Field and ground layer vegetation in birch forests after Oporinia damage

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LEHTONEN, JUHANI & YLI-REKOLA, MATTI. Field and ground layer vegetation in birch forests after Oporinia damage. Rep. Kevo Subarctic Res. Stat. 15: 27—32. Illus. 1979. — The development of the field and ground layer vegetation in *Oporinia* damage areas of 1960's in Utsjoki was studied analyzing 6 fenced areas and corresponding control areas in 1970, 1973 and 1978. Especially grasses increased prominently soon after damage, but only 6—8 years after the attack the luxuriance of the vegetation has again much decreased, and the same trend is still continuing. The vegetation has not returned to the situation similar to the predamage stage, but resembles a more alpine vegetation type.

KEY WORDS: — Betula — Oporinia — principal component analysis — vegetation

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1. Introduction

The caterpillars of the geometrid moth *Oporinia autumnata* Bkh., defoliated approx. 5000 km^2 of birch forest in Finnish Lapland in 1965, and in the area of Utsjoki (the northernmost district of Finland) alone about 1350 km^2 were damaged (Kallio & Lehtonen 1973, 1975).

Oporinia damage may even have very far-reaching influence upon the whole of the ecosystem attacked. Accordingly, the future of the defoliated birches — their possible, gradual recovery or final death — has been continuously followed, and also other vegetation in the damage areas is under observation. In this paper the development of the field and ground layer vegetation in the damage areas is studied.

2. Material and methods

The observations and vegetation analysis have been made in fenced areas of 20 × 20 m (experimental areas) that were built in 1970—1971 in Utsjoki in *Oporinia* damage areas (Fig. 1.), and in control areas of equal size, situated in close vicinity to the fenced areas. The purpose of the fences is to eliminate the effect of reindeer grazing. The vegetation of the sites was analyzed three years: 1970, 1973 and 1978; the site 6 was analyzed only in 1973 and 1978, because the fence was built in 1971.

In each experimental area and in corresponding control areas the analysis were made by studying 10 squares, each of 1 m^2. The coverage (as %) of all the species was carefully measured with the aid of a grid divided into 100 squares; only liverworts were not specified. In the first year, 1970, however, the coverage of only 8 species *(Deschampsia flexuosa, Trientalis europaea, Vaccinium myrtillus, Hylocomium splendens, Pleurozium schreberi, Peltigera aphthosa, Nephroma arcticum, Stereocaulon paschale)* and of the genus *Cladonia* was studied. Only the occurrence (presence or absence) of other species was noted. The coordinates of the squares were selected at random in the first analysis, and the same ones were used in later analysis. The degrees of damage and recovery of the birches damaged by *Oporinia* were studied at the same time. The damage was very intense and recovery, if it has occurred, has been of no importance for the ground vegetation. The tree shelter of field and

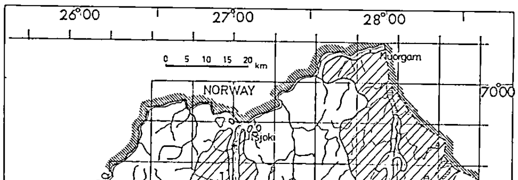

Fig. 1. The *Oporinia* damage areas in Utsjoki and the situation of the fenced areas. The sites are as follows: 1: Jesnalvaara, 2: Shirrajärvi, 3: Kenesvaara I (N), 4: Kenesvaara II (S), 5: Njallajärvi, 6: Luonnonpuisto (Kevo Nature Park).

ground layer vegetation was thus totally eliminated during the observation period.

The diversity indices of the field and ground layer vegetation, for the years 1973 and 1978, were determined according to McIntosh's formula:

$$M = \frac{N - \sqrt{\sum^{s} ni^2}}{N - \sqrt{N}}$$

(N = abundance of all the species in the studied area, n = abundance of i-species, s = number of the species). Similarly, the simple community dominance indices were determined for the years 1973 and 1978, using the formula

$$D = \frac{100(y_1 + y_2)}{y}$$

(y_1 = abundance of most abundant species, y_2 = abundance of second most abundant species, y = total abundances for all species). Principal component analysis of the primary material was performed with WANG mini-computer. The analysis is based on the product moment correlation coefficients between pairs of species, when the total variation of each species is equal. Thus the weight of the species does not depend on their abundances. The correlation coefficients are based on the absolute coverage observations, + being interpreted as 0.5 %. If the mean coverage value of a species in a studied area was under 0.2 % in every studied year, all the coverages were marked as 0. From the correlation matrix the eigenvalues and -vectors were solved by a modified Jacobi-method (WANG 2200 general program library, mathematics GLBR 22). The coordinates for the studied sites were calculated using the normalized eigenvectors: thus the principal component was weighted according to its standard deviation. For the detailed performance and limitations of principal component analysis see e.g. Cooley & Lohnes (1971) and Sheard & Jonescu (1974).

