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Invertebrates of young Scots pine stands near the industrialized town of Harjavalta, Finland

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TIIVISTELMÄ: NUORTEN MÄNNIKÖIDEN SELKÄRANGATTOMAT HARJAVALLAN TEOLLISUUSLAITOSTEN YMPÄRISTÖSSÄ

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Invertebrates of young Scots pine stands were preliminarily studied along a gradient of industrial air pollutants in Harjavalta, southwestern Finland. Bark samples and net samples on pine branches and needles were taken in May-June, 1987. The number of aphids on needles was highest near the industrial plants. The number of mites in bark was positively correlated with the increasing distance from the pollutant source. Detrended correspondence analysis ordination calculated according to the bark invertebrates showed that the sampling sites of the zones far from the emission source formed a distinct group while those of the zones near the source were relatively widely dispersed indicating disturbances in faunal structure.

Nuorten mäntyjen selkärangattomia tutkittiin alustavasti Harjavallan teollisuuslaitosten ympäristössä. Kuori- ja neulasnäytteitä otettiin touko-kesäkuussa 1987. Ilmansaasteet näyttivät vaikuttaneen selvimmin kuoren selkärangattomiin. Kirvojen määrä neulasilla oli suurimmillaan tehtaiden läheisyydessä. Kuoren punkkien runsaus oli suoraan verrannollinen etäisyyteen saastutuslähteestä. DECORANA järjesti kuoren eläimistön perusteella näytealat siten, että kaukana tehtaista sijaitsevat alat muodostivat selvän ryhmän, mutta teollisuuslaitosten lähiympäristön alat sijoittuivat etäälle toisistaan. Tämän voi tulkita olevan seurausta saasteiden aiheuttamista yhteisörakenteen muutoksista.

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1. Introduction

Conifers are highly susceptible to air pollution. The pressure of pollution is manifested primarily in them and it determines the course of the subsequent succession both of the stand and the invertebrate community. The physiological changes evoked in trees by the action of different toxic substances create favourable conditions for the development of many invertebrate species (Sierpinski 1970). Observations by various authors have revealed that a great number of noxious insects can appear as a result of emissions (Alstad et al. 1982, Führer 1985). After exposure to SO_2, pines has showed an increase in herbivore populations (Flückiger & Oertli 1978). Especially aphids have repeatedly been shown to increase near emission sources (Braun & Flückiger 1984 a, b, 1985). On the other hand, several insect groups are known to be sensitive to high concentrations of air pollutants (Strojan 1978, Alstad et al. 1982).

Previous studies have shown that several insect pests including the pine bark bug, diprionid sawflies and tortricid moths are unusually abundant in the surroundings of the factories in Harjavalta, though most of them are rare in the immediate vicinity of these pollutant sources (Heliövaara & Väisänen 1986 a, 1988). In this article, the effects of air pollutants upon the invertebrate fauna of pines in general are described. Invertebrates inhabiting pine bark and pine needles and branches were studied in young pine stands along a gradient around a distinctive pollution source.

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2. Material and methods

21. Study area

The field study was performed in a 20 . . .30-year-old forest of *Pinus sylvestris* (L.) in the surrounding of a small industrialized town of Harjavalta in southwestern Finland (61° 20'N, 22° 10'E). Samples for the study were collected around a factory complex in May-June, 1987. Heavy pollution load, even by international standards, comes from two factories, one producing copper and nickel and the other mainly sulphuric acid and fertilizers.

Air pollution has had a dramatic effect on the flora in the area since the mid 1940s. Coniferous trees have suffered most, and in the parks they have been largely substituted by poplars. Lichens have been observed to be absent within an area of 8.8 km² around the factory complex (Laaksovirta 1973, Laaksovirta & Silvola 1975). In addition to the floristic studies there is much background information available about the deposition and effects of air pollutants in the study area (Hynninen 1983, 1986, Hynninen & Lodenius 1986, Arstila et al. 1986, Kuokkanen 1986, Sippola & Erviö 1986).

