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Silva Fennica, joka vuosina 1926–66 ilmestyi sarjajulkaisuna (niteet 1–120), on vuoden 1967 alusta lähtien neljännesvuosittain ilmestyvä aikakauskirja. Suomen Metsätieteellinen Seura julkaisee myös *Acta Forestalia Fennica* -sarjaa vuodesta 1913 (nide 1) lähtien.

Tilauksia ja julkaisuja koskevat tiedustelut osoitetaan seuran toimistolle. Silva Fennican tilaushinta on 160 mk kotimaassa, ulkomaille 220 mk.

Occurrence of *Petrova resinella* (Lepidoptera, Tortricidae) in a gradient of industrial air pollu:ants

Kari Heliövaara

TIIVISTELMÄ: PIHKAKÄÄRIÄISEN ESIINTYMINEN ERÄÄN TEOLLISUUSALUEEN YMPÄRISTÖSSÄ

Heliövaara, K. 1986. Occurrence of *Petrova resinella* (Lepidoptera, Tortricidae) in a gradient of industrial air pollutants. Tiivistelmä: Pihkakääriäisen esiintyminen erään teollisuusalueen ympäristössä. Silva Fennica 20 (2): 83–90.

The relationship between industrial air pollutants and the occurrence of galls of *Petrova resinella* (Lepidoptera, Tortricidae) was studied around the industrialized town of Harjavalta in western Finland. There were forty-four sampling sites set out at logarithmic distances along five transects (NW, W, SW, S, SE) from a distinctive source of emissions. Each site consisted of three circular sample plots (30 m^2) in young Scots pine (*Pinus sylvestris*) stands. The number of galls, including cankers formed several years earlier, was highest in the vicinity of the factory complex on each transect. The highest number of two-year-old galls containing living larvae was usually recorded at the ends of the transects several kilometres from the factories. However, the significance of the differences both between zones and transects were rather low. Correlations between the deposition of heavy metals (Cd, Cu, Ni, Pb, Zn), used as an indication of the general level of air pollution, and the total number of galls, were positive and generally highly significant. It is concluded that *P. resinella* has benefited from air pollution although perhaps to less extent than some sap-sucking species.

Harjavallan kaupungin teollisuuslaitosten ympäristössä tutkittiin ilmansaasteiden ja pihkakääriäisen esiintymisen välisiä suhteita. Tutkimuksen 44 näytepistettä, joista kukin muodostui kolmesta 30 m^2 ympyräkoealasta, sijaitsivat saastutuslähteen ympärillä logaritmisen asteikon osoittamin etäisyyksin viidellä linjalla eri ilmansuuntiin. Pihkakääriäisen äkämien kokonaismäärä, menneiden vuosien äkämien aiheuttamat korot mukaanlukien, oli kaikilla linjoilla suurin tehdaskompleksin läheisyydessä. Eläviä toukkia sisältäviä kaksivuotisia äkämiä oli yleensä eniten havaintolinjojen päissä usean kilometrin etäisyydellä tehtaista, mutta erojen merkitsevyys vyöhykkeiden ja linjojen välillä oli melko alhainen. Äkämien kokonaismäärä puuta kohden oli suoraan verrannollinen ilman yleistä epäpuhtautta kuvaavien raskasmetallien laskeumiin. Pihkakääriäisen päätellään hyötyneen ilman saastumisesta, mahdollisesti rikin oksidien määrän lisääntymisestä, mutta kenties vähemmän kuin monet puilla elävät imeväsuiset hyönteiset.

Key words: Air pollution, *Pinus sylvestris*, Finland
ODC 425.1+145.7×18.28+174.7 *Pinus sylvestris*
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1. Introduction

In northern European countries, forests appear to be healthy and the level of industrialization is low compared with the situation in Central Europe. The gradual accumulation of pollutants and their transportation over long distances may, however, change the susceptibility of forest trees to insect attackt even in the north. Air pollutants certainly affect several insect species in one way or other. Some species may increase in numbers making them pests, and some may decline. However, there are several well-documented cases of long-term fluctuations in insect numbers, the reasons for which are not exactly known. The coincidence of pollutants and outbreaks of insect pests thus also raises the danger of exaggerating the effects of pollutants.