3. Results

In Table 1 there are given the frequencies and the mean coverage values for 14 species at 6 sites over the studied years. These species include the eight species and *Cladonias* for which there are coverage values from three years and in addition 5 species *(Empetrum hermaphroditum, Linnaea borealis, Solidago virgaurea, Vaccinium vitis-idaea, Polytrichum juniperinum)* which obviously react clearly to changes in environmental conditions after *Oporinia* damage (Kärenlampi 1972, Kallio & Lehtonen 1973). In Table 2 there is a presentation of the trends of these species, and also of some *Cladonia*-species. The diversity indices and the community dominance indices based on the whole primary material for the years 1973 and 1978 are given in Table 3.

The development of the vegetation in the periods 1970—1973 and 1973—1978 illustrated by principal component analysis is presented in Figs. 2 and 3. The principal component analysis tends to summarize the main directions of variation of the variables (= species). Because the variation is mixed with both areal and temporal elements, Figs. 2 and 3 can give only a rough picture of the species composition in different situations. Nevertheless, the principal components used in the diagrams explain a notable part of the total variation of the species, as follows; I: 39.3 %, II: 17.1 % and III: 15.3 %. The three first principal components thus account for 71.7 % together. — Table 2 is given to clarify the development and trends of the different species during those time periods.

4. Discussion

Oporinia damage causes notable changes in the environmental conditions of a birch forest ecosystem quite rapidly. Since the tree layer has in practice totally vanished, illumination at the level of the field and ground layers increases notably. Also the amount of nutrients in the soil increases markedly, because the production of debris is abundant

Table 1. Frequencies and mean coverage values of 13 species and of *Cladonias*, in experimental and control areas of the studied sites, in 1970, 1973 and 1978.

