spruce swamp — *Korpi*	40	12.5	—	22.5	7.5	—
	9.78	Pine bog — *Räme*	60	35	—	6.7	3.3	—
Muonio	9.78	Clear-cutting/pine bog *Avohakkuu/räme*	100	39	—	5	—	—
Rovaniemi	7.78	*Hylocomium-Myrtillus* type I — *HMT I*	50	—	—	20	—	—
	7.78	Abandoned field *Pakettipelto*	50	22	—	—	—	—
	9.77	*Hylocomium-Myrtillus* type II — *HMT II*	100	13	1	23	7	—
	7.78	*Hylocomium-Myrtillus* type II — *HMT II*	170	2.9	—	22.9	12.9	—
	9.78	*Hylocomium-Myrtillus* type II — *HMT II*	130	3.8	—	10.8	6.2	1.5
		x̄/100 trap nights *x̄/100 loukku-vrk*		15.8	0.56	12.0	2.1	0.08
		SD		12.27	1.20	13.33	3.80	0.35
		Total — *Yhteensä*	1590	239	10	200	42	2

unpubl.), no damaged deciduous trees were found in the thinning stands of this study.

Three years after the damage the mean height of the trees (n = 2899) growing on the plots in the fertilization study areas was 4.0 m (1.3—14.0 m), and the mean diameter at breast height 5.6 cm (1—27 cm). The trees mortally damaged by voles (n = 686) were 3.2 m (1.3—8.5 m) tall in the average and 4.2 cm (1—17 cm) in diameter, while those less severely damaged by voles (n = 827) were 4.7 m (1.3—9.6 m) and 6.8 cm (1—21 cm),

Fig. 19. Root vole debarking in older pines is clearly visible when it is located at the butt of the tree.
Kuva 19. Suurten mäntyjen tyvellä sijaitseva lapinmyyrän jyrsintäjälki on helppo havaita.

respectively. Three years after the damage the difference between the mean height of the gnawed and ungnawed trees was not significant ($F = 0.636$, $df = 1{,}82$, $P > 0.05$), and the mean diameter was the same in both groups because tree growth is slow on peatlands in Lapland.

The trees at Verkkolahdenjänkä were measured during the summer following the outbreak of damage. The average height of all the trees ($n = 437$) was 2.9 m (1.3—7.5 m), and the mean diameter at breast height 4.4 cm (1—13 cm). The corresponding values for killed trees ($n = 39$) were 2.8 m (1.3—6.1 m) and 3.8 cm (1—9 cm), and for less severely damaged trees ($n = 182$) 3.1 m (1.3—7.5 m) and 4.9 cm (1—13 cm).

The correlation between the height of the gnawed trees and the damage degree of the plots ($n = 52$) was not significant, while that between the mean diameter at breast height and the damage degree was ($r = 0.296$, $P < 0.05$). Recovery of the trees after vole attack depended on the proportion of the stem and root circumference gnawed. The trees examined in 1982 were distributed according to the severity of damage as follows: 13 % of the trees with less than half of the circumference eaten were dead, 36 % of those with 50—99 % of the circumference eaten were dead, and 84 % of those gnawed

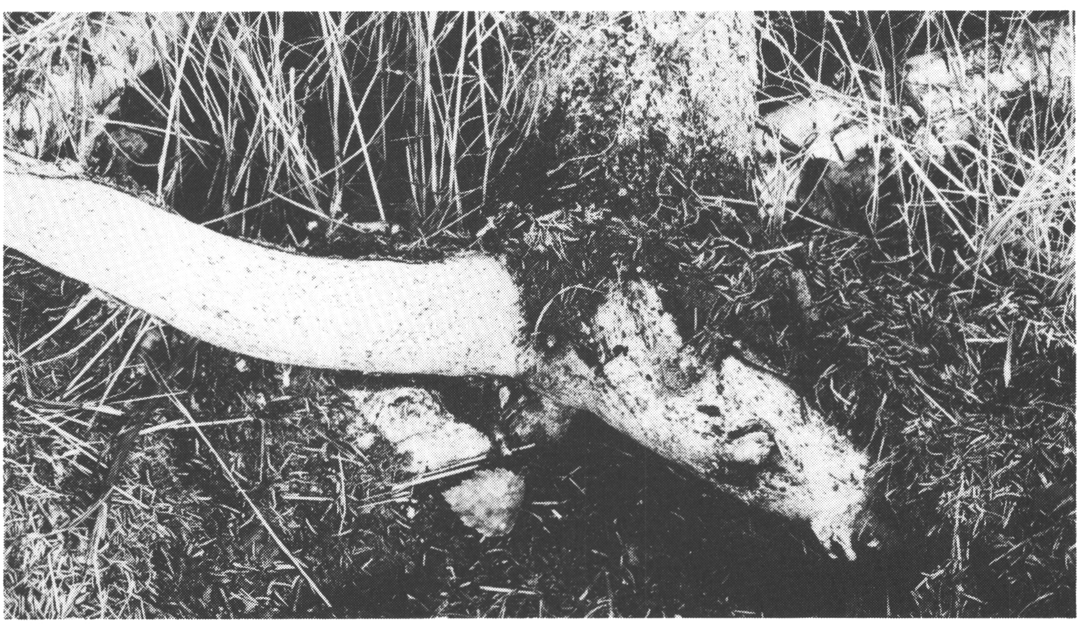


Fig. 20. Root vole debarking is often located on roots and thus not seen above the peat.
Kuva 20. Lapinmyyrän jyrsintäjälki sijaitsee usein juurissa eikä näy turpeen päälle.

Fig. 21. Typical appearance of a pine stand attacked by the root vole. Absence of older needles and a tendency to lean over are characteristic to trees with root damage.
Kuva 21. Lapinmyyrän aiheuttamat tuhot mäntyjen juurissa ilmenevät neulaskertojen vähäisyytenä ja puun kallistumisena tuulen ja lumen vaikutuksesta. Teuravuoman ojitusalueen tuhoja.

all around the butt were dead. Pines that had been gnawed all around the stem but which were still alive had all been attacked the previous winter. These trees will also die sooner or later.

Of 361 trees examined in the Teuravuoma line inventory, 7 % were totally debarked, 10 % were debarked over 50—99 % of the circumference, and 14 % under half of the circumference. Only root damage was found in more than 1/3 of the trees, and root damage in addition to stem damage in more than 1/4 of the trees. 1/3 of the trees were undamaged.

Repeated recovery surveys were done in Verkkolahdenjänkä. 23 of the pines attacked by voles during the previous winter were marked. One year after marking one of the study trees had fallen down, but the others were still alive. Four years after marking 26 % of the trees were dead but still standing, and 13 % had fallen down. The estimations done one year after the marking (and damage) proved to be fairly successful (Table 8), but were slightly optimistic. Four years after the damage had occurred, all those trees which had been gnawed only on the roots or on less than 20 % of the stem circumference were still assessed to be probably or possibly recovering (Table 9). All those trees on which at least 80 % of the stem circumference had been gnawed were dead or likely to die soon. Recovery of the trees on which 20—80 % of the stem circumference had been gnawed depended on other factors such as the total area debarked, root connections and insect attack. The growth of the trees was also negatively correlated ($r = -0.417$, $n = 23$, $P < 0.05$) with the proportion of the stem circumference debarked.

Table 8. Recovery of the trees debarked by the root voles in Verkkolahdenjänkä.
Taulukko 8. Lapinmyyrän jyrsimien puiden toipuminen Verkkolahdenjängällä.

Condition of the trees *Puiden terveydentila*	One year after the damage *1 v tuhon jälkeen* n	 %		Four years after the damage *4 v tuhon jälkeen* n	 %	
Dead, fallen *Kuolleita, kaatuneita*	1	4		3	13	
Dead, standing *Pystyyn kuolleita*	—	0	47 %	6	26	61 %
Dying — *Kuolevia*	6	26		3	13	
Most likely dying *Todennäköisesti kuolevia*	4	17		2	9	
Unknown — *Ei tietoa*	2	9	9 %	—	—	
Most likely recovering *Todennäköisesti toipuvia*	7	31	44 %	5	22	39 %
Recovering — *Toipuvia*	3	13		4	17	
Total — *Yhteensä*	23	100		23	100	

Table 9. Proportion debarked in trees of different condition classes and the height increment of them during the 4-year-period after the damage.
Taulukko 9. Puiden terveydentila suhteessa jyrsityn kuoren osuuteen ja neljän vuoden pituuskasvuun myyrätuhon jälkeen.

Condition of the trees *Puiden terveydentila*	Debarked % of the circumference *Syöty % ympärysmitasta* x̄	Height increment dm/4 years *Kasvu, dm/4 v.* x̄	 SD
Dead, fallen *Kuolleita, kaatuneita*	60	0	0
Dead, standing *Pystyyn kuolleita*	75	0.8	1.0
Dying — *Kuolevia*	85	3.3	5.8
Most likely dying *Todennäköisesti kuolevia*	50	4.0	5.6
Most likely recovering *Todennäköisesti toipuvia*	36	5.2	3.6
Recovering — *Toipuvia*	14	7.5	4.1

343. Drainage

The root vole damage in advanced seedling and young thinning stands occurred almost entirely on drained peatlands. Despite the extensive surveys, only a few damaged trees were found growing on mineral soil in habitats such as the edges of abandoned fields and inside reindeer fences. Damage was also rare on natural undrained peatlands, occurring only along streams with flooded meadows.

In a comparison study of drained and undrained peatlands, a total of 361 pines were examined in a line inventory of the Teuravuoma drained peatland and a total of 150 pines on the undrained Pohjasenvaara. The comparison area of Pohjasenvaara is a part of the same vast peatland as the Teuravuoma drainage area. Mire site types of the two areas were as follows:

	Mineral soil sites	Pine fens	Spruce swamps	Open fens	%
Drained	21	58	15	6	100
Undrained	10	50	18	22	100

Drainage had converted some of the previous open fens into pine fens in Teuravuoma. The mean height of the pines was 4.5 m (SD = 1.27) on drained peatlands, and 3.8 m (SD = 1.77) on undrained ones. The mean diameter at breast height was 6.8 cm (SD = 2.41) on drained, and 6.2 cm (SD = 4.20) on undrained peatlands. No damage was found on the trees on undrained peatlands, but on drained peatlands 67 % of the pines examined had been attacked by voles, 14.5 % of them being dead in 1985. The damage degree of the study plots did not correlate with either the height ($r = 0.080$, $P > 0.1$) or the diameter at breast height ($r = -0.010$, $P > 0.1$) of the trees. The damage intensity was different on different mire site types (Fig. 22). The lowland of Teuravuoma reaches far to the west. Since no forest draining has been done at Pajala, Sweden, this area appeared to be suitable for comparison. A total of 132 pines were examined, but no vole damage was found.

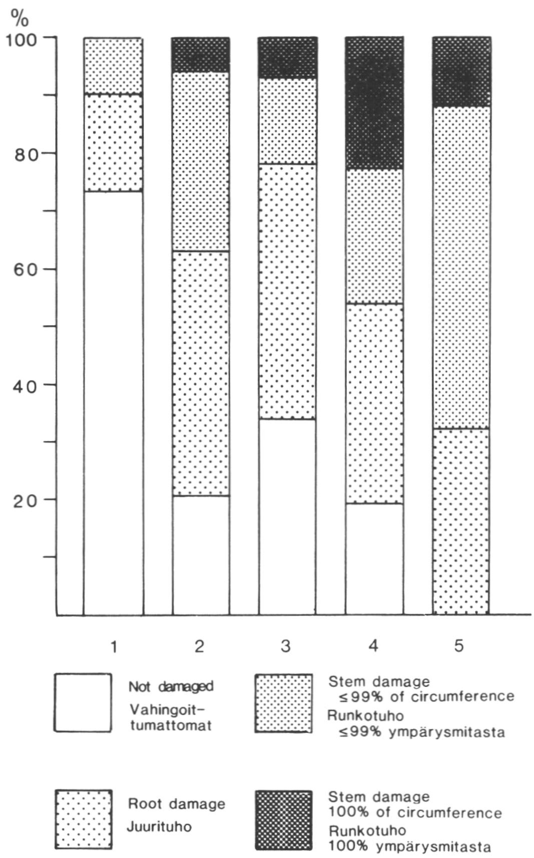


Fig. 22. Occurrence of different types of vole damage in pines growing on different mire site types in Teuravuoma drained peatland. 1 = *Hylocomium-Myrtillus* site type, 2 = productive pine bogs, 3 = low productive pine fens, 4 = spruce dominated swamps, 5 = birch dominated sedge fens.

Kuva 22. Myyrätuhojen jakaantuminen tuhotavoittain eri suotyypeillä kasvavissa männyissä Teuravuoman ojitusalueella. 1 = HMT, 2 = hyväkasvuiset rämeet, 3 = kitukasvuiset rämeet, 4 = korvet, 5 = koivuvaltainen RhSR.

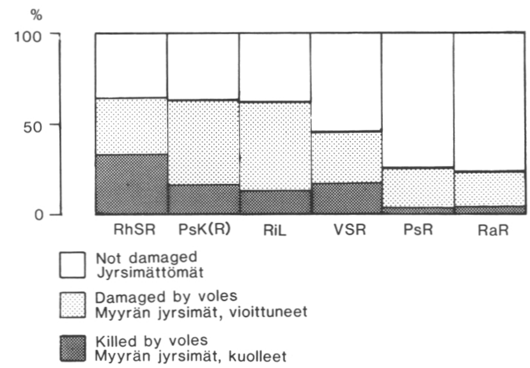


Fig. 23. The proportion of pines damaged by voles on different peatland site types in advanced seedling and young thinning stands. RhSR = herb-rich sedge birch-pine fen, PsK(R) = *Carex globularis* spruce (and pine) swamp, RiL = eutrophic flark fen, VSR = tall-sedge pine fen, PsR = *C. globularis* pine swamp, RaR = *Sphagnum fuscum* pine bog.

Kuva 23. Myyrän jyrsimien puiden osuudet eri suotyypeillä riuku- ja kasvatusmetsissä.

344. Fertilization and soil nutrients

Root vole damage was very common in the older fertilization study areas. Half of the 3336 trees examined in these areas were damaged by voles.

The mire types in the damaged fertilization study plots were as follows:

VSR	RhSR	PsR	PsK(R)	RiL	RaR	Total
46	35	6	5	5	3	100

The damage on the fertilized plots occurred most frequently on the richest peatland types: herb-rich birch-pine fens and spruce-pine swamps (Fig. 23). The damage degree in different mire site types differed significantly from each other ($F = 4.05$, $df = 5{,}46$, $P < 0.005$).

The relationship between fertilization and root vole damage was studied by comparing the damage in the fertilization study plots (Figs. 14—18). Interpretation of the results was made difficult by the fact that the fertilizers used in the different areas were not the same (Table 10). In any case, the average damage degrees of the different study areas did not differ significantly from each other ($F = 2.00$, $df = 4{,}47$, $P > 0.05$). In the pooled data the average damage degree of plots unfertilized with macronutrients was 43.6 %, the damage degree of plots given PK, PK + ash and PK + micronutrients 61.3 % and on NPK, NP and N plots 45.7 %. The averages differed from each other significantly ($F = 5.14$, $df = 2{,}49$, $P < 0.01$).

The most common soil type in the damaged areas was *Sphagnum*-peat (St), accounting for 3/4 of the study plots. The average pH of the soil on the study plots was 4.8 ($SD = 0.34$), the lowest values occurring in Imari and the highest in northern Suoloma-aapa, Sattasuo and SW Alajärvensuo. The correlation between acidity (pH) and damage degree was not significant ($r = 0.081$, $P > 0.1$).

Table 10. Root vole damage on the fertilization study plots in drained peatland forests.
Taulukko 10. Lapinmyyrätuhojen esiintyminen eri tavoin lannoitetuilla aloilla ojitetuilla turvemailla.

Fertilization *Lannoitus*	No. of plots *Aloja, kpl*	No. of trees *Puita, kpl*	Proportion of damaged trees, % *Myyrän jyrsimien osuus, %*	Porportion of killed trees, % *Myyrän tappamien osuus, %*
No fertilization *Ei lannoitusta*	10	495	39.6	10.1
Micronutrients *Hivenseos*	3	114	39.5	8.8
Ash — *Tuhka*	1	44	52.3	6.8
PK	14	1272	65.0	28.9
PK + micronutrients *PK + hivenseos*	4	123	61.8	16.3
PK + ash — *PK + tuhka*	1	57	50.9	8.8
PK + urea	2	82	31.7	6.1
NPK	8	666	42.8	25.2
NPK + micronutrients *NPK + hivenseos*	3	95	52.6	16.8
NP	5	357	44.5	20.7
N	1	31	58.1	19.4
Total — *Yhteensä*	52	3336	52.0	21.7

The main factor indicating the effect of fertilization on vole damage is the amount of nutrients in the soil. The nutrient analyses were made in 1981, three years after the damage had occurred, and the contents were thus lower than during the damage year. However, the analyses revealed that the available phosphorus and potassium contents were higher on plots fertilized with PK than on unfertilized ones. The highest contents of phosphorus were recorded in Suoloma-aapa, and the lowest in Alajärvensuo. The positive correlation between the phosphorus content and the damage degree was significant in Suoloma-aapa ($r = 0.874$, $P < 0.001$), in Alajärvensuo ($r = 0.661$, $P < 0.01$) and in Sattasuo ($r = 0.842$, $P < 0.05$), but negative in Imari ($r = -0.901$, $P < 0.05$). The average damage degree of the different study areas did not differ from each other significantly ($F = 2.49$, $df = 3,38$, $P > 0.05$), while the P content did ($F = 16.22$, $df = 3,38$, $P < 0.001$). The positive correlation between the phosphorus content and damage degree on all the plots was highly significant ($r = 0.499$, $n = 42$, $P < 0.001$) (Fig. 24). This positive correlation was also found when non-parametric correlation was determined ($r_s = 0.478$, $t = 3.44$, $df = 40$, $P < 0.005$).

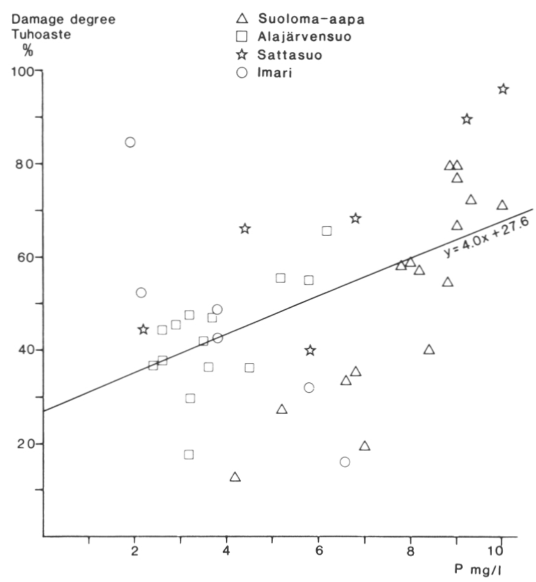


Fig. 24. The correlation between root vole damage intensity (proportion of gnawed trees in a study plot) and the phosphorus content (mg/l) of the soil ($r = 0.499$, $n = 42$, $P < 0.001$).
Kuva 24. Myyrätuhojen (jyrsittyjen puiden %-osuus alan puista) ja maaperän fosforipitoisuuden välinen korrelaatio ($r = 0,499$, $n = 42$, $P < 0,001$).