It seems that sucking insects especially benefit from a weakening of their host plants as a result of pollution (Wentzel 1965, Sierpinski 1966, 1970, Przybylski 1968, Charles & Villemant 1977, Villemant 1981, Katayev et al, 1983, Heliövaara & Väisänen 1986). However, pollutants do not only affect sucking species. Several insect species which earlier have been barely known, have recently appeared as pests on various conifers. Some taxa are assumed to be resistant to air pollution, and are thus able to increase in numbers. In this respect, much attention has been paid to some species of Lepidoptera, such as *Epinotia pygmaena* (Hübner), *Zeiraphera diniana* (Guenee) and *Operophtera brumata* (L.) (Baltensweiler 1985 and references therein). Sierpinski (1972) and Charles & Villemant (1977) reported that *Exoteleia dodecella* (L.), *Rhiaciopia (Rhyacionia) buoliana* (Denis & Schiffermüller) and *Petrova resinella* (L.) increased in polluted areas. Hågvar et al. (1976) in Norway assumed that an outbreak of *Exoteleia dodecella* was associated with air pollution. However, the moth has decreased recently in the area in spite of continuing pollution (A. Bakke, pers. comm.). Villemant (1980) reported that *Rhyacionia buoliana* was the only microlepidopterous species in France that exhibited a significant population increase in a pine stand exposed to high levels of atmospheric pollution by sulphur dioxide and fluorine. In that study, *R. pinicolana* (Doubleday), *R. pinivorana* (Lienig & Zeller), *Blastethia posticana* (Zetterstedt), *B. turionella* (L.) and *Petrova resinella* were present in low numbers and showed no tendency to increase on the polluted plots.

The present study locality, which represents a forest environment surrounding an industrial centre, offers us a possibility to study the densities of several insect species and pests around an emission source. The occurrence of *Petrova resinella* (Tortricidae) is investigated on several sample plots sited along a gradient of industrial air pollutants. The same plots have been used previously in an investigation on the densities of *Aradus cinnamomeus* Panzer (Heteroptera) in relation to pollution (Heliövaara & Väisänen 1986). The deposition level of various heavy metals, which indicate the general level of air pollution, is known in these sites (Hynninen 1983). The present study is restricted to determining whether there are any correlations between the level of pollution and the abundance of insect species in the field. *Petrova resinella* was selected as a target for this study because it is abundant and easy to detect in the study area. Moreover, Kangas (1932) has early noticed that this species may be favoured by increasing atmospheric pollution in eastern Finland.

The life history of *P. resinella*, the pine resin-gall moth, has been treated by e.g. Mjöberg (1909), Wolff & Krausse (1922), Gasow (1925), Crooke (1951), Eidmann (1961), and Scott (1972). In Finland, *P. resinella* lives mainly on *Pinus sylvestris* (L.). The species thrives best on dry upland forest sites and bogs, and has a life-cycle of two years. Adults fly in late June – early July, and deposit their eggs singly in the current annual shoots of pine saplings. A canker caused by the gall may remain visible for decades.

Even if the pine resin-gall moth is regarded as a pest of pine, it is not usually of any considerable economic importance. However, a gall on the leader shoot may drastically decrease the value of the stem. If, for instance, the shoot is already weak, then growth may be terminated and the trunk become distorted above the point of attack. Moreover, a gall represents a minor point of weakness in the main stem, rendering it liable to wind or snow-break (Juutinen 1962, Löyttyniemi & Piisilä 1983).

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2. Material and methods

2.1. Study area

The investigation was carried out in August – September, 1985, in the area surrounding the small industrial town of Harjavalta in western Finland (Finnish uniform grid 27° E 680:24). The town is situated on a wide esker area running in a northwest – southeast direction along the shore of the Kokemäenjoki river (Fig. 1).