22. Sampling

Invertebrates were collected in sample plots located along four transects running from the factory complex to SE, S, SW and W. Each transect was about 9 km long, and each contained nine sample plots at approximately logarithmic distances (Fig. 1). The same study plots have been exploited in our previous studies (Heliövaara 1986, Heliövaara & Väisänen 1986 a, b, Heliövaara et al. 1987).

Five pines at each plot were sampled, but in several cases this was not possible due to the height of pines. Branches of the pines were struck five times with a hoop net (diameter of the frame 450 mm). Contents of the hoop net were then set in plastic bags and transferred to laboratory, where the invertebrates were counted and identified. Bark samples were taken by removing 100x500 mm of loose bark with a knife at a height of 0.5–1.5 m. The bark samples were placed in plastic bags and frozen in the laboratory. All the invertebrates present in the bark slices were removed and preserved in alcohol. Very small (<0.5 mm) animals were not counted.

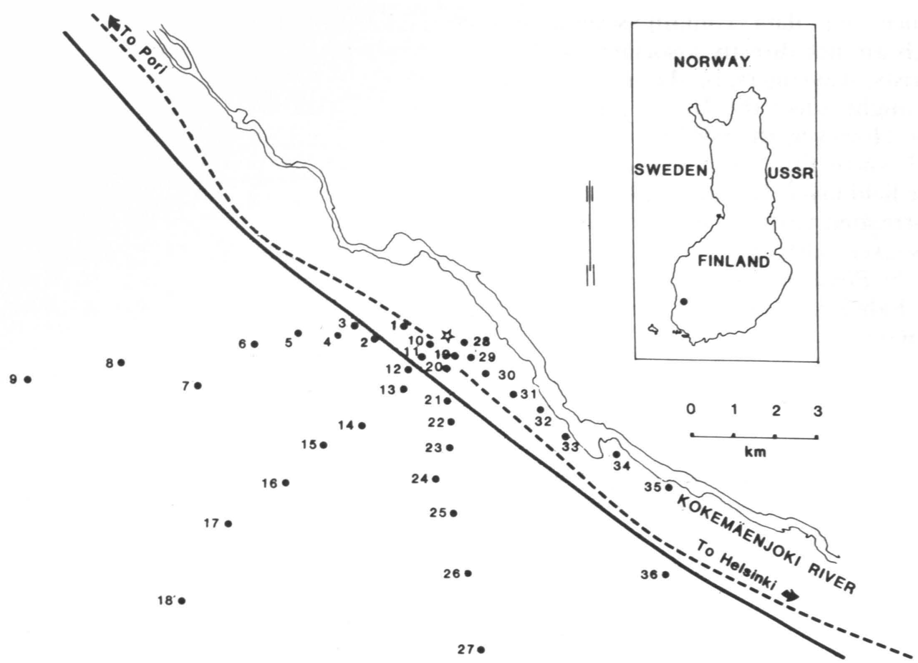

Fig. 1. Location of the sample sites along four 9-km-long transects in the study area (numbered dots). The factory complex is indicated by an asterisk.

A two-way indicator species analysis (TWINSPAN) was applied to classify the sample plots according to their vegetation. For this purpose, general information on floristic characteristics was collected at each sample plot. Vascular plant species were identified and their percentage of coverage estimated. Differences in the faunal composition of the bark fauna of the sites were analysed by a detrended correspondence analysis (DECORANA). The invertebrate material from needles was not sufficient for such an analysis. In DECORANA ordination SD-units indicate average standard deviations of species turnover. A full turnover in species composition of samples occurs in about 4 SD, and a half-change in about 1 SD (Gauch 1982, Goldsmith et al. 1986).

3. Results

Number of invertebrates totalled 933 individuals in the needle samples and 2692 in the bark samples. The most abundant groups were Collembola, Diptera, Homoptera and Acarina in the needles (Table 1) and Acarina, Collembola and Araneae in the bark (Table 2). There was much variation in the number of individuals and taxa among sample sites both within and between the zones and the transects. The TWINSPAN carried out for the vegetation characteristics clearly showed that there is no systematic difference among the transects (Fig. 2). The primary division among the habitats is that between exposed mineral soil sites (10, 19, 29) or lawn sites (31, 32, 33), and the others. This division is, of course, related to the level of air pollution and urbanisation.