Table 11. Some physical and chemical properties of peat in young thinning stands on drained and undrained peatlands.
Taulukko 11. Turpeen fysikaalisia ja kemiallisia ominaisuuksia harvennusikäisissä metsiköissä ojitetuilla ja ojittamattomilla soilla.

Area *Alue*	N	Electricial conductivity *Johtoluku* 10 × mS/cm x̄	SD	Acidity — *pH* Cultivated layer *Muokkauskerros* x̄	SD	Exchangeable calsium *Ca vaihtuva* mg/l x̄	SD	Exchangeable potassium *K vaihtuva* mg/l x̄	SD	Easily-soluble phosphorus *P helppoliuk.* mg/l x̄	SD	Exchangeable magnesium *Mg vaihtuva* mg/l x̄	SD
Teuravuoma (drained damaged area *ojitettu tuhoala)*	4	0.48	0.17	4.7	0.21	550	255	33.8	4.79	3.2	4.50	48	28
All damaged areas (drained) *Kaikki tuhoalat (ojitusalueet)*	46	0.68	0.16	4.8	0.32	779	312	35.6	17.1	5.5	2.79	—	—
Pohjasenvaara (undrained, not damaged — *ojittamaton, vahingoittumaton)*	8	0.48	0.23	5.1	0.46	1178	1010	54.4	21.1	2.0	0.95	219	183
Pajala (undrained, not damaged — *ojittamaton, vahingoittumaton)*	2	0.60	0.00	4.8	0.42	550	70	42.5	3.54	2.1	0.42	95	14
All undrained, not damaged comparison areas — *Kaikki ojittamattomat, vahingoittumattomat vertailualat*	11	0.79	0.21	5.0	0.48	995	902	50.4	19.1	2.2	1.1	—	—

	Soil type — *Maalaji* St	LSt	CSt	SCt	LSCt	LCt	Ct	Mm	HkMm	HkMr	HHK	Total *Yht.*
All damaged areas *Kaikki tuhoalat*												
No. — *Lkm.*	32	2	3	2	—	2	2	1	1	1	—	46
%	70	4	7	4	—	4	4	2	2	2	—	100
All undrained, not damaged comparison areas — *Kaikki ojittamattomat vertailualat*												
No. — *Lkm.*	4	—	1	1	1	2	—	1	—	—	1	11
%	36	—	9	9	9	18	—	9	—	—	9	100

St = *Sphagnum* peat, LSt = *Lycopodium-Sphagnum* peat, Ct = *Carex* peat, Mm = Mull, Mr = Till, Hk = Sand
St = Rahkaturve, LSt = Metsärahkaturve, Ct = Saraturve, Mm = Multamaa, Mr = Moreeni, Hk = Hiekka

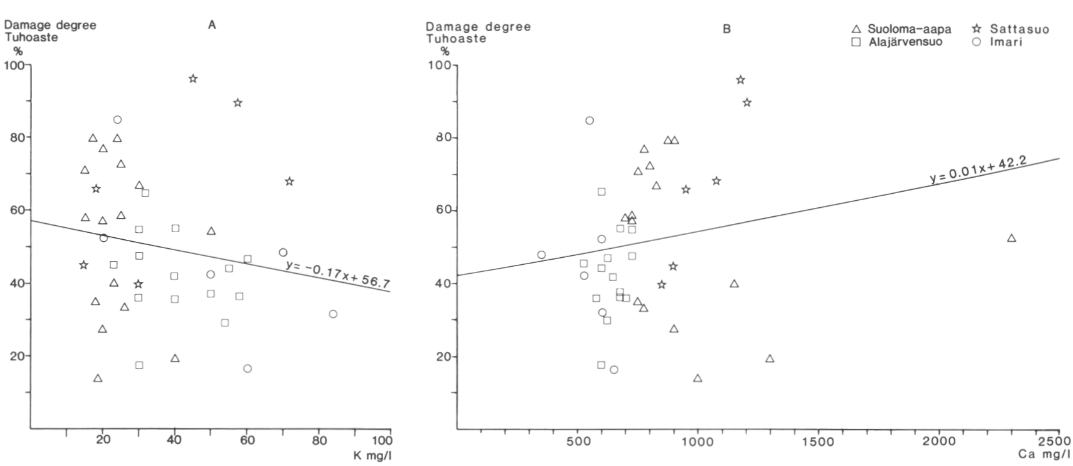


Fig. 25. The correlation between root vole damage intensity and A) potassium content of the soil (r = −0.152, P > 0.05) and B) calcium content of the soil (r = 0.158, P > 0.05).
Kuva 25. Myyrätuhojen ja A) maaperän kaliumpitoisuuden (r = −0,152, P > 0,05) ja B) maaperän kalsiumpitoisuuden (r = 0,158, P > 0,05) välinen korrelaatio.

The highest potassium contents occurred in Imari and the SW part of Alajärvensuo, and the lowest in Suoloma-aapa. The correlation between the potassium content and the damage degree was non-significant in all areas: $r_{Su} = -0.156$, $r_{Al} = -0.169$, $r_{Sa} = 0.556$, $r_{Im} = -0.659$, and in the pooled data ($r = -0,152$, $n = 42$, $P > 0.05$) (Fig. 25A).

The highest calcium contents occurred in northern Suoloma-aapa and Sattasuo, and the lowest in Imari. The correlation between the calcium content and damage degree was significant only in Sattasuo ($r = 0.959$, $n = 6$, $P < 0.01$), but in other areas and in the pooled data non-significant ($r = 0.158$, $n = 42$, $P > 0.05$) (Fig. 25B). The nitrate contents were under 10 mg/l on all the plots, and could not be analyzed with the methods used by Viljavuuspalvelu.

The soil analysis results tor the vole damage areas were compared to those of undamaged comparison areas. The analyses revealed that the phosphorus content of the soil in drained peatlands was higher than that in undrained ones, but the calcium, potassium and magnesium contents were lower (Table 11).

345. Stand density

The correlation between stand density and degree of vole damage was not significant ($r = -0.202$, $n = 52$, $P > 0.1$) (Fig. 26). On the other hand, in Alajärvensuo where the stand was rather dense the negative correlation between stand density and damage degree was significant ($r = -0.677$, $n = 14$, $P < 0.001$). No correlation was found in the less dense stand at Verkkolahdenjänkä. The relationship between vole damage and stand density was not linear. Most damage occurred on plots with a mean density of between 1400—1700 pines/ha. The damage degree was lower when the density was higher or lower than this value.

Many of the areas had been thinned 1—3 years before the damage occurred. Heavy thinning carried out according to a thinning model (Vuokila 1971) had preceded the damage in Teuravuoma. Thinnings had also been done in Suoloma-aapa and in some of the plots in Rovaniemi.

The stand density was rather low in the fertilization study areas. The average density of all the study plots was 1363 trees/ha before the damage occurred. Three years

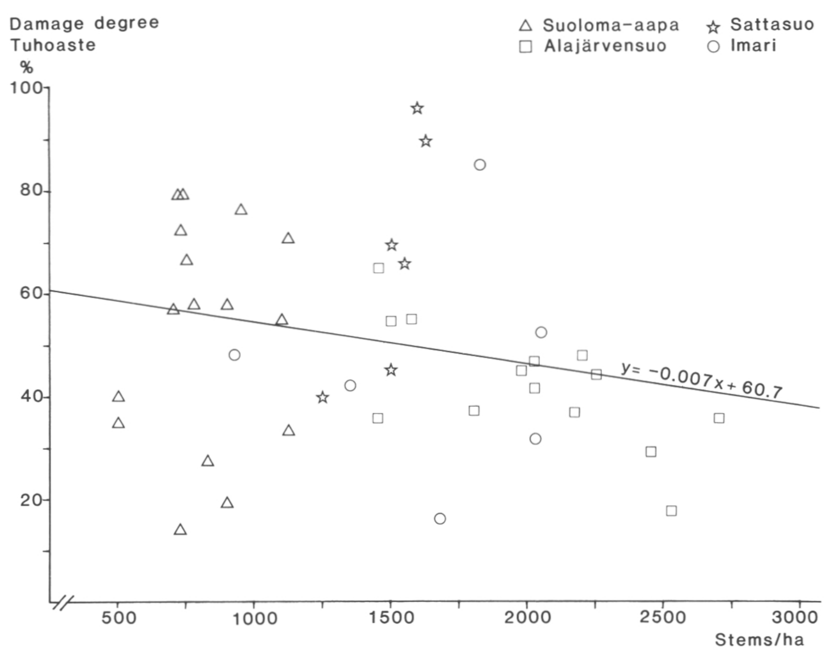


Fig. 26. Correlation between root vole damage intensity and the density of the stand (stems/ha) in advanced seedling and young thinning stands on peatlands ($r = -0.202$, $P > 0.1$).
Kuva 26. Myyrätuhojen ja puuston tiheyden (runkoa/ha) välinen korrelaatio riuku- ja kasvatusikäisissä metsissä turvemailla ($r = -0,202$, $P > 0,1$).

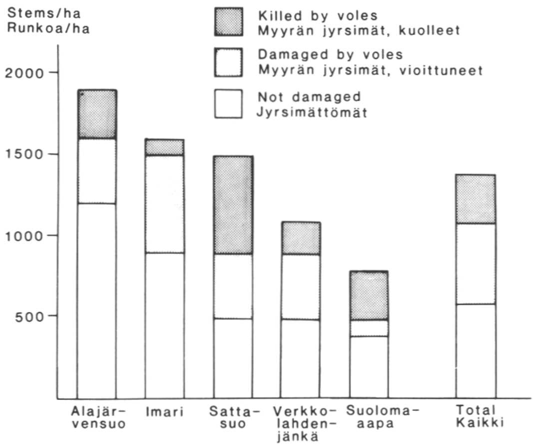


Fig. 27. The stand density of the fertilization study areas, prior to (whole column) and after the vole damage.
Kuva 27. Puuston tiheys lannoituskoealueilla ennen (koko pylväs) ja jälkeen myyrätuhojen.

after the vole damage the density of living trees was 1104 on the average, but only 695 trees/ha for undamaged trees (Fig. 27). The difference between the stand density before the damage and the density of the trees alive after the damage had occurred differed significantly from zero ($t = 7.34$, $df = 51$, $P < 0.001$), as did the difference between the density before the damage and the density of undamaged trees ($t = 14.66$, $df = 51$, $P < 0.001$).

According to the instructions of the Central Forestry Board, pine stands are considered to be understocked and underproductive if the number of stems is less than 60 % of the number recommended (Takala 1986). The recommendation for thinning stands varies between 1000—1300 stems/ha in northern Finland, depending on the fertility of the site. According to this classification, Sattasuo, four plots in Alajärvensuo and one in Verkkolahdenjänkä belonged to the group with a minimum of 1300 stems capable of development/ha; Imari, ten plots in Alajärvensuo, 14 plots in Suoloma-aapa and five in Verkkolahdenjänkä to the group of 1200 stems/ha, and four plots in Verkkolahdenjänkä and two in Suoloma-aapa to the group of 1000 stems/ha. Thus, prior to the damage, only Suoloma-aapa and part of Verkkolahdenjänkä were understocked, but after the vole damage all of the areas were underproductive (Fig. 27).

346. Vegetation

The field layer vegetation on the drained peatlands had changed as a result of ditching. *Betula nana* L. was more abundant and luxuriant on the drained peatlands than on the undrained ones. *Vaccinium vitis-idaea* and lichens were also more numerous on the drained peatlands, while *Andromeda polifolia* L. and *Equisetum fluviatile* L. dominated on undrained ones. The changes in plant cover in the fertilization study areas originated from draining, fertilization and thinning. As a whole, the vegetation was characterized by dwarf shrubs. The proportion of grasses and herbs varied from rather scarce to abundant.

The degree of vole damage was related to the occurrence of some plant species on the study plots. The occurrence of *Eriophorum vaginatum* L. was positively correlated with the damage degree, while the occurrence of *Empetrum* spp., *Vaccinium uliginosum* L. and *Andromeda polifolia* was negatively correlated with the damage degree (Table 12). The degree of vole damage was also compared to the vegetation according to physionomic plant groups (Kalliola 1973). The abundance of sedges and grasses was positively correlated with the damage degree ($r = 0.371$, $n = 42$, $P < 0.05$). On the other hand, the more dwarf shrubs there were, the lower the damage degree ($r = -0.463$, $n = 42$, $P < 0.001$) (Table 13). Dwarf shrubs in any

Table 12. Correlations between the intensity of the vole damage (proportion of trees damaged by voles) and the abundance of some common plant species.
Taulukko 12. Myyrätuhojen (jyrsittyjen puiden %-osuus koko puustosta) ja eräiden kasvilajien runsauden väliset korrelaatiot.

Plant species *Kasvilaji*	Correlation coefficient *Korrelaatiokerroin* r	Significant at the risk level *Merkitsevä (n = 42) riskitasolla*
Vaccinium vitis-idaea	−0.183	
Vaccinium uliginosum	−0.452	1 %
V. oxycoccos L. (+ *microc.*)	−0.243	
Betula nana	0.213	
Andromeda polifolia	−0.376	5 %
Empetrum spp.	−0.600	0.1 %
Ledum palustre L.	−0.157	
Menyanthes trifoliata L.	−0.044	
Rubus chamaemorus L.	−0.130	
Epilobium angustifolium	0.184	
Calamagrostis purpurea	0.088	
Carex chordorrhiza L. fil.	0.262	10 %
Eriophorum vaginatum	0.326	5 %

Table 13. Correlations between the intensity of the vole damage (proportion of trees damaged by voles) and the abundance of physionomic plant groups.

Taulukko 13. Myyrätuhojen (jyrsittyjen puiden %-osuus) ja fysionomisten kasviryhmien esiintymisen väliset korrelaatiot.

Plant group *Kasviryhmä*	Correlation coefficient *Korrelaatiokerroin* r	Significant at the risk level *Merkitsevä (n = 42) riskitasolla*
Equisetum spp. — *Kortteet*	−0.048	
Sedges and grasses *Sarat ja heinät*	0.367	5 %
Trees and bushes *Puut ja pensaat*	0.188	
Herbs — *Ruohot*	0.059	
Dwarf shrubs — *Varvut*	−0.463	1 %
Mosses — *Sammalet*	−0.228	
Lichens — *Jäkälät*	−0.287	10 %
Field layer *Kenttäkerros*	−0.181	
Litter — *Karike*	0.295	10 %

case were very abundant on all the damaged plots. However, the degree of damage diminished in cases where the abundance of dwarf shrubs restricted the occurrence of other plant groups.

The total number of plant species was 51 in the field layer and seven in the bush layer. Mosses and lichens occurred in the ground layer. Highly significant positive correlation was found between the number of plant species and the damage degree on the plots ($r = 0.535$, $n = 42$, $P < 0.001$). The damaged plots resembled each other according to diversity analysis (Table 14). The Shannon index correlated positively with the damage degree on the plots ($r = 0.384$, $n = 42$, $P < 0.05$). No correlation was found between the total coverage of the field layer and the damage degree.

A vegetation table was produced using a special vegetation table program (Appendix 4) (Mikkola, unpubl.). The study plots and

Table 14. Diversity analysis of the vegetation in the young thinning stands damaged or not damaged by voles. Damaged areas include the fertilization study areas numbers 1—10, 12—43 and Teuravuoma drained peatland numbers 54—57. Undamaged areas include Silva-plot number 11, Pohjasenvaara undrained peatland numbers 44—51, Muotkavuoma 52 and Juolamaa 53.

Taulukko 14. Pintakasvillisuuden diversiteettianalyysi kasvatusmetsien myyrätuhoaloilla ja vahingoittumattomilla vertailualoilla. Tuhoaloihin kuuluvat lannoituskoealat (1-10, 12-43) ja Teuravuoman ojitusalueen alat (54-57), vahingoittumattomiin Silva-ala (11) ja Pohjasenvaaran alat (44-51) sekä Muotkavuoma (52) ja Juolamaa (53).

Sample *Näyteala*	Species number *Lajiluku*	Simpson index D	Shannon index H'	Kempton index Q	Pielou index J'
1	27	0.724	1.855	0.000	0.563
2	25	0.674	1.680	0.000	0.522
3	19	0.884	2.403	4.343	0.816
4	22	0.688	1.801	7.935	0.583
5	17	0.690	1.603	7.282	0.566
6	16	0.728	1.690	4.971	0.609
7	20	0.781	1.897	5.139	0.633
8	16	0.717	1.604	7.282	0.578
9	14	0.657	1.466	3.907	0.556
10	22	0.748	1.877	15.870	0.607
11	13	0.583	1.331	3.728	0.519
12	14	0.724	1.668	3.366	0.632
13	17	0.660	1.594	7.282	0.563
14	17	0.676	1.578	7.282	0.557
15	13	0.675	1.657	3.728	0.646
16	14	0.650	1.455	3.907	0.551
17	18	0.631	1.540	5.592	0.533
18	17	0.681	1.564	0.000	0.552
19	16	0.731	1.778	3.031	0.627
20	17	0.682	1.749	4.971	0.617
21	19	0.673	1.642	9.102	0.558
22	13	0.632	1.313	8.656	0.512
23	15	0.707	1.573	4.465	0.581
24	17	0.696	1.692	4.111	0.597
25	18	0.722	1.633	12.984	0.565
26	13	0.697	1.573	2.885	0.613
27	20	0.759	1.973	4.809	0.659
28	19	0.853	2.279	5.139	0.774
29	18	0.697	1.683	5.023	0.582
30	19	0.714	1.788	5.139	0.607

Sample *Näyteala*	Species number *Lajiluku*	Simpson index D	Shannon index H'	Kempton index Q	Pielou index J'
31	23	0.810	2.199	8.656	0.701
32	26	0.645	1.632	0.000	0.501
33	22	0.814	2.103	10.013	0.680
34	19	0.681	1.637	14.427	0.556
35	13	0.589	1.217	8.656	0.475
36	18	0.681	1.713	6.492	0.593
37	19	0.637	1.709	5.581	0.580
38	18	0.830	2.144	4.625	0.742
39	18	0.713	1.786	12.984	0.618
40	16	0.675	1.501	11.542	0.542
41	23	0.727	1.876	7.456	0.598
42	18	0.656	1.670	5.023	0.578
43	11	0.710	0.608	2.606	0.671
44	17	0.842	2.188	4.900	0.772
45	20	0.914	2.626	5.974	0.877
46	19	0.899	2.489	4.809	0.845
47	15	0.833	2.103	3.970	0.777
48	19	0.907	2.619	15.810	0.890
49	19	0.890	2.465	5.581	0.837
50	27	0.907	2.727	8.276	0.827
51	21	0.823	2.241	6.213	0.736
52	21	0.900	2.528	4.551	0.830
53	11	0.834	2.067	7.610	0.862
54	14	0.864	2.197	4.916	0.833
55	15	0.810	2.057	4.028	0.759
56	13	0.830	2.081	4.269	0.811
57	14	0.870	2.226	3.616	0.843

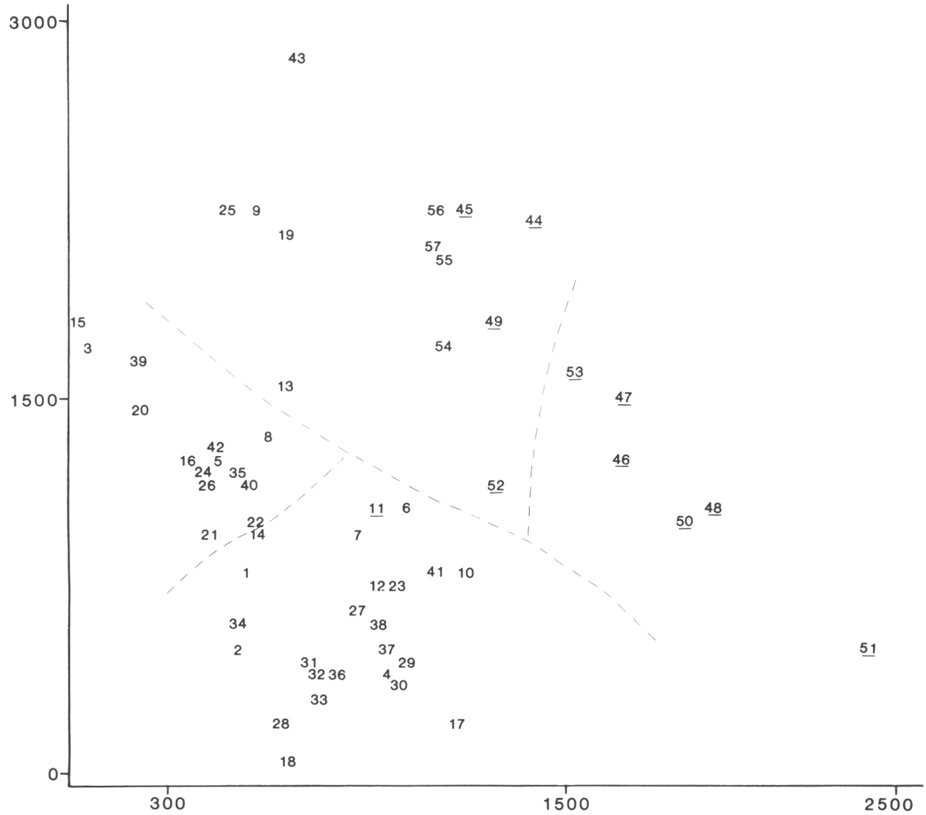


Fig. 28. DECORANA ordination analysis of the drained peatlands and undrained comparison areas. Ordination of sample plots in two axes according to the frequencies of plant species. Plot numbers 1—10, 12—43 and 54—57 damaged by voles, underlined numbers 11 and 44—53 undamaged. The clusters formed by TWINSPAN classification are shown with broken lines.