There are two large factories situated near to each other in the area: a metallurgical

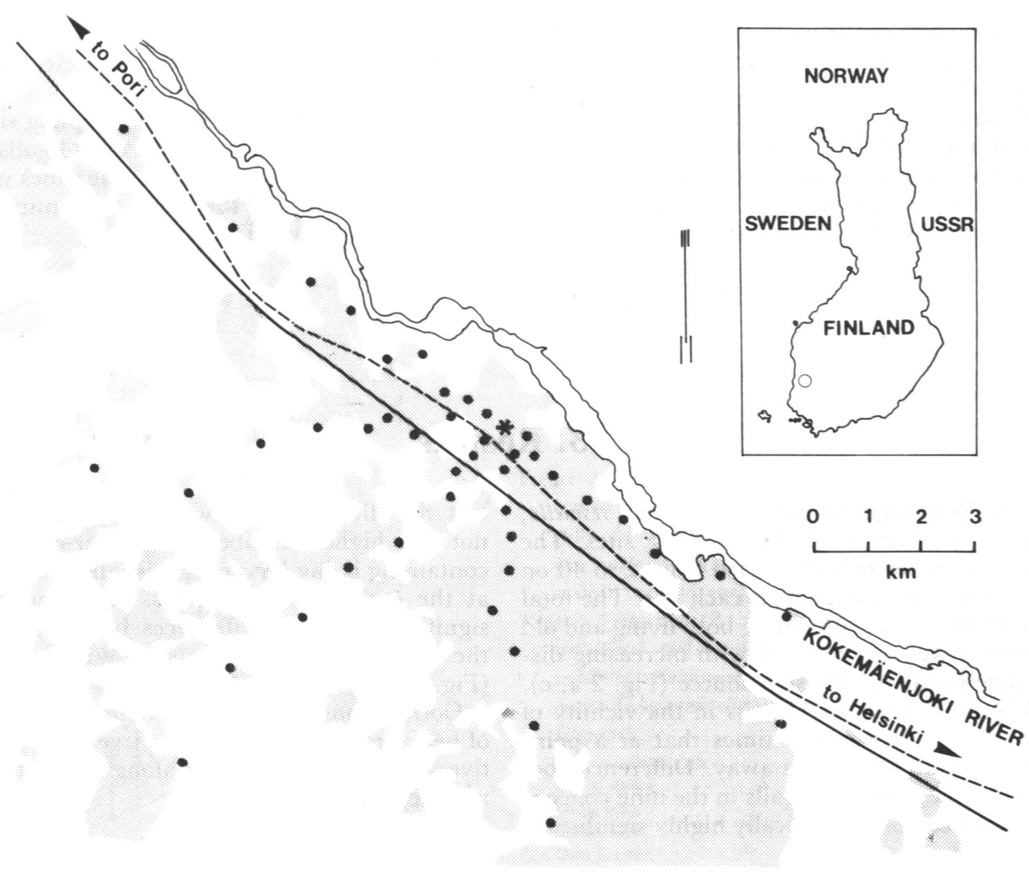


Figure 1. The study area in Harjavalta, western Finland. Black dots indicate the sampling sites along five transects running in a NW, W, SW, S and SE direction. Shaded areas indicate pine stands.
Kuva 1. Harjavallan tutkimusalue. Pisteet kuvaavat näytealoja viidellä linjalla. Mäntymetsät varjostettu.

plant producing copper and nickel, and a chemical plant producing sulphuric acid, aluminium sulphate and fertilizers. The industry in the area dates back to the early 1940s, and signs of pollution have been visible in the vegetation since then (Karhu 1982, Laaksovirta 1973, Laaksovirta & Silvola 1975). Annual emissions from the factories now total more than 10000 tons of sulphur oxides and sulphuric acid. In addition, other emission components in 1978 included more than 700 tons of carbon monoxide, 70 tons of nitrogen oxides and more than 1500 tons of particulate matter (Ympäristökonsultit Oy 1980).