Since our data contain several species which are not directly associated with pines (tourists, scavengers, predators, etc.), vegetation might affect the faunal composition on pines. However, the needle invertebrate data could not be fitted to the vegetation patterns of the field layer. Neither could they be clearly correlated with the distance of the pollutant source, although the number of aphids (mostly *Pineus pini* Gmelin and *Schizolachnus pineti* Fabricius) was highest near the industrial plants.

The number of mites in the bark samples was positively correlated to the increasing distance from the pollutant source ($t = 2.339$, $P = 0.048$, $df = 7$). The sampling sites were plotted on the first and second axes of detrended correspondence analysis according to their bark fauna (Fig. 3). The sampling sites of the zones 1-3 near the emission source were relatively widely dispersed while those of the zones 7–9 formed a distinct and compact group.

Table 1. Recorded taxa of invertebrates (individuals per sample per plot) in the needle samples at different distances from the factories (zones 1–9). Samples from two outermost sites have been combined.

	Zone							
	1	2	3	4	5	6	7	8+9
	Metres from the emission source							
Taxon	500	800	1400	1800	2600	3900	4800	7700
Aranea	0.22	0	0.22	0	0	0.99	0.40	0.20
Acarina	0.11	0.20	0.22	0.09	3.00	5.75	0.60	4.20
Collembola	0.78	0	13.89	3.00	11.80	6.75	1.60	3.20
Homoptera	8.89	1.00	1.67	2.27	3.22	1.26	0	0
Heteroptera	0.11	0	0.22	0	0	0	0	0
Thysanoptera	0.78	0	1.00	0.27	0.44	0	0	0.80
Diptera	1.11	0.40	1.45	0.45	1.11	11.41	1.00	9.40
Lepidoptera	0	0	0	0	0	0.08	0	0
Hymenoptera	0.77	0.20	0	0.09	0	0.50	0	0
Coleoptera	0.99	0	0.33	0.09	0	0.11	0.08	0

Table 2. Recorded taxa of invertebrates (individuals per sample per plot) in the bark samples at different distances from the factories (zones 1–9).

	Zone								
Taxon	1	2	3	4	5	6	7	8	9
Aranea	0.20	0.50	1.10	0.84	0.47	0.55	1.00	0.75	1.20
Acarina	0.50	1.60	1.25	4.37	12.89	8.75	17.53	47.15	14.80
Collembola	0.90	1.15	7.00	4.74	2.26	8.45	1.37	1.25	2.30
Heteroptera	0.10	0.35	1.10	0.21	0.21	0.10	0	0	0.05
Homoptera	0	0	0	0.05	0.05	0	0	0	0
Thysanoptera	0	0.20	0	0	0.26	0.10	0.05	0.15	0
Neuroptera	0	0.10	0.20	0	0	0	0	0	0.05
Diptera	0	0	0.10	0	0	0	0	0	0
Lepidoptera	0	0.20	0.10	0	0.05	0.05	0	0	0.10
Hymenoptera	0.20	0.45	0.05	0.63	0.16	0.15	0.05	0.25	0.20
Coleoptera	0.10	0.10	0.05	0.05	0.05	0.10	0	0	0.05

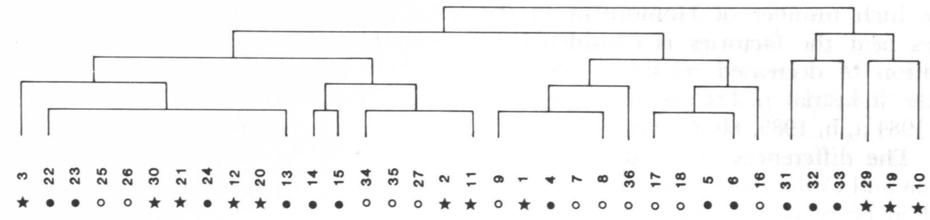

Fig. 2. A dendrogram of a two-way indicator species analysis (TWINSPAN). Numbers of sample sites refer to Fig. 1. Black stars – zones 1–3, black dots – zones 4–6, open circles – zones 7–9. Sample plot 28 has been omitted from the analysis due to an expanding carbon depot.