Kuva 28. Turvemaiden ojitusalojen ja ojittamattomien vertailualojen pintakasvillisuuden DECORANA-ordinaatioanalyysi. Näytealojen ordinaatio kahdella akselilla laskettuna kasvilajien esiintymisfrekvenssien perusteella. Myyrätuhot esiintyivät aloilla 1-10, 12-43 ja 54-57, tuhoja ei esiintynyt aloilla 11 ja 44-53 (alleviivatut). TWINSPAN-luokittelun avulla muodostetut ryhmät on erotettu katkoviivoin.

plant species were organized using DECORANA ordination analysis into two pairs of axes (Fig. 28). The analysis was made using species frequencies (eigenvalue = 0.404) and coverage (eigenvalue = 0.247). The threshold value for statistical significance in the analysis is considered to be 0.200. The main trend in the ordination was related to the moisture conditions, rather than to trophic levels. The plant species characterizing different peatland sites (Eurola and Kaakinen 1978) formed a continuum from spruce swamps to open fens (Fig. 29). Vegetation on the damaged plots differed from that on the undamaged plots and was associated with increasing moisture conditions. The order of the damaged plots did not correspond with either the damage degree or the phosphorus content of the soil.

Phytosociological classification of the material was done by CLUSTER and TWINSPAN analyses using species frequencies and coverages. CLUSTER analysis did not produce any relevant clusters. The best results for this material were given by TWINSPAN analysis based on species frequencies (Fig. 30). According to the TWINSPAN dendrogram, the plots were divided into two groups:

Fig. 29. Continuum formed by the plant species indicating different peatland site types (see Eurola and Kaakinen 1978) in the DECORANA ordination analysis based on the species frequencies. Plant species indicating pine bogs marked with R, spruce swamps with K, open bogs with N, open fens with L and forests with M.

Kuva 29. Eri suotyyppejä indikoivien kasvilajien (ks. Eurola and Kaakinen 1978) muodostama jatkumo DECORANA-ordinaatioanalyysissä lajien esiintymisfrekvenssien mukaan. Rämeitä indikoivat kasvilajit on merkitty R, korpia indikoivat K, nevoja N, lettoja L ja metsäisyyttä M.

I. *Eriophorum* group (38 plots) with two subgroups consisting of a) 12 plots at Alajärvensuo and one at Imari and b) one plot at Alajärvensuo, all of the plots at Sattasuo, the Silva comparison plot, one of the plots at Imari and all of the plots at Suoloma-aapa.

II. *Ledum* group (19 plots) with two subgroups consisting of a) one plot at Alajärvensuo, four at Imari, all of the damaged plots and four of the undamaged plots at Kolari and b) six undamaged plots at Kolari and Pajala.

The plant species were divided into two groups according to the results of frequency-based TWINSPAN and DECORANA analyses. Plant species typical to group I more or less indicated damage susceptibility. Such plants were *Eriophorum* spp., *Betula pubescens* Ehrh., *Potentilla palustris* (L.) Scop. and *Salix myrtilloides* L. Plant species more typical of the undamaged plots were *Ledum palustre* and *Vaccinium myrtillus.* Common species on all peatland study plots, both undamaged and damaged by voles, were *Betula nana, Vaccinium uliginosum, Andromeda polifolia* and *Rubus chamaemorus.* The coverage based analysis showed that *Betula nana* was more luxurious in drained (damaged) peatlands and *Andromeda polifolia* in undrained (undamaged) ones. The results of the ordination analyses were in agreement with the linear correlations between plant species and damage degree.

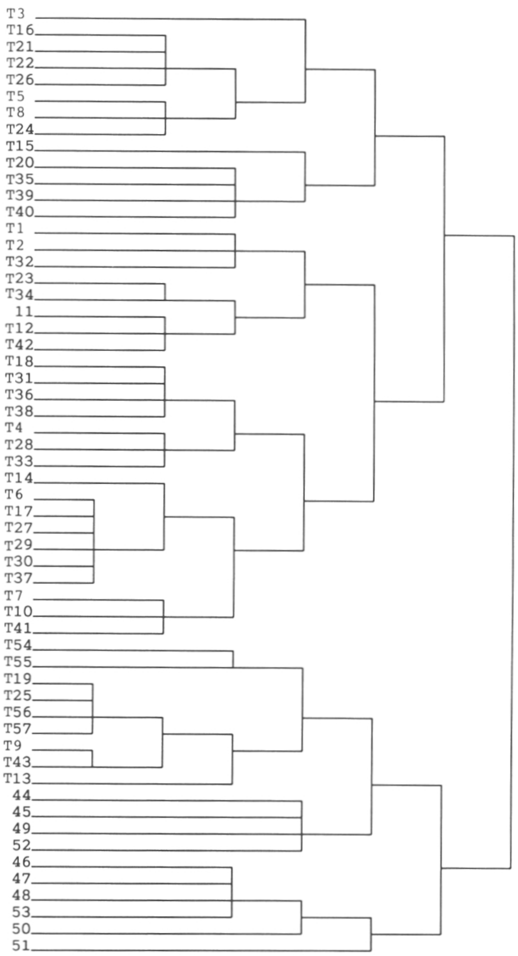


Fig. 30. TWINSPAN classification dendrograms of the drained and undrained peatland study plots based on frequencies of plant species. The plots with vole damage are marked with a T next to the plot number.

Kuva 30. Turvemaiden ojitusalojen ja ojittamattomien vertailualojen TWINSPAN-luokitteludendrogrammit kasvilajien esiintymisfrekvensseistä laskettuna. Myyrätuhoalat on merkitty T-kirjaimella alanumerojen edessä.

35. Discussion

351. Vole damage in thinning stands in other countries

The damage caused by the root vole in drained peatland forests has earlier been described in Finland only in the form of a minor report by the author of this manuscript (Korhonen et al. 1983). No reports of similar damage have been made from either northern Sweden or the Kola peninsula, except for a few observations in the Tornionjoki valley by Erkki Numminen (the Finnish Forest Research Institute, unpubl.). It may be that damage signs have not been found there. However, it is more likely that damage does not occur there to the same extent. The peatlands north of the Arctic Circle have not been drained in Sweden. Furthermore, in comparison to Finland there are less abandoned and cultivated fields in northern Sweden and on the Kola peninsula.

In most cases voles damage rather small seedlings such as those in the afforested fields in this study. Damage to older trees has usually been caused by climbing species such as *Clethrionomys glareolus* and *Cl. rufocanus* (Saalas 1949, Teivainen 1979, Nakatsu 1982, Timčenko 1983a, 1983b). In the Far East, as much as 90 % of the seedlings in pine plantations were damaged by voles during the peak year 1977—1978 (Timčenko 1986). The grey-sided vole had gnawed the bark above ground, and the far-eastern vole underground (Timčenko 1986).

In western Siberia the main vole species causing damage to both agriculture and forestry is the water vole, *Arvicola terrestris* (Maksimov 1977). Severe damage has also occurred in 20-year-old pine plantations, where water voles have gnawed the roots and bark at the butt (Nikolaeva 1971). In 1983 I was able to see damage of this kind in western Siberia and, although it appeared that the habitats were quite unlike those in Finland, the character of the gnawing resembled that of root vole damage in Finland. The water vole can cause minor damage in Finnish Lapland, too, but debarking of the butt is not typical of its behaviour in Finland.

In British Columbia, Canada, Townsend voles (*Microtus townsendii* Bachman) have caused damage in Douglas fir (*Pseudotsuga* *menziesii* Mirb.), western white hemlock (*Tsuga heterophylla* Sarg.) and western white pine (*Pinus monticola* Dougl.) stands less than 40 years of age by removing bark and cambium from stems, branches and roots (Harper and Harestad 1986). A common feature in the damage caused by Townsend voles in British Columbia and by root voles in northern Finland is that in most cases thinnings had preceded the damage.

352. Forest improvement methods and vole damage

The total area drained for forestry in Finland has been very much higher than that in the neighbouring countries (Braekke 1978). In Sweden, drainage is not considered to be profitable north of the Arctic Circle, and thus there are no drained peatlands in the range of the root vole. This may be the main reason why damage caused by the root vole has not been found in young thinning stands in Sweden.

The present study indicated that the root vole damage in advanced seedling and young thinning stands is a problem of drained peatlands. The fertilization of peatlands increased the damage susceptibility of pine stands. However, it is difficult, on the basis of the results, to distinguish between the effect of fertilization and drainage because both measures had been used on most plots. In any case, it is not possible in practice to raise a commercial forest on peatlands without using PK fertilization.

Nitrogen (N) is used on peatlands less than phosphorus and potassium. Nitrogen application is recommended only together with PK fertilization (Kaunisto and Paavilainen 1977). On the other hand, most of the information concerning the effect of fertilization on the susceptibility of trees to herbivores is about nitrogen fertilization. Nitrogen fertilization has been found to increase hare damage (Sullivan and Sullivan 1982, Bryant et al. 1983, Rousi 1983) and moose damage (Laine and Mannerkoski 1980, Löyttyniemi 1981). In the present study the NH_4 nitrogen contents of all the plots were lower than the critical values indicating a need for nitrogen fertilization (Kaunisto 1982). Besides the heavy damage on PK fertilization plots, damage was also found in this study inside reindeer fences, where the field vegetation had become grass-rich due to the fertilizing effect of reindeer grazing.

As well as increasing the growth of trees, draining and fertilization also increase the growth of the field vegetation: herbs, grasses and dwarf shrubs (Järvinen et al. 1977). The field layer vegetation retains 36 % of the nitrogen, 7 % of the phosphorus and 19 % of the potassium given as fertilizer (Heikurainen 1980). Fertilizing with phosphorus has strongly increased the plant biomass, the increase correlating directly with the increase in phosphorus. Nitrogen has only slightly increased the plant biomass, but the strongest effect was given by NPK fertilization (Heikurainen 1980). The coverages of *Eriophorum vaginatum* and *Epilobium angustifolium* increased both with increasing NPK fertilization and a narrower ditch spacing (Heikurainen and Laine 1976). The coverage of the shrub layer was not affected, but the height of the shrubs increased with more intense fertilization and narrower ditch spacing. The low temperature sum in northern Finland has a similar increasing effect on shrub growth (Heikurainen and Laine 1976). This explains the typical luxurious dwarf shrub layer of drained peatlands in northern Finland.

Schneider and Westman (1987) found that community trophic status correlated strongly with the phosphorus content of the peat. In their study on sedge pine fens, DECORANA ordination gave the trophic gradient as axis 1, and a hydrological gradient could not be interpreted.

According to Heikurainen (1980), the biomass of the field vegetation is at its greatest 3—4 years after fertilization. The changes in plant species composition caused by fertilization include an increase in species that rapidly utilize the added nutrients, at the expense of those species with a slow utilization ability (Chapin 1983). The changes in appearance, vegetation and ground water level due to draining and fertilizing are permanent. Dense stands of birch and willows appear along the ditches. The effect on *Eriophorum* spp. lasts for a long time, while that on herbs is shorter. On the other hand, the changes induced by draining are rather slow. Even in southern Finland the development towards transformed, heath type vegetation lasts at least 30—40 years (Sarasto 1952).

The results of the present study are in agreement with earlier reported effects of fertilization on the field vegetation. The main change in the habitat, due to draining and fertilization, was the increasing luxuriousness of the vegetation, which made a dense population of root voles possible. The most prominent difference between natural bogs and the drained fens and bogs was the richness of dwarf shrubs and some sedges and grasses.

The essential feature of a vole habitat is in fact the sufficiency of food and shelter. Before draining, many of the study plots had been natural pine bogs and swamps where root voles did not occur. Some of the plots had originally been flark fens, which are natural habitats of the root vole. In both cases, the habitat provided enough food and shelter after draining to attract voles and to make the increase in numbers possible. A very high root vole population rather rapidly destroys the sedge and grass vegetation, as was found to be the case in the afforested field areas. Consequently, the scarcity of high quality food in winter, combined with the normal tendency of voles to vary their food source, is the reason why the tree bark was eaten. During the snowless period the scarcity of food leads to the dispersion of young animals.

The effect of fertilization and even draining is not only a question of a change in habitat, but also a change in tree chemistry. Voles, as other herbivores, choose their food on the basis of both the nutritional quality and the presence of harmful substances in plants (Batzli 1983). The effect of harmful secondary compounds on feeding habits of mammalian herbivores has been emphasized in many recent studies (Löyttyniemi and Hiltunen 1978, Bryant and Kuropat 1980, Haukioja et al. 1983, Palo et al. 1983, Palo 1984, Bryant and Chapin 1985, Bryant et al. 1985, Tahvanainen et al. 1985, Helle et al. 1986, Lindroth and Batzli 1986). According to Dethier (1977), salt deficiency drive many vertebrates to use abnormal food while, on the other hand, hypersalinity in the plant has repelling effects. In any case, the changes in the trees brought about by fertilization favour the voles: both the nutrient content increases and the levels of harmful substances decrease.

353. Significance of root vole damage in forestry

The pines completely debarked around the stem by root voles during the winter still looked healthy the following summer. Later on the needles turn brown in colour and the trees will die. Although the trees with minor injuries remain more or less green for many years, the older needles are shed. This is the reason for the characteristic appearance of such a damage (Fig. 21).

Recovery of the damaged trees depends on the size of the debarked area, the root connections between trees and the conditions prevailing after damage. Timčenko (1983b) states that all trees with at least 90 % of the stem circumference debarked will die, and trees with more than 50 % debarked will suffer from retarded growth. Lodgepole pine (*Pinus contorta*), which is damaged by voles more than Scots pine (Hansson and Boström 1979), has a better ability to recover after vole damage than Scots pine (Hansson 1984). Even so, a reduction in growth and losses in timber quality took place in even slightly damaged seedlings (Hansson 1984).

The partially damaged trees are susceptible to secondary insect pests and diseases. The debarking scars initiated by voles may serve as entry ports for disease. The storm in autumn 1982 blew down great numbers of vole-damaged pines on peatlands. In western Siberia the water vole damage to older pines brought about the *Dentroctonus micans* (Kugelann) damage which rapidly killed the vole-damaged trees (author's own observation). The severe climate in northern Finland, cold winters and coolness and shortness of the growing season especially, can prevent the numbers of secondary insects (*Tomicus* spp., *Pissodes* spp.) from increasing, despite the availability of breeding material (Saarenmaa 1981).

In peatland forests consisting of advanced seedling and young thinning stands, thinnings are needed to ensure the growth of a commercial stand. Kuusela et al. (1986) proposed immediate (next 10-year-period) thinnings on a total of 60 km^2 in small-seedling stands, and 1329 km^2 in advanced seedling and young thinning stands in the NE Finland and southern Lapland Forestry Board Districts. In 1977, the year preceding root vole damage, thinnings were carried out on a total of 800 km^2 in Lapland (Metsätilastollinen... 1979). After heavy silvicultural measures and pre-commercial thinnings the field vegetation often becomes rich in grasses and herbs, which leads to the development of a favourable habitat for the root vole.

In the present study the Teuravuoma drained peatland was a typical example of an advanced seedling stand, which had been thinned pre-commercially according to the instructions. Now, following the root vole damage, it has a too low stocking density. Most of the fertilization areas in this study had also been thinned a few years before the damage. Also Virtanen et al. (1984) state that very severe vole damage has occurred after thinnings on study plots sited on peatlands in northern Finland. Recently Ikäheimo and Norokorpi (1986) stated that the amount of vole damage to the butt of trees on thinned study plots was 2—3 times higher than that on the plots not thinned. Besides the changes in habitat quality, the greater incidence of debarking by voles in thinned stands may have occurred because of the increased vigor of the trees. The Townsend vole has also been found to debark naturally regenerated Douglas-fir in thinned stands more than in unthinned ones (Harper and Harestad 1986). In this Douglas-fir study there were over 10 000 stems/ha in unthinned stands and 625—1225 in thinned.

Some recent studies carried out on peatlands in Finland support the present recommendations, i.e. no more than 2000—2500 seedlings/ha (Kaunisto and Tukeva 1986). This does not take into account the risk of vole damage. On the other hand, Kaunisto and Päivänen (1985) recommend denser stands on peatlands in northern Finland due to the damage risks.

As a result of vole damage, Scots pine stands became under-productive: Sattasuo, Verkkolahdenjänkä and Suoloma-aapa even below the level (500—700 stems/ha) at which there is a reasonable certainty of raising a stand (Hyvärinen 1986). Thus root vole damage can be of considerable economic importance. Draining, fertilization and silvicultural measures are expensive in remote forests and, if the forest becomes understocked and is no longer worth growing after 20—30 years, economical losses are high.

The risk of root vole damage depends on the luxury of the field layer vegetation in the stand. Afforested field areas are thus very vulnerable at a young age. The pine stands regenerated on open fens by means of draining and fertilizing are susceptible later on at the advanced seedling and young thinning stages. All silvicultural measures, such as heavy thinning and fertilization, which promote the luxurious growth of field vegetation, increase the risk of vole damage.