2.2. Sampling

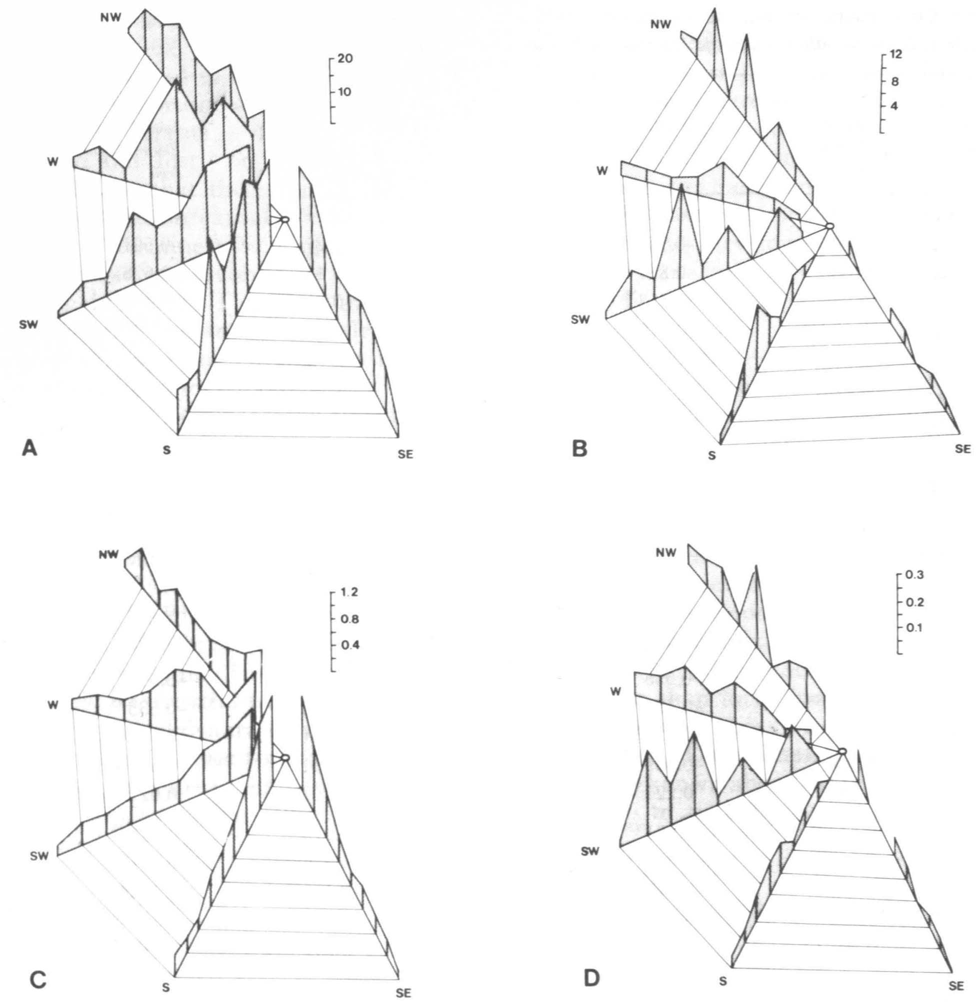
The galls of the moth were sampled on the same forty-four, pine-dominated sites included in previous studies (Hynninen 1983, Hynninen & Lodenius 1986, Heliövaara & Väisänen 1986). These sites were delimited on five radial transects (NW, W, SW, S, SE) extending from the factory complex. The sampling sites were located at logarithmic distances from the emission point. The transects were all about 9 kilometres long, and each had nine sampling sites, except for one, which had eight (Fig. 1). Each sampling site consisted of three adjacent, circular sample plots (30 m^2). The plots were marked out randomly by fixing a post as the centre point. Every pine higher than 40 cm, and every gall made by the moth, was then counted over an area, diameter 6.2 m, around this post. The occurrence frequency of the galls on every sampling site was compared with the heavy metal deposition level. The values for five heavy metals (Cd, Cu, Ni, Pb, Zn) were derived from Hynninen (1983). *Sphagnum* moss had been used as a collector of heavy metals during a three-month period in 1981 in that study. The deposition levels of all five heavy metals were highest in the vicinity of the factories (means: 139.8 ppm of Cd, 186.7 ppm of Cu, 501.3 ppm of Ni, 9.0 ppm of Pb, 43.2 ppm of Zn), and were considerably lower three kilometres from the factories (4.9, 3.3, 12.5, 0.9, 1.5 ppm, respectively).