	Jesnalvaara (1)						Shirrajärvi (2)						Kenesvaara I (3)						Kenesvaara II (4)						Njallajärvi (5)						Luonnonpuisto (6)					
	-70		-73		-78		-70		-73		-78		-70		-73		-78		-70		-73		-78		-70		-73		-78		-70		-73		-78	
	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
EXPERIMENTS																																				
D. flexuosa	100	26	100	14	90	9	100	14	100	11	100	8	100	19	100	20	100	7	100	14	100	10	60	1	—	—	10	+	10	+	x		100	7	100	2
T. europaea	30	+	40	3	40	+	30	2	40	2	—	—	90	15	90	5	90	4	100	7	90	2	40	+	—	—	—	—	—	—	x		20	+	—	—
V. myrtillus	100	1	100	3	100	1	100	2	100	8	100	7	90	1	90	6	90	8	50	+	30	1	30	+	—	—	20	+	30	+	x		100	2	100	3
H. splendens	80	14	20	1	60	2	80	2	60	+	—	—	100	5	60	1	70	2	10	+	10	+	—	—	—	—	—	—	—	—	x		—	—	10	+
P. schreberi	100	20	90	8	100	15	100	14	100	14	100	9	100	33	90	10	100	10	80	4	40	+	30	+	20	+	30	+	20	+	x		60	6	50	12
P. aphthosa	70	1	30	+	60	+	20	+	20	+	20	+	60	+	20	2	10	+	30	+	10	+	—	—	—	—	—	—	—	—	x		30	+	—	—
N. arcticum	30	2	30	1	30	2	50	3	50	2	60	3	50	3	60	2	50	4	—	—	—	—	—	—	—	—	—	—	—	—	x		50	2	40	3
S. paschale	—	—	—	—	—	—	—	—	—	—	10	+	30	+	20	+	20	+	100	3	80	3	100	6	90	+	100	1	100	1	x		100	14	100	22
Cladonias	70	3	90	3	90	9	100	1	100	1	100	5	100	1	90	1	100	3	100	5	100	7	100	13	100	3	100	9	100	11	x		100	14	100	17
L. borealis	100	x	100	3	90	2	100	x	100	1	80	3	100	x	90	6	90	1	90	x	80	1	30	+	—	—	—	—	—	—	x		40	1	—	—
S. virgaurea	40	x	40	2	40	3	—	—	—	—	20	+	10	x	30	+	10	+	70	x	70	1	80	1	—	—	—	—	—	—	x		40	1	—	—
V. vitis-idaea	100	x	100	4	100	4	100	x	100	1	100	2	100	x	100	6	100	11	100	x	100	7	100	6	100	x	100	3	100	4	x		100	4	100	3
E. hermaphroditum	100	x	100	35	100	44	100	x	100	48	100	49	100	x	100	31	100	46	70	x	60	16	70	27	100	x	100	51	100	46	x		100	21	100	26
P. juniperinum	70	x	50	3	80	1	50	x	20	+	—	—	70	x	80	1	80	2	100	x	100	5	100	10	100	x	100	1	90	1	x		100	+	80	2
CONTROLS																																				
D. flexuosa	100	14	100	7	100	6	100	10	100	10	100	10	100	9	100	8	100	5	100	12	100	9	100	3	—	—	—	—	—	—	x		100	8	90	3
T. europaea	60	2	60	2	20	+	—	—	—	—	—	—	100	5	100	2	70	1	100	7	100	3	40	+	—	—	—	—	—	—	x		20	+	—	—
V. myrtillus	80	1	90	3	100	4	90	2	100	4	100	4	100	4	100	3	100	5	70	1	70	1	70	1	10	+	50	+	40	1	x		90	3	100	5
H. splendens	100	13	90	6	20	+	30	+	—	—	—	—	80	6	90	1	70	1	10	1	—	—	10	+	—	—	—	—	—	—	x		—	—	—	—
P. schreberi	100	26	90	17	80	28	100	16	100	10	100	11	100	30	100	26	100	17	90	6	90	3	90	7	40	3	40	3	50	2	x		70	7	60	10
P. aphthosa	90	2	60	1	—	—	80	1	60	1	30	+	80	1	70	+	50	+	—	—	—	—	—	—	—	—	—	—	—	—	x		—	—	—	—
N. arcticum	40	1	40	1	10	+	30	2	40	1	10	+	80	7	70	3	100	4	40	1	50	1	30	2	—	—	10	+	20	+	x		50	1	40	2
S. paschale	—	—	10	+	—	—	30	+	50	1	50	1	—	—	60	+	—	—	80	2	80	+	60	2	20	+	20	+	30	+	x		100	8	90	11
Cladonias	100	2	100	22	100	23	90	2	100	6	90	8	90	1	100	1	100	6	100	4	100	4	100	5	100	5	100	6	100	8	x		100	7	100	10
L. borealis	100	x	80	6	80	1	40	x	70	3	70	1	100	x	90	2	80	1	60	x	100	2	90	1	—	—	—	—	—	—	x		—	—	—	—
S. virgaurea	70	x	30	+	20	+	—	—	—	—	—	—	70	x	90	2	60	1	80	x	100	3	50	1	—	—	—	—	—	—	x		—	—	—	—
V. vitis-idaea	100	x	100	5	90	6	100	x	100	3	100	4	100	x	100	7	100	6	100	x	100	6	100	8	100	x	100	2	100	3	x		100	4	100	7
E. hermaphroditum	100	x	100	32	100	42	100	x	100	28	100	37	100	x	100	30	100	37	80	x	100	31	100	45	100	x	100	58	100	67	x		100	20	100	26
P. juniperinum	70	x	60	6	60	8	60	x	30	+	—	—	100	x	100	2	50	1	90	x	90	5	100	5	60	x	90	1	70	1	x		70	1	80	1

Table 2. A. Trends of 9 species in 1970—1973 and 1973—1978 at studied sites. Numbers at how many sites the species have increased (+) or decreased (—). B. Trends of 9 species during 1973—1978.

A:	1970—1973				1973—1978			
	exp.		controls		exp.		controls	
D. flexuosa	—3	+1	—3		—5		—3	
T. europaea	—2	+1	—2		—5		—3	
V. myrtillus		+5		+2	—3	+2		+3
H.splendens	—3		—4		—2	+3	—1	+1
P. schreberi	—3		—4		—1	+2	—2	+3
N. arcticum	—3		—2	+1		+4	—2	+2
P. aphthosa	—1	+1	—2		—3		—2	
S. paschale		+1	—1	+3		+3	—2	+1
Cladonias		+2		+3		+6		+5

B:	1973—1978			
	exp.		controls	
E. hermaphroditum	—1	+5		+6
L. borealis	—4	+1	—4	
S. virgaurea	—1	+2	—2	
V. vitis-idaea	—2	+3	—1	+5
D. fuscescens	—1	+3	—3	+1
P. juniperinum	—2	+3	—2	+1
Cladonia mitis		+5	—1	+5
C. rangiferina		+3		+3
C. stellaris			—2	+1

Table 3. Diversity (M) and dominance (D) indices of field (fl) and ground (gl) layer vegetation, or of both together (tot.), at studied sites, in 1973 and 1978.