4. GENERAL DISCUSSION AND CONCLUSIONS

41. Comparison with earlier studies

The importance of the root vole as a damaging agent of forest trees, ranging from the small seedling stage to the thinning stage, was revealed in this study. Earlier studies on vole damage in Lapland have shown that the most prominent damage in plantations occurred during 1973—1974 and 1977—1978, but less in the 1980's (Teivainen 1979, Korhonen et al. 1983). According to our knowledge of the feeding habits of voles (e.g. Kalela 1957, 1962, Koškina 1957, Myllymäki 1959, 1975, Tast 1968b, Tast and Kalela 1971, Hansson and Zejda 1977, Teivainen 1978), the root vole, the field vole, the grey-sided vole, the bank vole and the water vole can be potential damaging agents of forest trees in northern Finland. To date, only the root vole has caused damage to coniferous trees on a considerable scale in this region.

Vole catches obtained on the study plots of this study, as well as those elsewhere by Kaikusalo (unpubl.), revealed that most of the damage in afforested field areas and drained peatlands is caused by the root vole. In addition, during the peak in 1977—1978 the root vole was found to be the most common vole species on abandoned fields ranging from northern Lapland to Simo and Kuivaniemi, 100 km to the south of the previously known edge of its distribution range (see Siivonen 1967).

Feeding experiments have shown that, compared to most of the other vole species, the root vole eats a lot of roots (Tast 1974, Teivainen 1978). The results of this study are in good agreement with this. The proportion of bark in the diet of the root vole has often been underestimated, due to the fact that the root vole eats bark almost exclusively during the winter. Most authors who have studied the winter food of the root vole have stated that bark makes up an important proportion of its winter diet (Barabaš-Nikoforov 1946, Karaseva et al. 1957, Fetisov 1958).

The appearance of the study plots in the present study indicated a deficit of food plants during wintertime before the population decline. This can mean that tree bark is eaten mainly during starvation conditions. In addition to the amount of food, the accessibility of the food is also vital. Thus the conditions during the winter, especially the structure of the snow, become important. During such winters when other food, e.g. green shoots preserved under the snow becomes scarce or hard to reach, the voles eat much more bark.

Dinesman (1961) has found that eating of bark in winter by the social vole (*Microtus socialis* Pallas) is affected by the previous growing season as follows:

Winter	Characteristics of grass growth during previous summer and state of the vegetation in winter	Role of woody plants in winter food of voles
1950/51	Growth of steppe vegetation ceased in summer.	Depression in vole numbers. No diet study.
1951/52	Growth of steppe vegetation was normal.	Depression in vole numbers. No diet study.
1952/53	Summer and autumn growth of the steppe vegetation was exceptionally good. Grasses stayed green under snow.	Vole diet consisted of vegetative parts and seeds of grasses. Woody plants were eaten rarely.
1953/54	Drought caused a stop in the growth of the steppe vegetation during summer.	Proportion of woody plants was 13—20 % of the winter diet.
1954/55	Drought halted the growth of the grasses in summer.	Woody plants were eaten very often.
1955/56	Grasses withered out at the end of May. No autumn growth of the grasses existed. An ice layer, 5—12 cm deep, covered the ground in winter.	Main food of the voles was woody plants.

Timčenko (1983b) states that, in the Far-East, the grey-sided vole causes damage to forest trees especially during winters when the snow layer is thick and the temperature conditions in the burrows of the vole colonies are optimal. Thus a large proportion of the population overwinters and, after eating up the high-calorific food available, starts debarking trees (Timčenko 1983b). This could be the explanation for the fact that root vole damage does not always coincide with high vole populations. On the other hand, there is some evidence that voles eat bark in spring in spite of the availability of other food, e.g. seeds of trees and bushes (Timčenko 1987). It can also be thought that a proportion of the root voles is specialized in eating bark. Ecomorphological differences of this type are found in western Siberia between lake, bog, and meadow phenotypes of the water vole (Nikolaeva 1981).

Voles, as well as hares, usually prefer broad-leaved trees to coniferous trees. During this study, however, mountain hares (*Lepus timidus* L.) were rather often found to have eaten the bark above the snow level of the same pines which the root vole had gnawn under the snow. The explanation for this is unknown.

Earlier reports of the root vole as a damaging agent of forest trees are scarce. In Poland the species caused damage to seedlings of broad-leaved trees on drained peatlands with a rich growth of grasses (Gebczyńska 1969, Buchalczyk et al. 1970). In contrast to this study, Scots pine was not gnawed at all. In the Krasnojarsk region vole damage has also occurred in pine and spruce-fir plantations (Švecova 1984). Stomach and leftover analyses of voles showed that the species responsible for the damage were the root vole, the field vole, the grey-sided vole, the narrow-skulled vole (*Microtus gregalis* Pallas) and the bank vole (Švecova 1980, 1984).

42. Old fields and peatland forests as root vole habitats

The present study deals with root vole damage in two rather different habitats: abandoned fields and pine forests on peat bogs. Abandoned fields seem to be optimal biotopes for root voles. The vole population can survive there during depression years, and their reproduction centres are also situated there. In older fields the root voles reproduce quickly and the population density can grow to over 400 voles/ha (Mäenpää 1985).

In afforested fields voles obtain all the food they need. Grasses, sedges and herbs in summer, underground organs of plants, green shoots preserved under the snow and the bark of willows and trees in winter are present in amounts sufficient to support a growing population. As a result of the luxurious growth of grass and often ploughing with forest machines, the afforested fields also provide plenty of cover for nesting burrows and runways. Dispersion from overcrowded field populations most often occurs during the autumn when the root voles move to new wintering sites.

The root vole moves more often and over longer distances than other vole species. Even the female changes its home range after every litter, the distance between different nesting sites being 15—140 m. Males have been found to move around an area of 5000 square meters during a single summer month (Tast 1966). The distance between summer and winter habitats is usually 20—200 meters, but young animals may migrate several kilometers (Tast 1966, Balahonov 1976). According to Tast (1966), most of the young root voles leave their native bogs before the end of the summer. Erdakov (1981b) has found that mature root voles orientate themselves to a new habitat quicker than young ones, but young voles move around actively to explore the new area.

In fact the root voles also change their range in winter. The root vole communities examined once every two weeks near Irkutsk had changed their site each time, and old exits had disappeared under the snow (Zonov 1962). These earlier studies support the idea that the root voles moving out from abandoned fields cause damage in peatland forests. It is still unknown whether the voles migrating from the surrounding areas cause the damage or whether it is their offspring which has become abundant on the drainage areas.

Some of the habitats on drained peatlands were dominated by grasses and sedges, e.g. the drained fens in Suoloma-aapa and Verkkolahdenjänkä. In most of the damaged stands the vegetation was characterized by luxurious dwarf shrubs, e.g. in Alajärvensuo and Teuravuoma. For large animals such as the moose (*Alces alces* L.) and for game birds these areas are very inaccessible, but voles which move under shrubs and along ditches profit from the good cover. In addition, the slopes of the ditches provide good nesting sites. The food selection on peat bogs is rather different from that on fields. Sedges, grasses and herbs are more scarce, and hence the amount of green summer food is restricted. On the other hand, the bark of woody plants is abundant and the varying snow cover with plenty of holes maintains a supply of green shoots well through the winter.

Compared to natural biotopes, the old fields are equal to flooded meadows and flark fens. In old fields, however, the root vole can stay all year and does not need special summer and winter habitats. The vegetation in hay fields is usually higher than that on aapa-fens, and hence the abandoned fields are more optimal for the root vole than their natural habitats. The drained peatlands resemble shrublands along river shores and the hummocks of open aapa-fens, i.e. the natural winter habitats of the root vole.

Furthermore, the vole catches indicated that drained peatlands serve as winter biotopes for root voles which have migrated from surrounding meadows, flark fens and abandoned fields, while on the afforested fields the catches were high during winter and summer. During summer 1981 when root voles were abundant in optimal grassland habitats in Rovaniemi, no voles of any species were caught, despite trapping on 200 trap nights, in the less optimal Sattasuo and Alajärvensuo study plots nearby. Although the differences in field vegetation between afforested fields and drained pine fens were clear, the luxurious growth of the field layer vegetation, typical for both habitats, distinguishes the damaged areas from most habitats on mineral soil sites in Lapland.

The survival of overwintering voles depends on the snow cover. If the snow is less than 20 cm deep, it will not provide enough cover for voles in an air temperature of −20°C (Timčenko 1986). The snow forms drifts on both ploughed afforested fields and drained peatlands, and even in winters with little snow it is deep enough in places. In many winters the depth of the snow cover in southern and central Lapland even exceeds the minimum needed for winter reproduction of the root vole (Tast and Kaikusalo 1976).

The age of the damaged trees was the most prominent difference between the afforested fields and drained peatlands. In the fields, damage was the heaviest to small seedlings, while in peatland stands the damage occurred on trees ranging from 1—10 m in height, no strong preference being shown for tree size or age. In British Columbia the Townsend vole showed a similar pattern, no preference for size and age occurring over the DBH range of 0—19 cm and age of 8—33 years (Harper and Harestad 1986).

The most important feature common to the afforested fields and drained peatlands was that both of them were man-made biotopes. New ecological niches are always filled, new habitats will be occupied sooner or later by animal species with a good adaptive capacity. The changes in vegetation and other conditions regulate this phenomenon. When man-made habitats are created and exploited for economic activities, new invading species will most likely cause damage of some significance.

43. Impact of man

In northern Finland the most prominent changes in land use have been the clearing of forest for fields after World War II, the abandoning of fields in the 1970's, the sudden increase in clear-cutting and artificial reforestation, as well as draining of peatlands for agriculture and forestry. All these habitat alterations have taken place during a period of some 20—30 years. As a consequence the voles have become a major problem for modern forestry.

Similar development in the Krasnojarsk region, Siberia, has led to a total change in the species composition of small rodents. Up until 1966 the area of plantations accounted for 20 % of the forest land in Krasnojarsk, but in 1973 it was more than 40 % (Švecova 1980). As a result, the previously common ruddy vole (*Clethrionomys rutilus*) became rare and other species (*Microtus oeconomus, M. agrestis, M. gregalis, Cl. rufocanus* and *Cl. glareolus*) occupied the new habitats (Švecova 1980). Equal effects on small mammal communities as a result of changes in land use are known from all over the world (Hansson 1975, 1978, Larsson 1976, Marcström 1977, Bejček 1981, 1982, Monthey and Soutiere 1985, Happold and Happold 1987.)

One of the most striking habitat alterations due to human influence has occurred in the Krusne Hory mountains in Czechoslovakia where air pollution has killed the conifer forests. Increased light under the canopy has changed the field layer vegetation totally into grassland. The plantations of *Picea pungens* Engelm., the only conifer which has tolerated heavy emissions, have as a consequence suffered from damage caused by the field vole, a species earlier very rare in the area (Tichy 1987 and the author's own observations 1985).

The numbers of voles and their damage to forest plantations have increased throughout Fennoscandia since the end of the 1950's (Larsson 1973, Christiansen 1975, Teivainen 1979). According to Christiansen (1979), the increase in vole damage in Norway is connected with changes in land use such as the increase in the afforestation of fields and the start of artificial reforestation. Timčenko (1986) states that the vast areas of clear-cutting and abundance of plantations in the Far East have caused changes in field vegetation, thus bringing about the increase in vole numbers. The vegetation on clear-cut areas on mineral soil resembles that of afforested fields. Light-demanding species dominate and short-lived growth of *Epilobium angustifolium, Rubus idaeus* L. and *Vaccinium vitis-idaea* is usual. In the mesic dwarf shrub type the transition from *V. myrtillus* to the grass *Deschampsia flexuosa* is typical after clear-cutting (Marcström 1977).

The changes in the peatland habitats caused by forest improvement measures, draining and fertilization, are as deep-going. For game animals the drained peatlands are considered to be both favourable and unfavourable (Karsisto 1974, Veijalainen 1974, Järvinen et al. 1977, Rajala and Linden 1982). The root vole, on the other hand, seems to have only benefited of the habitat alterations, and in consequence become a threat to pine forests.

REFERENCES

Agibaev, A. Z. 1979. Ekologija polevok v lesnyh ugod'ah Vostočnogo Kazahstana. In: Gryzuny-vrediteli sel'skohozjaistvennyh rastenij. Alma-Ata. Sbornik naučnyh trudov, VO VASHNIL XV: 125—143.

Ahvenainen, J. 1982. Kaksisataa vuotta Lapin metsätaloutta. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 82—89.

Balahonov, V. 1976. Uslovija zimovki myševidnyh v lesotundre Priobja. Ekologija 4: 96—98.

Barabaš-Nikoforov, I. 1946. Nekotorye nabludenija nad krysogolovoj *Microtus ratticeps stimmingi* Nehring. Bjulleten' Moskovskogo Obščestva Ispytanija Prirody, otdel biologij 51: 19—24.

Bärring, U. 1963. Sorkskador på tall- och granplantor under 1961—62. Summary: Damages caused by voles on seedlings of Scots pine and Norway spruce in 1961—62. Svenska Skogsvårdsföreningens Tidskrift 1. 40 p.

Batzli, G.O. 1983. Responses of arctic rodent populations to nutritional factors. OIKOS 40: 396—406.

Bejček, V. 1981. Vliv lesnicke rekultivace vysypek po povrchove hnědouhelne těžbě na společenstva drobnych savcu. Summary: Impact of the forestry recultivation of spoil banks after brown coal surface mining on the communities of small mammals. Sbornik okresniho muzea v Mostě. Řada přirodovědna 3: 117—131.

— 1982. Sukcese společenstev drobnych savcu v ranych vyvojovych stadiich vysypek v Mostecke kotlině. Summary: The succession of small mammal communities in the early development stages of spoil banks in the basin of Most. Sbornik okresniho muzea v Mostě. Řada přirodovědna 4: 61—86.

Braekke, F. 1978. Afforestation on peatland in Norway. Norsk Institutt for skogforskning (NISK), Ås, IPS-symposium: 72—96.

Bryant, J. P. & Chapin, F. S. III. 1985. Adaptation to resource availability as a determinant of chemical defense strategies in woody plants. Recent Advances in Phytochemistry 19: 219—237.

— , Chapin, F. S. & Klein, D. R. 1983. Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. OIKOS 40: 357—368.

— & Kuropat, P. J. 1980. Selection of winter forage by subarctic browsing vertebrates: The role of plant chemistry. Annual Review of Ecology and Systematics 11: 261—285.

— , Wieland, G. D., Clausen, T. & Kuropat, P. 1985. Interactions of snowshoe hare and feltleaf willow in Alaska. Ecology 66(5): 1564—1573.

Buchalczyk, T., Gebczynska, Z. & Pucek, Z. 1970. Numbers of *Microtus oeconomus* (Pallas, 1776) and its noxiousness in forest plantations. EPPO-publications Series A, 58: 95—99.

Chapin, F. S. 1983. Nitrogen and phosphorus nutrition and nutrient cycling by evergreen and deciduous understory shrubs in an Alaskan black spruce forest. Canadian Journal of Forest Research 13(5): 773—781.

Christiansen, E. 1975. Field rodent damage in Norway. Ecological Bulletin 19: 37—45.

— 1979. Skog- og jordbruk, smågnagere og rev. Noen tanker om hvordan driftsendringene i landbruket kan ha påvirket bestanden av enkelte dyrearter. Tidsskrift för Skogbruk 3: 115—119.

— 1981. Smågnagerskader på skogen i Norge 1971—78. Summary: Damage by small rodents in the Norwegian forests 1971—78. Norsk Institutt for Skogforskning (NISK), rapport 11: 1—24.

Dethier, V. G. 1977. The taste of salt. American Scientist 65: 744—751.

Dinesman, L.G. 1961. Vlijanie dikih mlekopitajuščih na formirovanie drevostoev. Izdatel'stvo Akademii Nauk. Moskva. 165 p.

Erdakov, L. N. 1981a. Sezonnaja cikličnost' v populjacijah gryzunov pojmy Obi. In: Maksimov, A.A. (Ed.). Sukcessii životnogo naselenija v biocenozah pojmy reki Obi. Nauka. Novosibirsk. p. 146—154.

— 1981b. Territorial'no-issledovatel'skoe povedenie polevki-ekonomki v pojme reki Obi. Summary: Territorial-exploratory behaviour of a tundra vole in the Ob river water meadow. Izvestija Sibirskogo Otdelenija Akademii Nauk, Serija biologičeskih nauk 2: 127—132.

— 1984. Organizacija ritmov aktivnosti gryzunov. Nauka. Novosibirsk. 179 p.

Etholen, K. & Saarnio, R. 1977. Kivalon kokeilualueen retkeilykohteiden selostukset. Metsäntutkimuslaitos. Helsinki. 82 p.

Eurola, S. & Kaakinen, E. 1978. Suotyyppiopas. WSOY. Porvoo. 87 p.

Fetisov, A.S. 1958. Materialy po ekologii polevki-ekonomki (*Microtus oeconomus* Pallas) v Vostočnoj Sibiri. Summary: Data on ecology of *Microtus oeconomus* Pallas in East Siberia. Bjulleten' Moskovskogo Obščestva Ispytanija Prirody, otdel biologij 63(2): 55—60.

Gauch, H.G. 1982. Multivariate analysis in community ecology. Cambridge University Press, New York. 298 p.

Gebczynska, Z. 1969. Nornik polnocny — *Microtus oeconomus* (Pallas, 1776) szkodnik upraw lesnych. Sylwan 4: 57—60.

Grodzinski, W. 1971. Food consumption of small mammals in the Alaskan taiga forest. Annales Zoologici Fennici 8: 133—136.

Häkkilä, M. 1984. Geographical aspects of the development and utilization of arable land area in Finland. Fennia 162(2): 217—235.

Hämet-Ahti, L., Suominen, J., Ulvinen, T., Uotila, P. & Vuokko, S. (Eds.). 1986. Retkeilykasvio. III edition. Helsinki. 598 p.

Hansson, L. 1975. Effects of habitat manipulation on small rodent populations. Ecological Bulletin 19: 163—173.

— 1978. Small mammal abundance in relation to environmental variables in three Swedish forest phases. Studia Forestalia Suecica 147: 1—40.

— 1984. Återhämtningskapacitet hos contorta-tall efter sorkangrepp. Summary: Regeneration capacity of *Pinus contorta* seedlings after vole attacks.