The material consisted of 44 sampling sites and 1758 pines bearing a total of 814 galls of *P. resinella*. The mean height of the pines was 2.1 m, S.D. 0.6, and the mean stem number per hectare 4500, S.D. 2300.

3. Results

Galls or signs of galls made by *P. resinella*, were recorded at all 44 sampling sites. The total number of galls varied from 2 to 40 on the three sample plots at each site. The total number of galls, including both living and old ones, gradually declined with increasing distance from the emission source (Fig. 2 a, c). The mean number of galls in the vicinity of the factories was five times that at a point about nine kilometres away. Differences between the number of galls in the nine concentric zones were statistically highly significant, but the differences between transects were not. The highest number of two-year-old galls containing living larvae was usually recorded at the ends of the transects. However, the significance of the differences between both the zones and the transects were rather low (Fig. 2 b, d, e).

Correlations between the deposition level of heavy metals and galls per tree were positive and highly significant along most of the transects (Table 1).



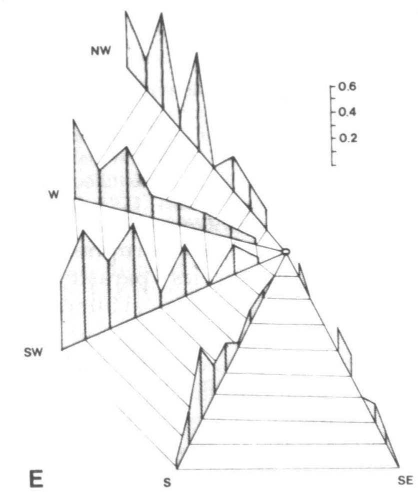


Figure 2. Significance of the zone factor (P_z) and the transect factor (P_t) in explaining the occurrence of galls of *P. resinella* around the emission source. Two-way analysis of variance. Distances on a logarithmic scale in the field, each transect about nine kilometres.

Kuva 2. Vyöhykkeen (P_z) ja havaintolinjan (P_t) merkitsevyys selitettäessä pihkakääriäisen esiintymistä saastutuslähteen ympärillä. Kaksisuuntainen varianssianalyysi. Etäisyydet maastossa logaritmisella asteikolla, kukin linja noin yhdeksän kilometriä.

A.	Total number of galls,	$P_z = 0.001$, df = 8,31
	Äkämät yhteensä,	$P_t = 0.251$, df = 4,31
B.	Living galls,	$P_z = 0.419$, df = 8,31
	Elävät äkämät,	$P_t = 0.172$, df = 4,31
C.	Galls per tree,	$P_z = 0.010$, df = 8,31
	Äkämät/puu,	$P_t = 0.804$, df = 4,31
D.	Living galls per tree,	$P_z = 0.785$, df = 8,31
	Elävät äkämät/puu,	$P_t = 0.040$, df = 4,31
E.	Proportion of living galls,	$P_z = 0.043$, df = 8,31
	Elävien äkämien osuus,	$P_t = 0.025$, df = 4,31

Table 1. Correlations between the deposition of heavy metals and the occurrence of galls along five transects.
Taulukko 1. Raskasmetallilaskeumien ja äkämien esiintymisen korrelaatioita viidellä linjalla.