		Jesnalvaara 1973	Jesnalvaara 1978	Shirrajärvi 1973	Shirrajärvi 1978	Kenesvaara I 1973	Kenesvaara I 1978	Kenesvaara II 1973	Kenesvaara II 1978	Njallajärvi 1973	Njallajärvi 1978	Luonnonpuisto 1973	Luonnonpuisto 1978
M_{fl}	exp.	.4685	.3525	.3575	.3873	.5670	.4082	.5844	.3367	.1520	.1485	.5129	.3603
	contr.	.4784	.3613	.4651	.4176	.4909	.3923	.4702	.2818	.0895	.0915	.5530	.5226
M_{gl}	exp.	.6566	.5200	.4049	.5917	.6175	.6457	.5970	.5600	.5025	.5687	.7823	.6204
	contr.	.6299	.5332	.5035	.4423	.3428	.4886	.7135	.6956	.7266	.6441	.6643	.6272
D_{fl}	exp.	74.24	81.53	80.82	75.75	65.38	75.00	65.00	82.50	93.22	92.45	70.00	76.31
	contr.	67.24	76.19	76.00	77.00	67.85	74.13	71.42	86.88	95.23	95.89	66.66	64.70
D_{gl}	exp.	57.89	77.41	76.19	70.00	61.90	58.33	66.66	69.69	66.66	68.18	47.91	50.74
	contr.	60.00	72.85	74.41	82.92	78.37	74.19	52.94	52.17	56.25	58.82	48.57	50.00
$D_{tot.}$	exp.	57.64	62.76	65.95	59.60	51.51	57.00	44.82	54.79	77.92	76.00	39.77	45.71
	contr.	43.90	52.63	53.76	58.82	60.21	60.67	54.79	63.09	81.01	83.33	37.66	39.39

after the death of the trees (at least of the parts above ground), and because the trees no longer take nutrients from the soil. The increase in nitrogen may be especially prominent in normally N-poor areas. Possibly it is just these factors that cause the well-known phenomenon that the vegetation of the field layer becomes much richer and lusher soon after the damage. Particularly grasses (e.g. *Deschampsia flexuosa, Festuca ovina, Linnaea borealis, Solidago virgaurea* and *Trientalis europaea)* increase in abundance (Holmgren 1905, Kalliola 1941, Hämet-Ahti 1963, Nuorteva 1963, Kärenlampi 1972, Kärenlampi & Kauhanen 1972, Kallio & Lehtonen 1973, 1975). The grasses evidently also benefit from the damage to dwarf shrubs caused by *Oporinia* in many places in birch damage areas.

Particularly notable changes occur in general, however, only locally, in mesic forest types. All the sites studied here are rather dry: according to the type classification by Hämet-Ahti (1963), sites 1—3 belong to the middle class (sELiPlT), and sites 4—6 represent the poorest type, sELiT. Due to the barrenness of the areas the changes in the field layer have obviously not been prominent, but many species, however, even in 1970, were much more abundant than normally.

What happened in the field and ground layers in the course of 8 years has been studied during two periods, 1970—1973 and 1973—1978. General observations can first be made studying the principal component analysis diagrams, Figs. 2 and 3. The development of the vegetation at different sites followed much the same lines along the first axis. This means that the first component is

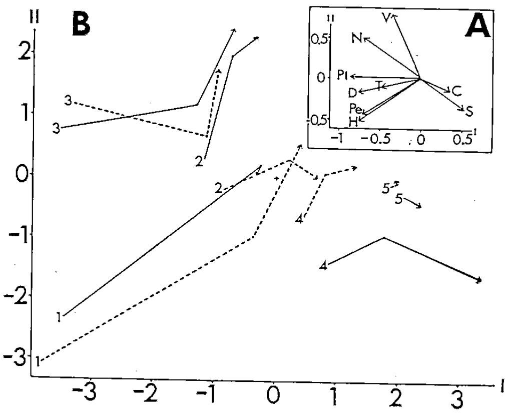

Fig. 2. A. An interpretative background of species trends for the examination of the studied sites in Fig. 2 B. The degree of explanation and the direction of the variation of the species using principal components I and II are described by eigenvectors of species. The eigenvectors are combined in a coordinate system of principal components I and II as arrows drawn from origo. The length of an arrow shows the degree of explanation and the direction the increase of a species. D: *D. flexuosa,* T: *T. europaea,* V: *V. myrtillus,* H: *H. splendens,* Pl: *P. schreberi,* N: *N. arcticum,* Pe: *P. aphthosa,* S: *S. paschale,* C: genus *Cladonia.*