Sveriges Skogsvårdsförbunds Tidskrift 82(6): 13—16.
— & Boström, U. 1979. Sorkskador på contortakulturer. Sveriges Skogsvårdsförbunds Tidskrift 77(5-6): 19—25.
— & Larsson, T.-B. 1980. Smågnagarskador i svenskt skogsbruk under 1970-talet. Summary: Small rodent damage in Swedish forestry during 1971—1979. Swedish University of Agricultural Sciences, Department of Wildlife Ecology. Uppsala. Rapport 1, 64 p.
— & Zejda, J. 1977. Plant damage by bank voles (*Clethrionomys glareolus* (Schreber)) and related species in Europe. EPPO Bulletin 7(2): 223—242.
Happold, D.C.D. & Happold, M. 1987. Small mammals in pine plantations and natural habitats on Zomba Plateau, Malawi. Journal of Applied Ecology 24: 353—367.
Harper, P. A. & Harestad, A. S. 1986. Vole damage to coniferous trees on Texada island. The Forestry Chronicle 62(5): 429—432.
Haukioja, E., Huopalahti, R., Kotiaho, J. & Nygren, K. 1983. Millaisia männyntaimia hirvi suosii? Summary: The kinds of pine preferred by moose. Suomen Riista 30 : 22—27.
Heikurainen, L. 1980. Metsäojituksen alkeet. II edition. Gaudeamus. Helsinki. 284 p.
— 1986. Suo-opas. IV edition. Kirjayhtymä. Helsinki. 51 p.
— & Laine, J. 1976. Lannoituksen, kuivatuksen ja lämpöolojen vaikutus istutus- ja luonnontaimistojen kehitykseen rämeillä. Summary: Effect of fertilization, drainage and temperature conditions on the development of planted and natural seedlings on pine swamps. Acta Forestalia Fennica 150: 1—38.
Helle, E., Tahvanainen, J., Julkunen-Tiitto, R. & Uotila, I. 1986. Miten ja miksi metsäjänis valikoi talviravintonsa? Summary: How and why does the mountain hare select its winter diet? Suomen Riista 33: 111—120.
Hokajärvi, P. 1982. Lapin metsät ja uudenaikainen metsätalous. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 125—129.
Hyvärinen, E. 1986. Taimikon hoito. Tapion taskukirja. XX edition. Gummerus. Jyväskylä. p. 191—199.
Ikäheimo, E. & Norokorpi, Y. 1986. Perkauksen vaikutus männyn istutustaimikoiden kehitykseen, laatuun ja tuhoihin Pohjois-Suomessa. Summary: The effect of cleaning on the incidence of damage and the development and quality of Scots pine plantations in northern Finland. Folia Forestalia 647. 49 p.
Itkonen, T. J. 1948a. Suomen Lappalaiset vuoteen 1945. I. WSOY. Porvoo. 589 p.
— 1948b. Suomen Lappalaiset vuoteen 1945. II. WSOY. Porvoo. 629 p.
Ivanter, E.V. 1986. Mlekopitajuščie. Životnyj mir Karelii. II edition. Karelija. Petrozavodsk. 224 p.
— & Ivanter, T.V. 1986. K ekologii temnoj polevki (*Microtus agrestis* L.). In: Ivanter, E.V. (Ed.). Ekologija nazemnyh pozvonočnyh Severo-Zapada SSSR. Petrozavodsk, Karel'skij filial AN SSSR. p. 64—91.
Jaatinen, S. 1982. Itsenäisyyden ajan asuntopolitiikka Lappia muovaamassa. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 198—215.
— & Alalammi, P. 1978. The field-reservation scheme of Finland 1969-1977. Nordia 12(1): 13—30.
Järvinen, O., Kuusela, K. & Väisänen, R. 1977. Metsien rakenteen muutoksen vaikutus pesimälinnustoomme viimeisen 30 vuoden aikana. Summary: Effects of modern forestry on the numbers of breeding birds in Finland in 1945—1975. Silva Fennica 11(4): 284—294.
Jukola-Sulonen, E.-L. 1983. Vegetation succession of abandoned hay fields in Central Finland. A quantitative approach. Seloste: Kasvillisuuden sukkessio viljelemättä jätetyillä heinäpelloilla Keski-Suomessa kvantitatiivisin menetelmin tarkasteltuna. Communicationes Instituti Forestalis Fenniae 112. 85 p.
Kalela, O. 1957. Regulation of reproduction rate in subarctic populations of the vole *Clethrionomys rufocanus* (Sund.). Annales Academiae Scientiarum Fennicae (A IV) 34. 60 p.
— 1962. On the fluctuations in the numbers of arctic and boreal small rodents as a problem of production biology. Annales Academiae Scientiarum Fennicae (A IV) 66. 38 p.
Kalliola, R. 1973. Suomen kasvimaantiede. WSOY. Porvoo. 308 p.
Karaseva, E.V., Korenberg, E.I. & Merkova, M.A. 1960. Melkie mlekopitajuščie central'noj Jakutii i ih značenie v prirodnyh očagah nekotoryh boleznej čeloveka. Zoologičeskij Žurnal 39(11): 1690—1698.
— , Narskaja, E.V. & Bernstein, A.D. 1957. Polevka-ekonomka, obitajuščaja v okrestnostjah ozera Nero, Jaroslavskoj oblasti. Summary: The *Microtus oeconomus* inhabiting the neighbourhood of lake Nero in Yaroslav region. Bjulleten' Moskovskogo Obščestva Ispytanija Prirody, otdel biologii 62(3): 5—18.
Karsisto, K. 1974. Metsänparannusalueet riistan kannalta. Summary: Forest amelioration and the stocks of game. Suo 25(2): 35—40.
Kaunisto, S. 1982. Development of pine plantations on drained bogs as affected by some peat properties, fertilization, soil preparation and liming. Seloste: Männyn istutustaimien kehityksen riippuvuus eräistä turpeen ominaisuuksista sekä lannoituksesta, muokkauksesta ja kalkituksesta ojitetuilla aloilla. Communicationes Instituti Forestalis Fenniae 109. 56 p.
— & Paavilainen, E. 1977. Response of Scots pine plants to nitrogen refertilization on oligotrophic peat. Seloste: Typpijatkolannoituksen vaikutus männyn taimien kehitykseen karulla turvealustalla. Communicationes Instituti Forestalis Fenniae 92(1). 54 p.
— & Päivänen, J. 1985. Metsänuudistaminen ja metsittäminen ojitetuilla turvemailla. Kirjallisuuteen perustuva tarkastelu. Summary: Forest regeneration and afforestation on drained peatlands. A literature review. Folia Forestalia 625. 75 p.
— & Tukeva, J. 1986. Kasvatustiheyden vaikutus männyn istutustaimikoiden kehitykseen turvemailla. Summary: Effect of tree spacing on the development of pine plantations on peat. Folia Forestalia 646. 36 p.
Kempton, R. A. & Taylor, L. R. 1976. Models and statistics for species diversity. Nature 262: 818—820.
Korhonen, K.-M. 1981. Lapinmyyrä, *Microtus oeconomus* (Pallas), Pohjois-Suomen taimikoiden tuholaisena. Manuscript. University of Helsinki, Department of Environmental Conservation. 55 p.
— 1985. Varttuneiden metsien myyrätuhot metsäta-

loustoimenpiteiden seurannaisena Pohjois-Suomessa. Manuscript. University of Helsinki, Department of Environmental Conservation. 100 p.
— , Teivainen, T., Kaikusalo, A., Kananen, A. & Kuhlman, E. 1983. Lapinmyyrän aiheuttamien tuhojen esiintyminen Pohjois-Suomen mäntymetsissä huippuvuoden 1978 jälkeen. Summary: Occurrence of damage caused by the root vole (*Microtus oeconomus*) on Scots pine in northern Finland after the peak year 1978. Folia Forestalia 572. 18 p.
Koškina, T.V. 1957. Sravnitel'naja ekologija ryžih polevok v Severnoj tajge. Fauna i ekologija gryzunov 5. Izdatel'stvo MGU. Moscow. p. 3—65.
Kostian, E. 1970. Habitat requirements and breeding biology of the root vole, *Microtus oeconomus* (Pallas), on shore meadows in the Gulf of Bothnia, Finland. Annales Zoologici Fennici 7: 329—340.
Kujala, V. 1979. Suomen metsätyypit. Abstract: Forest types of Finland. Communicationes Instituti Forestalis Fenniae 98(8). 45 p.
Kurki, M. 1982. Suomen peltojen viljavuudesta III. Helsinki. 181 p.
— , Lakanen, E., Mäkitie, O., Sillanpää, M. & Vuorinen, J. 1965. Viljavuusanalyysien tulosten ilmoitustapa ja tulkinta. Summary: Interpretation of soil testing results. Annales Agriculturae Fenniae 4: 145—153.
Kuusela, K. 1979. Tutkimustoiminta Lapin metsien hoidon ja käytön suuntaajana: Metsäteollisuuden laajentuminen. Silva Fennica 13(1A): 19—22.
— , Mattila, E. & Salminen, S. 1986. Metsävarat piirimetsälautakunnittain Pohjois-Suomessa 1982—1984. Summary: Forest resources in North Finland by Forestry Board Districts, 1982 to 1984. Folia Forestalia 655. 86 p.
Laine, J. & Mannerkoski, H. 1980. Lannoituksen vaikutus männyntaimikoiden kasvuun ja hirvituhoihin karuilla ojitetuilla nevoilla. Summary: Effect of fertilization on tree growth and elk damage in young Scots pine stands planted on drained, nutrient-poor open bogs. Acta Forestalia Fennica 166. 45 p.
— , Päivänen, J., Schneider, H. & Vasander, H. 1986. Site types at Lakkasuo mire complex. Field guide. Tiivistelmä: Suojuoksu. Suotyyppinäytealojen retkeilyreitti. Publications from the Department of Peatland Forestry, University of Helsinki, 8. 35 p.
Lapin maatalous 1959—1969. 1975. Lapin seutukaavaliitto. Series A, publ. 9. 107 p.
Lapin maatalous-2000. 1986. Lapin maatilatalouden kehittämisneuvottelukunta. Rovaniemi. 31 p. + 11 app.
Lapin maatalousmaa-alueet. 1981. (Cultivated land in Lapland). Lapin seutukaavaliitto. Series A, publ. 47. 81 p.
Larsson, T.-B. 1973. Smågnagarskador på skogskulturer i Sverige 1900—1970. Institutionen för Skogszoologi, Skogshögskolan. Rapporter och Uppsatser 14. 26 p.
— 1975. Skogliga markbearbetningsmetoders inflytande på bestånd och skadegörelse av smågnagare. Abstract: The influence of forest regeneration measures on the abundance and damage caused by small rodents. Skogshögskolan, Institutionen för Skogszoologi. Rapporter och Uppsatser 24. 44 p.
— 1976. Smågnagarförekomst på hyggen i Jämtland i relation till biotopstrukturer. Doctoral thesis at Skogshögskolan. Stockholm. 54 p.
— & Hansson, L. 1976. Vole diet on experimentally managed afforestation areas in northern Sweden. Doctoral thesis at Skogshögskolan. Stockholm. 27 p.
Lavrov, I.K. & Zonov, G.B. 1963. Raspredelenie i čislennost' polevki-ekonomki v Irkutskoj oblasti. Doklady Irkutskogo Protivočumnogo Instituta 5: 115—116.
Lindroth, R.L. & Batzli, G.O. 1986. Inducible plant chemical defenses: a cause of vole population cycles? Journal of Animal Ecology 55: 431—449.
Litvin, V.J. 1975. Materialy po ekologii polevki-ekonomki, polučenye metodom mečenija zver'kov. Materialy k poznaniju fauny i flory SSSR. Nov. B., Otdel Zoologii, vyp. 49: 98—128.
Löyttyniemi, K. 1981. Typpilannoituksen ja neulasten ravinnepitoisuuden vaikutus hirven mäntyravinnon valintaan. Summary: Nitrogen fertilization and nutrient contents in Scots pine in relation to the browsing preference by moose (*Alces alces* L.). Folia Forestalia 487. 14 p.
— & Hiltunen, R. 1978. Monoterpenes in Scots pine in relation to browsing preference by moose (*Alces alces* L.). Silva Fennica 12(2): 85—87.
Mäenpää, E. 1985. Lapinmyyrän (*Microtus oeconomus* Pallas) populaatiodynamiikka *Deschampsia cespitosa* -niityllä Kolarissa vuosina 1980—1983. Manuscript. University of Jyväskylä, Department of Biology. 99 p.
Maksimov, A.A. 1977. Tipy vspyšek i prognozy massovogo razmnoženija gryzunov (na primere vodjanoj krysy). Nauka. Novosibirsk. 189 p.
— (Ed.). 1978. Soobščestva melkih mlekopitajuščih Baraby. Nauka. Novosibirsk. 231 p.
— (Ed.). 1981. Sukcessii životnogo naselenija v biocenozah pojmy reki Obi. Nauka. Novosibirsk. 263 p.
— & Erdakov, L.N. 1985. Cikličeskie processy v soobščestvah životnyh: bioritmy, sukcessii. Nauka. Novosibirsk. 236 p.
Marcström, V. 1977. Silviculture and higher fauna in Sweden. XIIIth International Congress of Game Biologists. Atlanta. p. 401—413.
Massa, I. 1983. Ihminen ja Lapin luonto. Suomen Antropologisen Seuran toimituksia 12. 163 p.
Mattila, E. 1986. Lapin metsävarat alueittain. Lapin valtakunnan metsien 7. inventointi vuosina 1978 ja 1982—84. Summary: The forest resources of Finnish Lapland by sub-areas. The 7th national forest inventory in 1978 and 1982—84. Folia Forestalia 661. 77 p.
Metsätilastollinen vuosikirja. Yearbook of Forest Statistics. Years 1968—1986. Folia Forestalia numbers 70, 96, 130, 165, 195, 225, 255, 295, 345, 375, 430, 460, 510, 550, 590, 620, 660, 690.
Mikkola, K. & Jukola-Sulonen, E.-L. 1984. Yhteisöekologisten aineistojen käsittely ja analysointi VAX-tietokoneella. Metsäntutkimuslaitoksen tiedonantoja 168. 30 p.
Monthey, R. W. & Soutiere, E. C. 1985. Responses of small mammals to forest harvesting in northern Maine (USA). Canadian Field-Naturalist 99(1): 13—18.
Myllymäki, A. 1959. Bedeutung und Ursachen der Mäusefrasschäden in Finnland. Publications of the Finnish State Agricultural Research Board 178: 75—100.
— 1975. Outbreaks and damage by field rodents and other harmful small mammals in Finland. Ecological Bulletin 19: 17—36.
Nakatsu, A. 1982. The relationship between the population density of *Clethrionomys rufocanus bedfordiae* and the damage caused by these voles to forests. (In Japanese with English summary). Annual Report of

the Hokkaido Branch, Forestry and Forest Products Research Institute: 85—89.
Nikolaeva, A.I. 1971. Bolotno-ozerno-leznoj očag massovogo razmnoženija vodjanoj krysy v Altajskom krae. In: Folitarek, C.C. (Ed.). Ekologija vodjanoj krysy i bor'ba s nej v Zapadnoj Sibiri. Novosibirsk. p. 95—137.
— 1981. O vnutripopuljacionnoj izmenčivosti formi tela vodjanoj polevki (*Arvicola terrestris* L.). Naučno-tehničeskij Bjulleten' VASHNIL, Sib.otd., 37: 8—16.
Očirov, J.D. 1966. K rasprostraneniju i ekologii polevki-ekonomki v Čitinskoj oblasti. Izvestija Irkutskogo Gosudarstvennogo Naučno-issledovatel'skogo Protivočumnogo Instituta Sibiri i Dal'nego Vostoka 26: 186—191.
Paavilainen, E. 1970. Koetuloksia suopeltojen metsittämisestä. Summary: Experimental results of the afforestation of swampy fields. Folia Forestalia 77. 24 p.
— 1977. Männyn istutus suopeltojen metsityksessä. Abstract: Planting of Scots pine in afforestation of abandoned swampy fields. Folia Forestalia 326. 27 p.
— 1978. PK-lannoitus Lapin ojitetuilla rämeillä. Ennakkotuloksia. Abstract: PK-fertilization on drained pine swamps in Lapland. Preliminary results. Folia Forestalia 343. 16 p.
Palo, R.T. 1984. Distribution of birch (*Betula* spp.), willow (*Salix* spp.), and poplar (*Populus* spp.) secondary metabolites and their potential role as chemical defense against herbivores. Journal of Chemical Ecology 10(3): 499—520.
— , Pehrson, Å. & Knutsson, P.-G. 1983. Can birch phenolics be of importance in the defence against browsing vertebrates. Finnish Game Research 41: 75—80.
Paulaharju, S. 1939. Sompio. Luiron korpien vanhaa elämää. WSOY. Porvoo. p. 102.
Pielou, E.C. 1966. Shannon's formula as a measure of specific diversity. Its use and misuse. American Naturalist 100: 463—465.
Pjastolova, O.A. 1966. K ekologii populjacii polevki-ekonomki v Severnom Kazahstane. In: Skalon, V.I. (Ed.). Ohrana i racional'noe ispol'zovanie resursov dikoj živoj prirody, Alma-Ata p. 148—149.
— 1971. Polevka-ekonomka. Trudy Instituta Ekologija Rastenij i Životnyh Ural'skogo Naučnogo Centra AN 1: 127—149.
— 1974a. O vozmožnosti peremeščenij polevki-ekonomki v tundre. Informativnye materialy Instituta Ekologija Rastenij i Životnyh 2: 32—33.
— 1974b. Novye dannye o razmnoženii subarktičeskih polevok. Informativnye materialy Instituta Ekologija Rastenij i Životnyh 2: 31—32.
— & Jaskin, V. 1975. Novye dannye o razmnoženii subarktičeskoj populjacii polevki-ekonomki. Ekologija 5: 69—72.
Pohtila, E. 1979. Tutkimustoiminta Lapin metsien hoidon ja käytön suuntaajana: 1960-luvun vastoinkäymiset. Silva Fennica 13(1A): 22—24.
Rajala, P. & Linden, H. 1982. Rämeiden ojituksen ja lannoituksen vaikutuksista riistaeläinten esiintymisrunsauteen. Summary: Effect of drainage and fertilization of pine swamps on the abundance of some game animals. Suomen Riista 29: 93—97.
Raumolin, J. 1982. Metsäteollisuuden kehityksen vaikutuksia asutukseen Pohjois-Suomessa, Pohjois-Ruotsissa ja Quebecissa. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 90—124.
Rousi, M. 1983. Susceptibility of pine to mammalian herbivores in northern Finland. Silva Fennica 17(4): 301—312.
Saalas, U. 1949. Suomen metsähyönteiset sekä muut metsälle vahingolliset ja hyödylliset eläimet. WSOY. Helsinki. 719 p.
Saarenmaa, H. 1981. Ytimennävertäjien lisääntyminen ja torjuntamahdollisuudet Pohjois-Suomessa. Metsäntutkimuslaitoksen tiedonantoja 6: 81—88.
Sarasto, J. 1952. Metsäojituksen aiheuttamista aluskasvillisuuden muutoksista eräissä suotyypeissä. Referat: Über Veränderungen in der Untervegetation einiger Moortypen als Folge der Waldentwässerung. Communicationes Instituti Forestalis Fenniae 40 (13). 32 p.
Schneider, H. & Westman, C.J. 1987. Relation of peat nutrients to ground vegetation communities on sedge pine fens. Tiivistelmä: Turpeen ravinteisuuden suhde pintakasvillisuuteen sararämeillä. Suo 38: 29—36.
Shannon, C.E. & Weaver, W. 1949. The mathematical theory of communication. The University of Illinois Press, Urbana. 117 p.
Siivonen, L. 1967. Pohjolan nisäkkäät. (Mammals of Northern Europe). Otava. Helsinki. 181 p.
Šilov, I.A., Kaleckaja, M.L., Ivaškina, I.N. & Soldatova, A.N. 1977. Prostranstvennaja struktura populjacij polevok-ekonomok (*Microtus oeconomus*) v Darvinskom zapovednike. Summary: Spatial structure of the *Microtus oeconomus* population in the Darwinian State Reservation. Zoologičeskii Žurnal LVI(2): 257—267.
Simpson, E.H. 1949. Measurement of diversity. Nature 163: 688.
Siuruainen, E. 1978. On the history of rural settlement in Finland. Nordia 12(1): 67—78.
— 1982. Saamelaisten elinkeinot ja niissä tapahtuneet muutokset. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 156—165.
Sladek, J. & Mošansky, A. 1985. Cicavce okolo nas. Osveta. Banska Bystrica. 247 p.
Sullivan, T. P. & Sullivan, D. S. 1982. Influence of fertilization on feeding attacks to Lodgepole pine by Snowshoe hares and Red squirrels. The Forestry Chronicle 58(6): 263—266.
Švarc, S.S., Bol'šakov, V.N., Olenev, V.G. & Pjastolova, O.A. 1969. Population dynamics of rodents from northern and mountainous geographical zones. In: Petrusewitz, K. & Ryszkowski, L. (Eds.). Energy flow through small mammal populations. Warszawa. p. 205—220.
Švecov, J.G. 1970. K ekologii polevki-ekonomki v del'te r. Selengi. Fauna i Ekologija Gryzunov 9: 218—230.
Švecova, V.J. 1980. Faktory, opredeljajuščie vrednuju dejatel'nost' myševidnyh v lesnyh biogeocenozah. Ohrana lesnyh resursov Srednej Sibiri. Krasnojarsk. p. 73—94.
— 1984. Povreždenie kul'tur sosny myševidnymi gryzunami v Krasnojarskom krae. Lesnoe Hozjajstvo 2: 54—56.
Sviridenko, P.A. 1953. Myševidnye gryzuny i zaščita ot nih urozaja, zapasov produktov i drevesnyh kul'tur. Izdatel'stvo AN UkrSSR, Kiev.
Tahvanainen, J., Helle, E., Julkunen-Tiitto, R. & Lavola, A. 1985. Phenolic compounds of willow bark

as deterrents against feeding by mountain hare. Oecologia (Berl.) 65: 319—323.