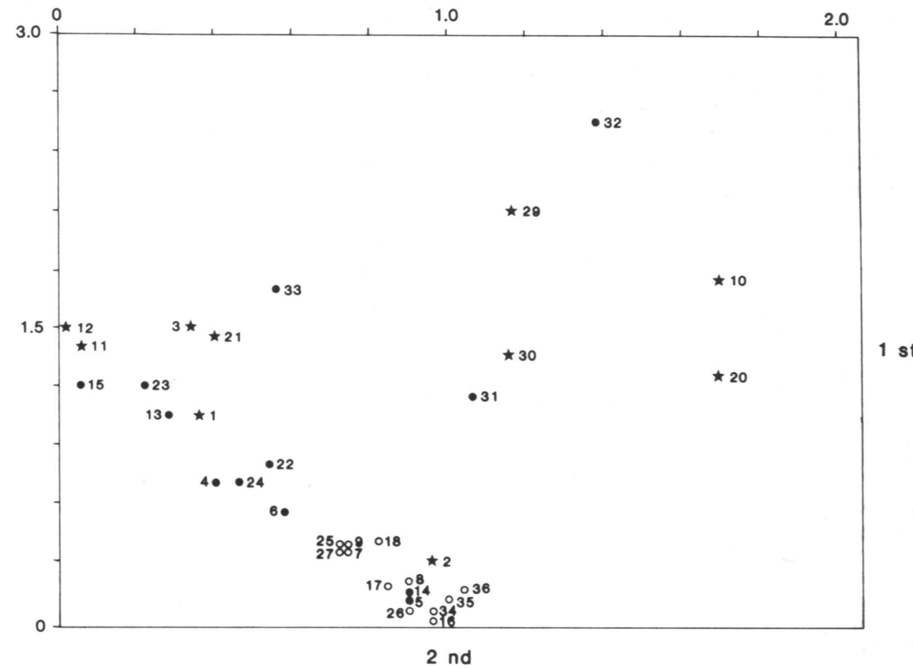

Fig. 3. The sampling sites plotted on the 1st and 2nd axes (eigenvalues 0.41 and 0.16) of detrended correspondence analysis ordination (DECORANA) according to their bark invertebrates. Symbols as in Fig. 2.

4. Discussion

Air pollution has detrimental direct and indirect effects on invertebrate populations (Gilbert 1971, Alstad et al. 1982, Bengtsson & Rundgren 1982, 1984, Bengtsson et al. 1983, Katayev et al. 1983, Beyer et al. 1985, Gunnarsson 1988), but the present data do not necessarily allow such conclusions. The results show that the effect of habitat, vegetation, microclimate and chance can outweigh the effect of industrial air pollution on the needle invertebrates. Admittedly, this may be partially due to rough methods and limited material.

The hich number of Homoptera in the needles near the factories is considered an indication of decreased resistance of pines near the industrial plants (see Braun & Flückiger 1984 a, b, 1985, Heliövaara & Väisänen 1988). The differences observed in Diptera, Acarina and Collembola among sites are suggested to be related to their habitat preferences (in this case moist microclimate may be decisive). The material was collected in May-June when the needle eating insects such as *Panolis flammea* (Noctuidae) and diprionids had not yet reached their seasonal consumption peaks (Tenow & Larsson 1987). These herbivores may be more susceptible to pollutants and their indirect effects than most of the groups here investigated. However, the species assemblage of needle invertebrates appears such a complex system that even excluding annual and seasonal fluctuations the present method can give only a preliminary snapshot picture of invertebrates in a pollutant gradient.

Although the bark invertebrate data could not be simply fitted to the vegetation patterns, the results from the DECORANA suggest that pollution may have an important role in shaping the species assemblage. Far from the pollutant source the species assemblage appears to be rather similar, although the distances between sampling sites were long, while near the factories there is much more variation among the more closely situated sampling sites. Thus, pollution may have violated the balance in the fauna. For instance, the decreased number of bark mites near the factories is either an indication of their sensitivity to air pollutants or a response to changes in their food sources.

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