B. The points of the time series of experimental areas at 5 studied sites are combined in two-part arrows. The starting point of an arrow describes the year 1970, the turning point the year 1973 and the point the year 1978. The control areas are similarly described using dotted line arrows. The numbers of the sites are as in Fig. 1.

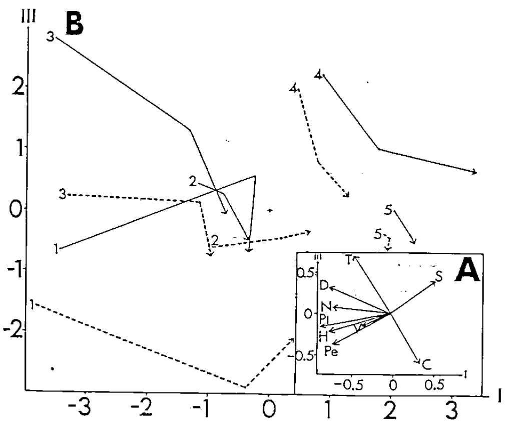

Fig. 3. As Fig. 2, but the principal components are I and III.

most clearly to be interpreted as the time dimension, but also as the luxuriance dimension (see the forest type classification and the Figs. 2A and 3A): the negative end is more mesic and the positive side is poorer. — The development to the poorer direction was, in addition, faster during the first period, though this was shorter.

The second component describes best differences between areas. The development seems to be principally two-fold: towards *Vaccinium myrtillus* or towards *Cladonia* spp. and *Stereocaulon paschale* (Fig. 2). After 8 years the vegetation compositions at different sites were, anyway, more uniform than they were at the beginning; the 1978 points are closer together than those of 1970. This is even more clearly seen in Fig. 3 (principal components I and III). The trends suggest that environmental conditions have become more similar in originelly different areas. — On the third axis, on the other hand, the experiment and control sites are better separated from each other than in the case of the other components.

The total coverage values for the field and ground layers (determined using the whole primary material) decreased during 1973—1978, while the diversities decreased and the dominances increased (Table 3).

After the lush period the vegetation of the damage areas accordingly suffered a clear and uniform set-back at least 6—8 years after the damage, and this development is still continuing after 13 years, the reasons being obviously again the changes in the environment. As regards the different species, the grasses *(Deschampsia, Trientalis, Linnaea, Solidago)* have typically decreased, as well as the mosses of mesic areas and forest types *(Hylocomium, Pleurozium).* The dwarf shrubs (especially *Empetrum,* but also *Vaccinium*-species) have become more abundant, and in the ground layer the *Cladonias* have increased their proportions. The changes in vegetation after the lush period are thus not restricted to the field layer, but the whole life form composition seems to be changing. The vegetation obviously does not return to the situation existing in the pre-damage stage, but it resembles an alpine vegetation type, described e.g. by Kalliola (1961).

There were no decisive differences between the experimental and control areas in 1978. This may be because of the small size of the fenced areas and the relatively short time followed, and maybe also because of the consumption of voles inside the fences.

Oporinia damage with its consequences are clearly an unfavourable phenomenon from the point of view of reindeer husbandry and the food economy of reindeer. The birch itself is one of the most important plant species in the diet of the reindeer in summer, and also grasses are important (Haukioja & Heino 1974, Nieminen & al. 1976). Even the occurrence of mushrooms and *Alectoria*-species obviously much decreased in damage areas; both are important fodder for reindeer. The proportion of lichens has obviously decreased after the damage, while the field layer has become lusher. Later, however, lichens increase, but this increase is very slow, and it hardly seems possible that the biomass of lichens will be increased, compared with the predamage stage, or that they could compensate for the losses of fodder occurring elsewhere. This is partly due to the overgrazing of the areas (Kärenlampi 1973).

Kallio & Lehtonen (1973) predicted that about half of the *Oporinia* damage areas of the 1960's in Utsjoki would be finally changed to treeless tundra, and that the trend is similar also elsewhere. This, with its consequences would, accordingly, mean a considerable loss for reindeer or husbandry.

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