Takala, P. 1986. Metsien käsittely. Tapion taskukirja. XX edition. Gummerus. Jyväskylä. p. 200—215.

Tast, J. 1966. The root vole, *Microtus oeconomus* (Pallas), as an inhabitant of seasonally flooded land. Annales Zoologici Fennici 3: 127—171.

— 1968a. The root vole, *Microtus oeconomus* (Pallas), in manmade habitats in Finland. Annales Zoologici Fennici 3: 230—240.

— 1968b. Influence of the root vole, *Microtus oeconomus* (Pallas), upon habitat selection of the field vole, *Microtus agrestis* (L.) in northern Finland. Annales Academiae Scientiarum Fennicae (A IV) 136. 23 p.

— 1972. Lapinmyyrä. In: Siivonen, L. (Ed.). Suomen Nisäkkäät I. Keuruu. p. 404—414.

— 1974. The food and feeding habits of the root vole, *Microtus oeconomus* in Finnish Lapland. Aquilo, Series zoologica 15: 25—34.

— & Kaikusalo, A. 1976. Winter breeding of the root vole, *Microtus oeconomus*, in 1972/73 at Kilpisjärvi, Finnish Lapland. Annales Zoologici Fennici 13: 174—178.

— & Kalela, O. 1971. Comparisons between rodent cycles and plant production in Finnish Lapland. Annales Academiae Scientiarum Fennicae (A IV) 186. 14 p.

Teivainen, T. 1978. Eräiden poppelikloonien myyrätuhoalttius ruokintakokeiden mukaan. Summary: Resistance of some poplar clones to vole damage through feeding experiments. Folia Forestalia 339. 12 p.

— 1979. Metsäpuiden taimien myyrätuhot metsänuudistusaloilla ja metsitetyillä pelloilla Suomessa vuosina 1973—76. Summary: Vole damage to forest tree seedlings in reforested areas and fields in Finland in the years 1973—76. Folia Forestalia 387. 23 p.

— 1984. The damage risk and the extent of vole damage in forest plantations in Finland. Proceedings of a Conference on the Organisation and Practice of Vertebrate Pest Control. 30 August — 3 September 1982, Elvetham Hall, Hampshire, England. p. 573—587.

— , Jukola-Sulonen, E.-L. & Mäenpää, E. 1986. Pintakasvillisuuden kemiallisen torjunnan vaikutus peltomyyräpopulaation kehitykseen. Summary: The effect of ground-vegetation suppression using herbicide on the field vole, *Microtus agrestis* (L.) population. Folia Forestalia 651. 19 p.

Tichy, V. 1987. Drobni myšoviti hlodavci v lese a obrana proti nim. Abstract: Small mouse-like rodents. Lesnicka Prace 2: 70—75.

Timčenko, L.I. 1983a. Attraktivno-biologičeskij metod ogranicenija čislennosti myševidnyh gryzunov. Lesnoe Hozjajstvo 2: 56—57.

— 1983b. Povreždenija kedrovo-širokolistvennyh lesov mlekopitajuščimi na Dal'nem Vostoke. Ekologija i zaščita lesa. Mežvuz. Sbornik Naučnyh Trudev: 65—69.

— 1986. Povreždenie derev'ev i kustarnikov životnymi na Dal'nem Vostoke. Lesnoe Hozjajstvo 1: 64—66.

— 1987. Massovoe povreždenie aralii Man'čžurskoj izjubrami i gryzunami v Habarovskom krae. Lesnoe Hozjajstvo 3: 66—67.

Tutkimus pellonvaraustilojen käytöstä Lapin läänissä. 1975. Lapin maatilatalouden kehittämisneuvottelukunta. Rovaniemi. 51 p.

Vahtola, J. 1982. Lapin talonpoikaisasutuksen kehitys 1600-luvun loppupuolelle asti. In: Aho, S. & Heikkola, L. (Eds.). Lapin plakaatista tilojen autioitumisen aikaan. Oulu University, Research Institute of Northern Finland. Series C, 42: 135—155.

Varjo, U. 1967. Lapin maatalous 1950-59. Lapin seutusuunnittelun kuntainliitto. Rovaniemi. 75 p.

— 1978. Problems facing rural life in northern Finland. Nordia 12(1): 79—86.

Veijalainen, H. 1974. Metsänparannettu ja luonnontilainen suo eläinten talvisena elinympäristönä. Summary: Winter habitat preferences of wild animals on improved and virgin peatlands. Metsäntutkimuslaitoksen suontutkimusosaston tiedonantoja 3. 10 p.

Virtanen, J., Norokorpi, Y. & Kaunisto, S. (Eds.). 1984. Metsänuudistamisen ja taimikonhoidon periaatteet. Metsäntutkimuslaitoksen tiedonantoja 135. 12 p.

Vuokila, Y. 1971. Harvennusmallit luontaisesti syntyneille männiköille ja kuusikoille. Summary: Thinning models for natural pine and spruce stands in Finland. Folia Forestalia 99. 18 p.

Zonov, G.B. 1962. O zimnem pitanii polevki-ekonomki. Doklady Irkutskogo Protivočumnogo Instituta 4: 137—138.

Total of 166 references

SELOSTE

Lapinmyyrä metsätuholaisena Pohjois-Suomessa

Johdanto ja tutkimuksen tarkoitus

Myyrät ovat osoittautuneet merkittäväksi nykyaikaisen metsätalouden ongelmaksi erityisesti Fennoskandiassa ja Siperiassa. Jyrsimällä taimien kuorta ne ovat aiheuttaneet tuhoja pellonmetsitys- ja metsänviljelyaloilla. Tämä tutkimus käsittelee Pohjois-Suomessa esiintyviä myyrätuhoja, joiden pääasialliseksi aiheuttajaksi todettiin lapinmyyrä, *Microtus oeconomus* Pallas.

Lapinmyyrän luontaisia esiintymispaikkoja ovat jokien ja järvien tulvarannat sekä tulvivat aapasuot. Näiltä laji on vuosisatojen ja erityisesti viime vuosikymmenien aikana levinnyt mitä erilaisimmille ihmistoiminnan muovaamille biotoopeille. Pääosa lajin esiintymistä ja ravintoa koskevista tutkimuksista on julkaistu vain Neuvostoliitossa.

Pohjois-Suomessa viime vuosikymmeninä tapahtuneista maankäytön muutoksista huomattavimpia ovat olleet sodanjälkeinen metsien ja soiden raivaaminen pelloksi, peltojen hylkääminen 1970-luvulla, avohakkuiden ja metsänviljelyn nopea runsastuminen sekä laajamittainen soiden ojitus. Näiden seurauksena on syntynyt uusia ihmisen luomia biotooppeja varsinkin Etelä- ja Keski-Lappiin.

Tutkimus koostuu kahdesta osasta. Ensimmäisessä osassa tutkitaan lapinmyyrän aiheuttamia tuhoja pelloille istutetuissa taimikoissa, toisessa osassa tuhoja turvemaiden mäntymetsissä. Lapinmyyrätuhojen syntyyn vaikuttaneita tekijöitä ja tuhojen seurauksia selvitetään. Koska aikaisempia tutkimuksia aiheesta ei juuri ole, huomattava osa tutkimuksesta on tuhojen kuvaamista ja analysointia. Tarkoituksena on selvittää, mitkä tekijät vaikuttavat myyrätuhojen syntyyn, mikä on eri metsänuudistus- ja metsänparannusmenetelmien merkitys ja ovatko myyrätuhot seurausta ihmisen toiminnan aiheuttamista muutoksista Pohjois-Suomen metsissä.

Lapinmyyrätuhot metsitetyillä pelloilla

Pellonmetsitysalojen myyrätuhoja tutkittiin 11 kunnan alueella Etelä- ja Keski-Lapissa Veitsiluoto Oy:n vuosina 1972—77 metsittämillä 87 pellolla. Lapinmyyrätuhoja esiintyi 37 %:lla pelloista, mikä vastasi 54 % metsitettyjen peltojen pinta-alasta. Kenttätutkimukset suoritettiin vuosina 1978 ja 1979. Kenttäkoealoiksi valittiin 23 tuhojen kohteeksi joutunutta taimikkoa ja yhtä monta vertailutaimikkoa, joissa tuhoja ei esiintynyt. Taimikoiden perustamis- ja hoitotoimenpiteitä sekä pintakasvillisuus- ja maa-analyysien tuloksia vertailtiin tuhoalojen ja vahingoittumattomien alojen kesken. Alat luokiteltiin pintakasvillisuuden perusteella ryhmiin TWINSPAN- ja DECORANA-analyysien avulla. Myyriä pyydystettiin tappoloukuin 961 loukkuvuorokautena myyrätuhoaloilla. Pääosalla pelloista lapinmyyrä oli ainoa laji, mutta eteläisimmiltä tuhoaloilta saatiin myös peltomyyriä. Kaikkiaan 112 pyydystetystä myyrästä oli lapinmyyriä 83 % ja peltomyyriä 17 %.

Lapinmyyrien jyrsintäjäljet sijaitsivat taimien tyvellä ja/tai juurissa. Pienimmät taimet oli jyrsitty lähes kokonaan silpuksi. 95 % istutetuista taimista oli mäntyjä, joten pääosa tuhoistakin oli männyissä. Tuhojen kohteeksi joutuneet taimikot olivat pinta-alaltaan keskimäärin suurempia kuin tuhoilta säästyneet taimikot ($t = 3{,}70$, $df = 49{,}9$, $P < 0.001$). Keski-iältään tuhoalojen taimikot olivat 8,5 kk nuorempia kuin vahingoittumattomat taimikot ($t = 2{,}05$, $df = 83{,}7$, $P < 0{,}05$). Niinikään tuhon kohteeksi joutuneista taimikoista oli suurempi osa istutettu käyttäen paljasjuurisia taimia ($H = 4{,}68$, $P < 0{,}05$), ja heinäntorjuntaa oli niissä tehty vähemmän kuin tuhoilta säästyneissä taimikoissa ($H = 2{,}70$, $P < 0{,}1$).

Kaikkien pellonmetsitysalojen pintakasvillisuutta vallitsivat heinät. Märkien ja kosteiden kasvupaikkojen lajit olivat yleisempiä tuhoaloilla kuin vahingoittumattomilla aloilla. Näytealat ja kasvilajit järjestettiin DECORANA-ordinaatioanalyysin avulla akseliparille kasvilajien esiintymisfrekvenssien perusteella, mutta muutossuunnissa ei havaittu eroja tuho- ja vertailualojen välillä. TWINSPAN-analyysin avulla muodostetuille kasvisosiologisille ryhmille oli yhteistä heinien ja maitohorsman runsaus. Tuhoalttiimmiksi todettiin saramaisen kasvillisuuden luonnehtimat alat, vähiten alttiiksi metsäkasvien luonnehtimat alat. Pintakasvillisuus oli tuhojen kohteeksi joutuneissa taimikoissa yhtenäisempää kuin vahingoittumattomissa taimikoissa ja niiden Shannon diversiteetti-indeksit erosivat merkitsevästi toisistaan ($F = 4{,}97$, $df = 1{,}44$, $P < 0{,}05$). Metsitetyillä pelloilla maan ravinnepitoisuudet olivat alempia kuin alueen viljelyksessä olevilla pelloilla. Maaperän fosfori-, kalium- ja kalsiumpitoisuudet olivat tuhon kohteeksi joutuneissa taimikoissa merkitsevästi korkeampia kuin tuhoilta säästyneissä taimikoissa (fosfori: $t = 4{,}72$, $df = 24{,}6$, $P < 0{,}001$; kalium: $t = 4{,}59$, $df = 30{,}3$, $P < 0{,}001$; kalsium: $t = 2{,}28$, $df = 43{,}8$, $P < 0{,}05$).

Lapinmyyrätuhot turvemaiden metsissä

Turvemaiden metsien lapinmyyrätuhoja tutkittiin Etelä- ja Keski-Lapissa vuosina 1980—85. Pääosa tuhoista oli syntynyt talvella 1977—78, vähäisempi osa talvella 1981—82. Tuhojen esiintymistä ojitetuilla ja ojittamattomilla turvemailla selvitettiin linja-arvioinnilla Kolarin Teuravuoman ojitusalueella ja viereisellä luonnontilaisella suolla. Muut tutkimukset tehtiin Metsäntutkimuslaitoksen suontutkimusosaston lannoituskoealueilla. Kasvillisuus- ja maa-analyysit sekä puustomittaukset tehtiin 46 tuhoalalla ja 11 vertailualalla, samoin menetelmin kuin pellonmetsitysaloilla. Tulokset käsiteltiin VAX 11/785 tietokoneella BMDP- ja kasvillisuusanalyysiohjelmia käyttäen. Myyriä pyydettiin 1590 loukkuvuorokauden ajan vuosina 1977—78. Kokonaissaalis oli 493 myyrää, joista lapinmyyriä oli 49 %. Lapinmyyrä oli yleisin laji kaikilla pyyntibiotoopeilla lukuunottamatta HMT-kuusikkoa, jossa metsämyyrä oli yleisin.

Turvemaiden metsissä tuhot kohdistuivat ojitusalueiden harvennusikäisiin mäntymetsiin. Ojitetuilla alueilla tarkastettiin ja mitattiin yhteensä 3 697 puuta, ojittamattomilla vertailualueilla 420 puuta. Tuhojen kohteeksi joutuneilla ojitusaloilla puolet puista oli myyrän jyrsimiä. 40 % jyrsityistä puista oli kuollut kolmen vuoden kuluttua vioituksesta. Ojittamattomien soiden puissa tuhoja ei esiintynyt. Myyrät olivat jyrsineet kuoren puiden tyveltä ja/tai juurista. Jyrsittyjen puiden keskipituus oli 4 m (1,3—10,0 m) ja rinnankorkeusläpimitta 6 cm (1—21 cm).

PK- ja PK+tuhka/hivenlannoitetuilla aloilla myyrän jyrsimien puiden osuus oli 61 %, NPK-, NP- ja N-lannoitetuilla 46 % ja pääravinteilla lannoittamattomilla aloilla 44 %. Erot olivat tilastollisesti merkitseviä ($F = 5,14$, $df = 2,49$, $P < 0,01$). Eri koealueiden tuhoasteiden välillä ei ollut merkitsevää eroa ($F = 2,00$, $df = 4,47$, $P > 0,05$). Turpeen fosforipitoisuus oli tuhoaloilla korkeampi ja kalium-, kalsium- ja magnesiumpitoisuudet alhaisemmat kuin vertailualoilla. Turpeen fosforipitoisuuden ja tuhon ankaruuden välinen positiivinen korrelaatio oli erittäin merkitsevä ($r = 0,499$, $n = 52$, $P < 0,001$). Sen sijaan kalium- ja kalsiumpitoisuudet eivät korreloineet merkitsevästi tuhoasteen kanssa.

Pääosa tuhoista esiintyi aloilla, missä puuston tiheys oli 1400—1700 mäntyä hehtaarilla. Puuston keskitiheys oli tuhojen kohteeksi joutuneilla aloilla ennen tuhoja 1363 mäntyä/ha. Kolme vuotta tuhon jälkeen eläviä puita oli 1104 hehtaarilla, mutta kokonaan tuholta säästyneitä vain 695 runkoa/ha. Parittaiset keskitiheyksien erotukset erosivat merkitsevästi nollasta ($t = 7,34$ ja $t = 14,66$, $df = 51$, $P < 0,001$). Kaikilla tutkimusalueilla myyrätuhot olivat aiheuttaneet puuston vajaatuottoisuuden, Sattasuolla, Verkkolahdenjängällä ja Suolomaavalla jopa alle jatkokasvatuksen kannattavuusrajan (500—700 runkoa/ha).

Ojitettujen alojen pintakasvillisuus poikkesi ojittamattomien vertailualojen pintakasvillisuudesta, vaikka alkuperäiset suotyypit vastasivat toisiaan. Tuhojen ankaruudessa eri suotyypeillä oli merkitsevä ero ($F = 4,05$, $df = 5,46$, $P < 0,005$). Ojituksen ja lannoituksen seurauksena varpujen rehevyys ja korkeus oli lisääntynyt, heinät ja sarat olivat runsastuneet. DECORANA-ordinaatioanalyysiä käytettiin ilmaisemaan kasvisosiologisia muutossuuntia aineistossa. Päävaihtelusuunnaksi osoittautui kosteuden, eikä ravinnetason muutos. Aineiston kasvisosiologiseen luokitteluun käytettiin TWINSPAN -analyysiä. Sen avulla koealat jaettiin kahteen ryhmään: 1) Tupasvilla-ryhmä (38 alaa) ja 2) Suopursuryhmä (19 alaa). Kasvilajeista tupasvilla, hieskoivu, kurjenjalka, vaivaiskoivu ja juolukkapaju olivat tyypillisiä tuhoaloille kun taas suopursu, suokukka ja mustikka vahingoittumattomille aloille.

Tulosten tarkastelu

Lapinmyyrätuhot esiintyivät kahdella hyvin erilaisella biotoopilla: metsitetyillä pelloilla ja ojitetuilla turvemailla. Pelloilla myyrätuhon kohteeksi joutuivat pienet taimet. Sen sijaan ojitusalueilla tuhot esiintyivät suurissa puissa. Metsitetyt pellot ovat myyrille erittäin suotuisa elinympäristö, jossa ne voivat lisääntyä silloinkin kun kanta on hyvin vähäinen. Ojitetuilla turvemailla lapinmyyriä esiintyi vain kannan ollessa hyvin runsas. Suotuisissa oloissa ne lisääntyivät ojitusaloilla ja aiheuttivat tuhoja.

Turvemaiden mäntymetsissä ojitus oli rehevöittänyt pintakasvillisuutta ja muuttanut kasvupaikat myyrille suotuisiksi. Samalla tavalla olivat vaikuttaneet useissa tapauksissa tuhoja edeltäneet harvennushakkuut. Myös lannoitus näytti lisäävän männiköiden myyrätuhoalttiutta. Tulosten perusteella on kuitenkin vaikea erottaa lannoituksen ja ojituksen vaikutuksia toisistaan, sillä molemmat toimenpiteet oli tehty lähes kaikissa tuhon kohteeksi joutuneissa metsiköissä. Käytännössä talousmetsän kasvattaminen ojitetuilla soilla lienee mahdotonta ilman PK-lannoitusta. Ojitus muuttaa pintakasvillisuutta hitaasti ja suon kuivuminen turvekankaaksi kestää kymmeniä vuosia. Sen sijaan lannoitus ja harvennushakkuut aiheuttavat nopeamman ja lyhytaikaisemman muutoksen pintakasvillisuudessa.

Metsitetyillä pelloilla taimikot jouduttiin myyrätuhojen vuoksi täydennysistuttamaan useitakin kertoja. Ojitetuilla soilla tuhot sattuivat pääosin yhden tavallista korkeamman myyrien esiintymishuipun aikana, mutta niillä on pitkäaikaiset vaikutukset metsikön tuottoon. Lapinmyyrän aiheuttamien tuhojen lopullinen merkitys ilmenee kasvutappioina, laatuvikoina ja mahdollisina seuraustuhoina vasta vuosien kuluttua. Myyrätuhojen riski tulisi ottaa huomioon laskettaesssa ojituksen ja lannoituksen kannattavuutta Pohjois-Suomessa. Turvemaiden taimikoissa nykysuosituksia korkeammat kasvatustiheydet vähentäisivät myyrätuhoriskiä ja tuhojen seurauksia. Myös harvennushakkuiden ja jatkolannoitusten ajoitus myyräkannan romahdusvaiheeseen vähentäisi tuhoja.

KORHONEN, K.-M. 1987. Damage caused by the root vole *(Microtus oeconomus)* to Scots pine in man-made habitats in northern Finland. Seloste: Lapinmyyrä metsätuholaisena Pohjois-Suomessa. Communicationes Instituti Forestalis Fenniae 144. 61 p.

Appendix 1. Food of the root vole according to Fetisov (1958). +++ = eaten very often, ++ = eaten moderately, + = eaten seldom.

Liite 1. Lapinmyyrän ravintokasvit Fetisovin (1958) mukaan. Syönnin aste: +++ = paljon, ++ = kohtalaisesti, + = vähän.

Plant species-Kasvilaji	Tissues eaten-Syödyt kasvinosat	Intensity Syönnin voimakkuus
Equisetum fluviatile L., Equisetum spp.	heads-tähkät	++
Pinus cembra L.	shoots-versot	+
Pinus sylvestris L.	bark of fallen branches pudonneiden oksien kuori	+
Milium effusum L.	leaves-lehdet	+
Agrostis canina L.	leaves-lehdet	++
Calamagrostis spp.	stem, leaves-varsi,lehdet	++
Avena sativa L.	seeds-siemenet	+
Catabrosa aquatica (L.) Beauv.	leaves-lehdet	+
Glyceria lithuanica Gorski	stem,leaves-varsi,lehdet	+
Carex spp.	roots-juurakot	+++
Carex spp.	stems,leaves-varret,lehdet	++
Eriophorum spp.	stems,leaves-varret,lehdet	++
Salix myrtilloides L., Salix sp.	bark,twigs-kuori,oksat	+
Populus tremula L.	bark,fallen leaves in winter kuori,pudonneet lehdet	++
Populus spp.	bark,fallen leaves in winter kuori,pudonneet lehdet	++
Polygonum viviparum L.	stems,leaves-varret,lehdet	+
Polygonum viviparum	roots in stores-juurakot	+++
Polygonum alopecuroides Turcz.	roots in stores-juurakot	++
Polygonum bistorta L.	roots in stores-juurakot	++
Atriplex patens Litw.	stems,leaves-varret,lehdet	++
Silene spp.	stems,leaves-varret,lehdet	+
Trollius asiaticus L.	leaves-lehdet	++
Eranthis sibirica DC	roots in stores-juurakot	+++
Anemone crinita Juz.	leaves-lehdet	+
Corydalis sibirica L.	stem,leaves-varsi,lehdet	+
Dentaria tenuifolia Ledeb.	roots in stores-juurakot	+++
Capsella bursa-pastoris (L.) Medicus	leaves,stems-lehdet,varret	+
Bergenia spp.	leaves-lehdet	+
Fragaria spp.	leaves-lehdet	+
Sanguisorba officinalis L.	leaves-lehdet	+
Trifolium repens L.,T. pratense L.	leaves-lehdet	++
Lathyrus spp.	stems,leaves-varret,lehdet	+
Geranium spp.	roots in stores-juuret	+
Erodium cicutarium (L.) L'Hér.	roots in stores-juuret	+
Carum carvi L.	roots in stores-juuret	++
Aegopodium spp.	leaves-lehdet	+
Cornus sibirica Lodd.	bark-kuori	+
Vaccinium myrtillus L.	twigs in winter-varvut	++
Galium spp.	stems,leaves-varret,lehdet	++
Maianthemum bifolium (L.) F.W. Schmidt	stems,leaves-varret,lehdet	++
Trientalis europaea L.	stems,leaves-varret,lehdet	+
Parnassia palustris L.	roots in stores-juuret	+
Dryas oxidontha Juz.	leaves,stems-lehdet,varret	+
Linnaea borealis L.	leaves,stems-lehdet,varret	+
Phlomis tuberosa L.	roots in stores-juurakot	+++

Appendix 2. Vegetation analysis of the afforested field areas. Comparison of plots with or without vole damage. The plant species are ranked according to their frequencies (f, %).

Liite 2. Metsitettyjen peltojen pintakasvillisuusanalyysi. Myyrätuhoalojen ja vahingoittumattomien alojen vertailu. Kasvilajit on järjestetty esiintymisyleisyyden (f, %) mukaan.

Species - Lajit	F	C	Damaged plots - Tuhoalat																							Not damaged plots - Vertailualat																						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
40 EPIL ANGU	95.7	58.5	90	99	90	90	60	70	10	70	90	99	10	40	80	10	10	60	10	.	20	99	10	90	30	70	60	99	99	40	20	70	80	50	99	99	99	30	50	70	50	60	99	50	70	80	10	.
11 DESC CESP	93.5	69.6	.	90	90	50	80	90	99	80	70	70	40	60	70	99	99	99	80	80	70	60	70	.	30	70	99	70	30	80	90	99	60	90	70	40	90	99	90	10	.	80	90	70	20	99	80	99
9 AGRO CAPI	93.5	54.3	10	40	.	80	90	90	50	30	99	10	.	50	80	40	90	80	50	90	10	10	.	40	20	90	30	50	90	20	80	70	99	50	90	99	99	90	40	80	10	10	60	20	60	60	70	70
20 RUME ACET	84.8	39.3	30	50	30	.	20	60	80	30	70	30	90	.	10	90	50	60	10	30	10	20	40	40	40	40	30	.	.	20	90	60	.	.	90	10	10	10	60	50	60	10	99	70	40	.	90	80
14 FEST RUBR	84.8	35.0	30	.	10	30	10	20	30	30	10	80	80	90	70	70	70	40	10	20	30	50	30	70	.	60	30	10	60	50	99	.	10	.	30	50	20	.	10	.	20	10	40	70	50	.	50	60
13 POA PRAT	82.6	38.7	40	20	.	10	20	80	10	.	80	99	90	90	99	90	70	80	50	.	60	20	20	40	20	.	70	30	50	20	20	.	.	.	20	20	40	30	20	.	50	10	10	80	50	90	40	40
50 ACHI MILL	76.1	28.5	.	.	.	20	20	20	.	.	30	.	20	30	60	90	40	40	10	70	20	.	10	40	60	80	20	10	50	.	60	20	10	.	60	40	60	30	.	30	.	20	50	30	50	10	90	10
62 SALI SP	69.6	23.9	.	.	40	60	40	40	60	60	50	10	10	.	.	.	.	10	20	20	40	.	30	50	.	.	.	10	.	.	.	20	90	40	20	60	60	20	10	.	20	40	60	30	10	10	20	40
61 BETU PUBE	67.4	24.3	.	20	10	70	50	50	30	20	10	.	.	.	10	.	.	.	10	10	20	.	50	20	.	.	10	40	10	20	.	20	90	50	50	90	70	10	40	.	70	40	90	.	10	.	.	30
87 CARE CANE	65.2	23.7	20	.	40	.	.	.	70	10	20	20	90	10	.	.	30	20	20	.	10	.	40	.	.	60	20	.	10	99	30	70	.	10	20	.	20	10	99	.	40	40	80	10	10	.	.	60
29 RANU ACRI	63.0	23.5	.	10	20	.	10	50	.	.	.	40	20	.	10	20	80	50	20	60	.	.	20	20	60	90	40	30	.	.	60	80	.	.	70	20	20	.	.	.	10	.	20	30	20	.	60	40
30 RANU REPE	60.9	21.1	.	.	30	.	20	20	10	.	.	.	10	20	.	30	10	60	10	.	20	20	50	.	60	.	40	.	.	.	30	20	10	.	50	.	40	.	.	90	80	.	30	20	70	30	20	70
21 RUME ACLA	58.7	19.1	50	.	.	.	40	.	30	90	30	10	20	50	50	10	.	.	.	.	.	10	.	.	10	10	10	20	70	.	.	.	40	10	.	50	70	50	50	.	.	10	20	40	.	.	20	10
81 EPIL PALU	54.3	19.1	.	.	.	.	.	40	80	10	50	20	30	.	.	30	10	.	.	.	40	50	10	.	.	.	10	.	.	80	20	30	.	40	.	.	.	.	50	10	40	30	60	40	10	10	.	80
49 ACHI PTAR	54.3	15.2	.	.	.	20	90	50	.	.	.	.	10	.	10	30	.	20	10	20	10	.	20	.	99	40	30	.	.	.	10	20	20	.	.	20	30	.	.	30	20	20	.	10	30	30	.	.
26 CERA FONT	43.5	9.1	.	10	10	.	.	10	.	.	20	10	.	.	10	20	10	40	.	.	10	.	10	.	.	40	20	.	.	10	30	.	.	.	.	60	20	.	.	.	.	.	.	.	20	.	10	50
90 CALA PURP	39.1	12.0	.	.	.	.	20	.	.	10	.	.	.	.	10	.	.	.	.	.	70	.	.	.	.	.	.	60	.	.	.	10	.	20	10	.	.	10	10	30	30	90	50	50	30	30	.	10
8 PHLE PRAT	37.0	9.3	10	.	.	.	.	10	.	.	.	.	.	70	10	.	.	.	20	10	.	.	.	.	30	20	30	20	30	.	70	10	.	.	.	.	.	.	.	.	.	.	10	.	20	10	50	.
73 POTE PALU	28.3	9.1	.	.	20	.	.	.	.	.	20	.	10	.	.	.	.	.	.	.	60	50	70	.	10	.	.	.	.	20	.	20	.	.	.	.	.	.	.	.	50	40	.	40	.	.	.	10
92 TRIE EURO	28.3	6.5	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	10	10	.	10	50	.	.	.	.	.	.	20	10	90	.	.	.	.	10	.	50	.	.	.	.	10	.	.	.	10
5 LUZU MULT	28.3	6.1	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	10	10	.	.	.	.	.	30	.	.	.	60	.	40	10	.	10	.	.	.	10	.	.	.	10	10	.	.	40	20
35 TRIF REPE	28.3	4.8	10	.	.	.	.	.	.	.	.	.	.	.	10	.	10	10	10	10	.	.	.	10	.	50	.	.	.	.	30	.	.	.	20	.	30	.	.	10	.	.	.	.	.	.	10	.
93 VIOL EPIP	26.1	9.8	10	.	.	.	.	.	.	.	.	.	50	.	.	.	.	10	30	20	80	80	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	.	30	10	40	.	.	.
95 CALA STRI	26.1	8.5	.	.	.	.	10	.	20	.	50	80	.	10	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	10	.	40	.	.	40	40	.	.	50
24 STEL GRAM	26.1	6.5	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	50	.	30	.	.	.	.	.	10	10	.	.	.	30	.	.	.	40	20	30	10	.	.	.	.	.	.	20	.	30	.
55 TARA SP	26.1	6.1	.	.	.	.	.	60	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	20	.	50	10	.	.	.	50	.	.	.	.	10	10	.	.	10	.	.	.	.	30	10	10	.
66 RHIN MINO	23.9	5.7	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	10	20	60	.	.	.	30	.	20	.	.	.	.	.	.	.	.	.	40	10	.	.	.	.	.	.	20	20	.	20	.
32 RUBU ARCT	23.9	5.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	20	20	10	20	80	10	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	20	.	.	10	20	.	.	.
53 CIRS HELE	23.9	3.9	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	.	.	10	.	.	40	.	10	.	.	.	.	.	.	.	.	20	.	10	.	.	.	.	.	.	10	10	30	20	.
3 PINU SYLV	23.9	3.7	30	.	.	.	.	.	.	.	10	20	.	10	.	.	.	.	10	20	.	10	.	10	.	.	.	.	.	.	.	.	10	.	.	.	30	.	10	.	.	.	.	.	.	.	.	.
58 VIOL PALU	21.7	8.0	.	.	.	.	.	50	10	.	.	.	20	.	.	.	.	.	.	.	.	.	90	10	.	10	.	.	.	99	50	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	20	.
34 FILI ULMA	21.7	6.1	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	40	.	.	.	.	20	70	.	.	.	.	.	.	30	10	.	.	.	.	.	.	.	30	50	.	.	10	10	.	.	.
88 EQUI PALU	21.7	6.1	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	40	.	.	20	.	.	30	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	99	20	10	.	10	30	.	.	.
60 JUNC FILI	21.7	5.9	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	10	30	.	.	70	.	.	30	.	.	.	50	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	10	30
54 LEON AUTU	21.7	4.6	.	.	.	40	.	.	10	.	.	.	.	10	.	.	.	.	.	10	.	.	.	.	.	30	.	.	10	.	.	.	50	.	.	.	30	.	.	.	.	.	10	.	.	.	10	.
47 GALI ULIG	21.7	4.3	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	10	.	.	10	.	.	10	.	.	.	10	30	.	.	.	.	.	.	.	.	.	10	.	30	.	10	.	.	50
41 GALE BIFI	17.4	5.4	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	30	.	.	.	.	.	.	.	.	.	20	.	.	.	.	90	50	.	.	.	20	10	.	.
89 ERIO ANGU	17.4	4.6	.	.	10	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	10	30	.	40	.	.	.	40	20	.	.	.	.	.	.	.	.	.
91 CARE MAGE	17.4	4.5	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	10	.	.	.	.	.	30	99	.	.	.	10	.	.	.	.	20
4 CARE SP	17.4	3.0	30	.	.	.	.	.	.	10	.	20	10	.	.	.	.	.	10	.	20	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10
59 PICE ABIE	17.4	2.0	.	.	.	10	10	.	.	.	.	.	.	.	.	.	.	10	.	10	.	.	.	.	.	.	.	.	.	.	.	.	20	10	.	.	.	.	10	.	10	.	.	.	.	.	.	.
16 ELYM REPE	15.2	4.3	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	30	.	10	.	.	.	10	.	.	.	.	70	.	.	.	.	.	.	30	.
23 STEL MEDI	15.2	3.5	.	.	.	.	.	30	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	40	10	.	.	.	.	.	.	.	.	.	.	10	50	.	.	.	10	.	.	.	.
84 DESC FLEX	15.2	3.3	10	.	.	30	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	.	.	10	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	30	.
6 LUZU PALL	15.2	3.0	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	10	.	.	20	.	.	.	.	.	.	10	.	.	.	.	.	.	30	.	.	.	40
76 VACC MYRT	15.2	2.8	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	60	.	10	10	10	.	.	.	.	.	.	.	.	.	10	.
56 VACC VITI	15.2	2.4	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	10	10	.	.	10	10	.	.	.	.	.	.	.	.	30	.
48 SOLI VIRG	15.2	2.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	30	.	.	.	.	10	.	.	.	.	.	10	.	.	.	.	.	.	10	20	.	10	.
98 EMPE NIGR	13.0	2.4	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	10	.	.	.	40	.	.	10	.	10	.	.	.	.	.	.	.	.	.	.
85 EQUI FLUV	13.0	2.2	.	.	30	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	10	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	10
36 TRIF PRAT	13.0	2.0	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	10	.	.	.	.	.	10	.	.	.	.	.	.	.	10	.	10	.
77 CARE NIGR	10.9	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	40	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	40	.
122 RORI PALU	10.9	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	90	30	10	.	.	10	.	.	.
43 GALE SPEC	10.9	2.2	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	50	20	.	.	.	.	.	10	.
104 MENY TRIF	10.9	2.0	.	.	.	.	.	20	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.
2 EQUI SYLV	10.9	1.7	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	10	.	.	30	10	.	.	.	.	.	.	.	.	.	.	.
22 CHEN ALBU	10.9	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	10	.	.	.	30	.	10	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.
118 HIER UMBE	10.9	1.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	.	.	10	.	20	.
65 ANGE SYLV	10.9	1.3	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	10	.	.
69 CALA ARUN	8.7	3.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	40	50	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
124 ERIO VAGI	8.7	3.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	.	30	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	20
57 VERO LONG	8.7	2.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	.	.	.	.	.	.	.	20	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.
1 EQUI ARVE	8.7	1.7	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.
131 RUBU CHAM	8.7	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	10	40	.	.	10	.	.	.	.	.	.
97 VACC ULIG	8.7	1.1	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	10	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12 POA TRIV	8.7	1.1	.	10	.	.	10	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
19 RUME LONG	8.7	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	10	.	.	.	.	10	.	.
105 BETU NANA	8.7	1.1	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	10	10	.	.	.	.	.	.	.	.	.
133 VICI CRAC	8.7	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	10	.	.	.	.	20	.	10	.
25 SILE DIOI	8.7	0.9	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	.	.	.
86 VALE OFFI	6.5	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.
7 ANTH ODOR	6.5	1.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.
46 MELA SYLV	6.5	1.3	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	20	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
67 PILO OFFI	6.5	1.3	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.
78 CARE ROST	6.5	1.3	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.
44 VERO SERP	6.5	1.1	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.
71 MELA PRAT	6.5	0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	10	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
52 CIRS PALU	6.5	0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10 AGRO CANI	6.5	0.7	.	.	.	.	.	.	.	10	10	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
83 GALI PALU	6.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	10	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
116 LEUC VULG	6.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	10	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.
68 JUNI COMM	6.5	0.7	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
107 AGRO STOL	4.3	2.4	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
119 DACT GLOM	4.3	1.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	70	.	.	.	.	.	.	.	.
75 LUZU PILO	4.3	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
106 CARE AQUA	4.3	1.1	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
64 GEUM RIVA	4.3	0.9	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.
127 LEDU PALU	4.3	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.
15 FEST PRAT	4.3	0.7	.	.	.	.	10	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
38 LATH PRAT	4.3	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.
63 LYSI VULG	4.3	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.
70 JUNC EFFU	4.3	0.4	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
31 BARB VULG	4.3	0.4	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
132 CAMP ROTU	4.3	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	10	.
108 POA ANNU	4.3	0.4	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
128 TRIC CESP	2.2	0.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.
135 MYOS ARVE	2.2	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.
129 ERYS CHEI	2.2	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.
39 EPIL SP	2.2	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
126 POTE EREC	2.2	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
37 VICI SEPI	2.2	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
134 GNAP SYLV	2.2	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.
99 CALA LAPP	2.2	0.4	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
72 PEUC PALU	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
27 SPER ARVE	2.2	0.2	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
74 STEL PALU	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
42 GALE TETR	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
28 RANU AURI	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
109 CARE LASI	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
110 TROL EURO	2.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Appendix 2. Continued.
Liite 2. Jatkoa.

Species - Lajit	F	C	Damaged plots - Tuhoalat																							Not damaged plots - Vertailualat																						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
!111 FEST OVIN !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!112 CARE BRUN !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!113 ALCH SP !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!114 CALL VULG !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!115 CAMP PATU !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 51 TUSS FARF !	2.2!	0.2 !	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!117 CIRS VULG !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 33 POTE NORV !	2.2!	0.2 !	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 79 POA PALU !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!120 POLY LAPA !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!121 POLY SP !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 80 VIOL RIVI !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!123 TANA VULG !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 94 SAUS ALPI !	2.2!	0.2 !	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!125 SCUT GALE !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 45 VERO ARVE !	2.2!	0.2 !	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 96 TRIC ALPI !	2.2!	0.2 !	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 82 GALE SP !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
! 17 ALNU INCA !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!130 CARD CRIS !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.
! 18 URTI DIOE !	2.2!	0.2 !	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!100 CARE CHOR !	2.2!	0.2 !	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!101 ORTH SECU !	2.2!	0.2 !	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!102 PARN PALU !	2.2!	0.2 !	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!103 SELA SELA !	2.2!	0.2 !	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
!136 POA SP !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.
!137 TRIP INOD !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.
!138 BETU PEND !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.
!139 PLAN MAJO !	2.2!	0.2 !	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.

Appendix 3. The basic data of the fertilization study plots used in the vole damage research.
Liite 3. Turvemaiden lannoituskoealojen perustiedot.

Study area, plot numbers *Tutkimusalue, alojen numerot*	Fertilization experiment *Lannoituskoe* Year *Vuosi*	Plot size *Ruutukoko*	Fertilizers — *Lannoitteet* kg/ha	Supplementary fertilization *Jatkolannoitus* Year *Vuosi*	Fertilizers *Lannoitteet* kg/ha						Draining *Perusojitus* Year *Vuosi*	Spacing *Sarkaleveys*	Afforestation *Metsitys* Year *Vuosi*	Method *Tapa*	Thinnings, year *Harvennus-hakkuut, vuosi*
Alajärvensuo	1965	0.04 ha		1975[1]							1936	70 m	1936	broad-cast sowing *haja-kylvö*	1975
					Phf	Psf	Prf	Pkf	K_2O	N					
8, 23, 31			potassium salt		—	—	—	—	—	—					
4, 20, 39			*kalisuola*		50	—	—	—	—	100					
7, 21, 30			65—195		100	—	—	—	—	100					
11, 27, 42					150	—	—	—	—	100					
6, 25, 36			urea		—	50	—	—	120	100					
10, 19, 33			200		—	100	—	—	120	100					
13, 22, 37					—	150	—	—	120	100					
9, 15, 35			phosphorus		—	—	50	—	120	100					
14, 17, 38			*fosfori*		—	—	100	—	120	100					
12, 18, 29			50—150		—	—	150	—	120	100					
1, 24, 41					—	—	—	50	120	100					
5, 26, 34					—	—	—	100	120	100					
3, 16, 32					—	—	—	150	120	100					
2, 28, 40					—	—	100	—	120	100					
Sattasuo	1970	0.2 ha									1933	45 m	naturally regenerated *metsittynyt luontaisesti*		1970, 1974
	PK/ April *huhtik.*	PK/ May *toukok.*	PK/ June *kesäk.*												
1, 4	500	—	—												
2, 5	—	500	—												
3, 6	—	—	500												
Imari	1968	strips *kaistat*	PK-fertilizer *PK-lannos*								1956	5—300 m			1973
2, 4, 5			0												
1, 3, 6			1000												
Suoloma-aapa	1964	0.04 ha		1976[2]							1939	40 m	1939	patch sowing *ruutu-kylvö*	1975, 1976
					N	P	K	micro-nutrients *hiven*							
1, 27					357	357	178	110							
32, 46					—	357	178	110							
6, 11, 28, 37			phosphorus		—	357	178	—							
42			*fosfori*		357	357	—	—							
26			700		—	357	—	110							
47			potassium		357	—	—	110							
21, 34			*kalium*		357	—	—	—							
7, 25, 41			200—370		—	—	—	110							
2, 24, 33					—	—	—	—							
Verkkolahden-jänkä	1968	0.04 ha		1978[3]							1968	30 m			1978
					PK	urea	micro-nutrients *hiven*	dry ash *tuhka*							
27, 56, 74					500	250	—	—							
19, 42, 88, 93					500	—	100	—							
65			PK-fertilizer		500	—	—	10000							
2, 24, 28, 67			*PK-lannos*		500	—	—	—							
7			400—500		—	—	—	10000							
12, 66, 69, 100, 111					—	—	—	—							

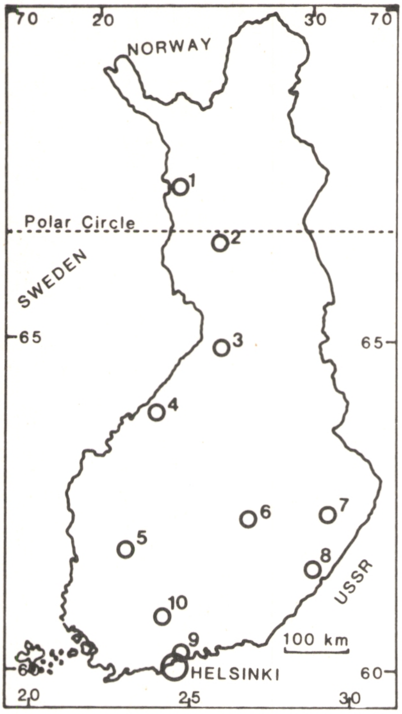
[1] Phf = Fine-ground rock phosphate — *hienofosfaatti*, Psf = Super phosphate — *superfosfaatti*, Prf = Rock phosphate — *raakafosfaatti*, Pkf = Potassium phosphate — *kaliummetafosfaatti* (Sokli).
[2] N = Oulu saltpeter — *Oulunsalpietari* (27,5), P = Rock phosphate — *raakafosfaatti* (33), K = Potassium salt — *kalisuola* (60), Micro = Mixture of micronutrients + borate — *hivenseos* + *lannoiteboraatti*.
[3] PK = Granular phosphorus-potassium fertilizer of peatland forests — *suometsien PK-lannos, rakeinen* (0-20-20), Urea = *Urea* (46,3), Micro = Mixture of micronutrients — *hivenseos*, Ash = Dry ash — *kuiva tuhka*.

Appendix 4. Vegetation analysis of the vole damage areas (numbers 1—10, 12—43, 54—57) on drained peatlands and the comparison areas (numbers 11, 44—53) on undrained peatlands. Plant species and study plots are organized according to the TWINSPAN analysis. The groups produced by TWINSPAN are separated with lines.

Liite 4. Ojitettujen turvemaiden myyrätuhoalojen (1-10, 12-43, 54-57) ja ojittamattomien vertailualojen (11, 44-53) pintakasvillisuusanalyysi. Kasvilajit ja näytealat on järjestetty TWINSPAN-luokitteluanalyysin mukaan. TWINSPANilla muodostetut ryhmät on erotettu viivoin.

Plots-alat

Species-lajit	F	C	3	16	21	22	26	5	8	24	15	20	35	39	40	1	2	32	23	34	11	12	42	18	31	36	38	4	28	33	14	6	17	27	29	30	37	7	10	41	54	55	19	25	56	57	9	43	13	44	45	49	52	46	47	48	53	50	51
67 RUBU ARCT	5.3	2.8	99	.	.	.	.	40	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
76 LINN BORE	1.8	1.4	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
85 SALI MYRT	31.6	14.7	99	40	40	.	40	40	20	80	20	.	20	60	20	60	.	.	.	99	.	40	80	.	.	.	20	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.
14 CARE CANE	22.8	5.3	.	.	.	.	.	.	.	.	.	.	.	20	40	20	20	20	.	.	.	20	20	40	20	20	20	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
68 EPIL SP	8.8	3.5	.	.	.	.	.	.	.	.	.	.	.	.	40	20	60	60	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
83 PYRO MINO	10.5	2.5	.	.	.	.	.	.	.	.	20	20	.	.	.	20	20	40	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
65 CARE SP	14.0	4.5	.	.	.	.	.	.	.	.	.	.	.	.	.	20	20	20	.	.	.	.	.	.	20	.	.	.	20	.	.	.	99	.	.	20	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71 EPIL PALU	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
77 CARE CHOR	24.6	12.3	.	.	.	.	.	.	.	.	.	.	.	.	.	40	80	80	20	40	60	.	40	99	60	.	40	.	40	40	.	.	20	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
78 AGRO MERT	1.8	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
79 HUPE SELA	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
90 GYMN DRYO	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
81 EQUI SP	3.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
82 MONE UNIF	8.8	3.2	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	40	.	40	.	20	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
84 PYRO ROTU	3.5	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
70 CALA CANE	5.3	2.8	80	.	.	.	.	.	.	.	.	.	.	.	.	60	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
72 ERIO ANGU	42.1	23.1	.	.	60	20	.	20	40	20	.	.	.	.	.	20	60	20	.	.	.	.	.	99	80	99	.	40	60	80	40	20	99	80	40	80	80	60	40	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
74 VIOL EPIP	5.3	2.5	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17 CARE MAGE	36.8	19.9	.	20	20	.	.	20	.	20	.	.	.	.	.	.	.	.	.	40	20	20	.	99	80	.	80	20	80	99	.	.	99	20	99	99	99	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	40
43 MENY TRIF	52.6	31.5	.	.	.	.	.	.	.	.	.	.	.	.	.	40	40	99	99	99	99	99	20	99	40	20	40	40	40	60	.	20	60	80	20	40	20	20	80	40	.	.	.	.	.	.	.	.	.	.	.	.	99	80	20	80	.	99	99
75 CALA STRI	14.0	5.6	.	.	.	20	.	.	.	.	.	.	.	.	.	.	60	60	.	.	.	.	.	.	.	40	.	60	20	40	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13 ERIO VAGI	75.4	52.4	40	80	99	60	60	40	60	40	.	40	80	20	99	80	80	80	99	80	99	80	20	20	80	80	99	80	99	99	20	99	.	80	99	40	60	99	99	99	.	.	.	20	.	.	.	.	80	.	.	60	60	99	20	.	60	.	.
30 EPIL ANGU	29.8	7.7	.	.	20	.	40	.	.	.	.	20	40	20	.	20	.	20	.	.	.	.	.	.	.	.	.	40	60	20	20	.	20	20	.	20	20	.	.	.	.	20	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
36 BETU PUBE	64.9	27.0	.	.	99	.	20	60	20	60	40	60	40	40	20	60	40	60	20	40	.	.	.	60	40	40	20	.	40	60	40	20	20	60	40	20	40	80	40	40	40	20	.	20	20	.	.	.	40	.	.	.	60	.	.	.	.	.	.
7 JUNI COMM	10.5	4.6	80	20	20	20	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99	.
73 CALA PURP	21.1	7.4	20	20	.	20	40	.	.	.	60	40	.	40	20	.	20	.	.	.	.	.	.	20	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10 LIST CORD	19.3	6.0	.	.	.	.	.	.	.	.	.	.	.	.	.	40	20	60	.	20	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	20	40	20	.	.	.	.	.	.	.	.	.	40	40	.	20	.	.	.	.	.	.
31 POTE PALU	35.1	16.1	.	.	.	.	.	.	.	.	20	.	.	.	.	99	80	80	.	20	.	.	40	20	60	20	.	40	.	40	.	.	.	.	.	.	.	40	20	40	40	60	.	.	.	.	.	.	.	.	.	20	99	.	.	40	.	40	.
6 PICE ABIE	26.3	8.1	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	20	.	.	.	.	.	40	40	.	.	20	.	.	.	.	20	20	.	.	.	60	40	40	.	.	.	.	20	60	.	.	.	.	.	20	20	20	.	.	.	.	.
12 TRIC CESP	40.4	19.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	40	40	40	.	40	20	20	60	40	80	40	99	60	40	40	.	.	.	.	.	.	.	.	20	.	20	.	60	60	60	80	20	.	99
27 MOLI CAER	15.8	10.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	99	40	80	40	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	.	99	99
4 EQUI FLUV	47.4	26.6	.	.	.	.	40	.	20	.	.	.	.	.	.	99	99	99	20	80	.	60	.	.	.	.	.	.	.	.	20	60	60	20	20	20	.	40	60	80	20	.	.	.	.	.	.	.	20	.	.	80	99	40	40	99	20	99	99
53 VACC ULIG	93.0	65.4	80	99	99	99	99	60	99	99	40	40	20	99	60	80	40	40	40	20	80	60	80	.	.	20	40	20	.	.	80	99	20	60	40	60	60	80	80	60	80	20	99	99	99	99	99	40	99	99	99	99	80	99	99	80	80	80	20
37 BETU NANA	96.5	87.5	80	99	99	99	99	99	99	99	.	80	99	60	99	99	99	99	99	99	99	99	99	40	80	99	99	99	80	99	99	99	99	80	99	99	80	99	99	99	99	60	99	99	99	99	99	.	80	60	99	80	40	99	80	99	99	99	40
39 SALI SP	40.4	14.4	.	.	.	.	.	20	20	20	.	.	.	20	20	.	20	.	20	60	.	.	.	.	20	.	.	60	20	60	.	.	.	60	40	40	40	.	.	20	80	.	.	.	.	40	.	.	20	20	.	.	80	.	.	.	.	20	.
55 VACC OXYC	93.0	68.2	.	80	99	99	80	80	99	80	20	20	99	20	80	99	80	60	99	99	99	80	99	80	99	80	80	80	60	60	80	80	99	60	60	80	20	60	99	99	40	.	40	20	60	80	.	.	60	40	40	60	99	99	99	99	80	99	20
56 ANDR POLI	96.5	65.4	60	20	80	60	60	80	99	60	.	20	20	40	60	99	40	99	99	99	80	99	80	60	99	40	80	60	40	60	60	80	99	60	99	40	40	80	99	40	40	20	60	20	20	80	80	20	60	.	60	99	99	99	99	99	99	99	80
58 EMPE NIGR	84.2	51.1	80	60	99	20	60	80	99	99	.	20	60	40	.	20	.	40	40	.	40	80	99	20	40	40	60	.	40	20	60	99	20	60	20	.	20	99	80	99	20	.	60	40	99	99	60	20	80	80	80	99	80	80	99	80	.	20	.
69 MELA PRAT	31.6	11.9	20	.	20	.	.	20	.	.	.	20	.	20	.	80	99	60	.	99	.	.	20	.	.	.	.	.	.	.	.	.	.	20	.	.	.	40	.	20	.	.	20	40	.	.	40	20	20	.	.	.	.	.	.	.	.	.	.
40 TRIE EURO	36.8	17.9	99	40	60	80	20	20	.	20	20	60	.	.	.	.	.	.	.	.	.	.	.	20	80	80	.	80	60	20	60	.	.	.	.	.	.	.	.	.	20	20	.	.	.	.	.	.	.	.	20	.	.	.	.	40	.	99	.
60 SOLI VIRG	5.3	2.1	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	60	.	.	.	.	.	.	.	.
21 CARE DIOI	12.3	2.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	20	20	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	40	.	.	.	.	.	20
45 PYRO SP	3.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.
47 RUBU CHAM	61.4	42.0	.	.	.	.	.	.	.	.	60	80	99	80	80	60	20	.	.	.	99	.	.	.	60	.	60	.	20	80	.	80	.	80	20	60	20	99	99	99	.	40	40	99	60	80	20	99	40	.	.	99	60	99	99	60	99	40	.
66 SALI PHYL	3.5	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.
5 PINU SYLV	29.8	9.8	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	20	.	.	.	.	40	.	20	40	20	.	40	.	20	.	20	20	60	20	.	.	.	.	.	.	.	60	40	40	.	60	.
16 CARE LIMO	3.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
28 TOFI PUSI	15.8	6.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	20	.	.	.	.	.	.	40	60	.	.	.	.	.	.	.	.	.	40	.	60	.	.	.	20	.	20	99
34 DACT MACU	3.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
54 VACC VITI	54.4	33.9	60	40	40	.	.	40	99	40	80	80	40	99	20	20	20	.	.	.	20	.	60	20	20	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	80	99	99	99	99	99	99	80	20	60	99	99	.	.	.	.	.	.
57 LEDU PALU	47.4	28.2	80	.	.	.	.	60	20	20	40	20	.	40	20	.	.	.	20	.	99	.	80	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	60	40	60	40	80	60	90	60	80	99	99	80	20	60	.	99	.	.
26 DESC FLEX	5.3	2.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99	40	.	.	.	.	.	.	.	.
52 VACC MYRT	26.3	13.0	20	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	20	.	.	.	.	60	80	99	60	80	99	40	40	20	40	20	.	.	.	.	.	.
2 EQUI SYLV	12.3	7.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	20	99	20	40	.	80	.	.	99	.	.	.	.	.	.	.	.
20 CARE GLOB	15.8	11.5	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	80	80	99	99	99	.	40	60	.	.	.	.	.	.	.	.
25 CALA SP	3.5	2.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44 ORTH SECU	5.3	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	20	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.
48 RUBU SAXA	1.8	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
59 MELA SYLV	7.0	2.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	60	.	20	20	.	.	.	.	.	.
3 EQUI ARVE	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.
18 CARE NIGR	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.
24 AGRO SP	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.
41 VERO SERP	3.5	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	20	.	.	.	.	.	.	.	.
46 RUBU IDAE	1.8	1.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99	.	.	.	.	.	.	.	.
23 CARE VAGI	7.0	2.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	20	40	.	.	.	.	.	60	.
1 EQUI PALU	14.0	6.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	40	99	20	.	.	20	.	60	.
15 CARE LASI	8.8	6.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	60	.	99	.	99	99
19 CARE ROST	8.8	4.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	40	.	60	40	.	60
22 CARE PAUC	8.8	5.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.	80	20	80	99	.	.
42 VIOL PALU	3.5	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	60	.
8 JUNC STYG	1.8	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40
9 SELA SELA	3.5	2.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	80
11 TRIC ALPI	8.8	5.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	80	99	40	40
29 SCHE PALU	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.
32 PARN PALU	1.8	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	.
33 DROS ROTU	10.5	7.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	99	80	80	.	80	80
35 DROS ANGL	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20
38 ALNU INCA	1.8	1.1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	.
49 FILI ULMA	1.8	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80	.
50 PEDI PALU	1.8	0.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.
61 PING ALPI	1.8	0.7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40
62 UTRI VULG	1.8	1.4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	80
51 CALL VULG	12.3	5.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	60	80	60	.	60	20



THE FINNISH FOREST RESEARCH INSTITUTE

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1 Kolari
2 Rovaniemi
3 Muhos
4 Kannus
5 Parkano
6 Suonenjoki
7 Joensuu
8 Punkaharju
9 Ruotsinkylä
10 Ojajoki

FACTS ABOUT FINLAND

Total land area: 304 642 km^2 of which 60—70 per cent is forest land.

Mean temperature, °C:	Helsinki	Joensuu	Rovaniemi
January	-6,8	-10,2	-11,0
July	17,1	17,1	15,3
annual	4,4	2,9	0,8
Thermal winter (mean temp. < 0°C):	20.11.—4.4.	5.11.—10.4.	18.10.—21.4.

Most common tree species: Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens

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Communicationes Instituti Forestalis Fenniae

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