		Total number of galls *Äkämät yhteensä*	Living galls *Elävät äkämät*	Galls per tree *Äkämät/puu*	Living galls per tree *Elävät äkämät/puu*	Proportion of living galls *Elävien äkämien osuus*	df
Cd	NW	0.583°	–0.134^{NS}	0.935***	0.142^{NS}	–0.415^{NS}	7
	W	0.404^{NS}	–0.561^{NS}	0.195**	-0.271^{NS}	–0.591^{NS}	6
	SW	0.660°	–0.331^{NS}	0.909***	–0.434^{NS}	–0.628°	7
	S	0.289^{NS}	–0.353^{NS}	0.930***	–0.213^{NS}	–0.460^{NS}	7
	SE	0.480^{NS}	0.379^{NS}	0.794*	0.886**	0.109^{NS}	7
Cu	NW	0.819**	–0.025^{NS}	0.919***	0.185^{NS}	–0.476^{NS}	7
	W	0.656°	–0.310^{NS}	0.957***	–0.306^{NS}	–0.727*	6
	SW	0.857**	–0.183^{NS}	0.935***	–0.356^{NS}	–0.695*	7
	S	0.463^{NS}	–0.225^{NS}	0.934***	–0.049^{NS}	–0.385^{NS}	7
	SE	0.642°	0.309^{NS}	0.911***	0.770**	0.117^{NS}	7
Ni	NW	0.877**	0.103^{NS}	0.846***	–0.226^{NS}	–0.400°	7
	W	0.210^{NS}	–0.485^{NS}	0.530^{NS}	–0.435^{NS}	–0.089^{NS}	6
	SW	0.812**	–0.229^{NS}	0.949***	–0.361^{NS}	–0.676*	7
	S	0.479^{NS}	–0.143^{NS}	0.932***	0.005^{NS}	–0.329^{NS}	7
	SE	0.553^{NS}	0.339^{NS}	0.879**	0.802**	0.153^{NS}	7
Pb	NW	0.689*	–0.038^{NS}	0.917***	0.174^{NS}	–0.419^{NS}	7
	W	0.373^{NS}	–0.594^{NS}	0.890**	–0.296^{NS}	–0.535^{NS}	6
	SW	0.415^{NS}	–0.272^{NS}	0.488^{NS}	–0.451^{NS}	–0.690*	7
	S	0.184^{NS}	–0.559^{NS}	0.835**	–0.391^{NS}	–0.538^{NS}	7
	SE	0.740*	0.221^{NS}	0.820**	0.703*	0.027^{NS}	7
Zn	NW	0.548^{NS}	–0.101^{NS}	0.925***	0.170^{NS}	–0.415^{NS}	7
	W	0.603^{NS}	–0.353^{NS}	0.973***	–0.316^{NS}	–0.721*	6
	SW	0.731*	–0.345^{NS}	0.874**	–0.475^{NS}	–0.708*	7
	S	0.336^{NS}	–0.287^{NS}	0.908***	–0.060^{NS}	–0.376^{NS}	7
	SE	0.592°	0.328^{NS}	0.880**	0.851**	0.118^{NS}	7

NS = not significant, ° = $P < 0.1$, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

4. Discussion

Air pollution has been found to have both a direct and indirect effect on insect populations. The direct effects of airborne pollutants are usually implicated in the toxicology and decline of insect numbers, while indirect effects may result either in a decrease or an increase in insect abundance. Secondary interactions may involve evolutionary changes in insect colouration, such as the industrial melanism resulting from a decline in lichens (e.g. Mikkola 1975, Douwes et al. 1976), pest outbreaks, resulting from disruptions of the equilibria with the species' parasitoids and predators, or from physiological alterations in the host trees and food quality. Sulphur oxides have been found to change the physiology of plants at levels far below those that cause direct injury (Dässler 1963, Materna 1973, Schnaider 1973). Such changes are assumed to be associated with increased densities of certain Microlepidoptera on pines (see Templin 1962, Sierpinski 1970, Hågvar et al. 1976). Alstad et al. (1982) have summarized the literature on the effects of five major air pollutants – fluorides, sulphur, ozone, lead and dust – on insect populations. They point out that there are several unacceptable correlation/causality confusions and failures to determine which agents in a polluted air mass are involved in the development of field effects. The basic mechanisms associated with the secondary effects of air pollution on insect populations are, however, generally poorly understood.

Führer (1985) has recently classified the occurrence of some insect species into three categories according to their relationship to air pollutants. Some species of Microlepidoptera, such as *Exoteleia dodecella* and *Rhyacionia buoliana*, were placed in the category of insects which obviously have some advantage at high impact intensity, and therefore reach outbreak levels in areas influenced by pollutants. In the present study area, *Aradus cinnamomeus* was also classified in this category (Heliövaara & Väisänen 1986). The response of *Petrova resinella* to air pollutants in the study area seems to be analogous to that of *A. cinnamomeus* although much less pronounced.

In some cases, insect herbivores have been assumed to be more tolerant of air pollutants than trees (Gilbert 1970, Boullard 1973, Alstad et al. 1982, Führer 1985). This especially concerns those species which have hidden life habits, and which seldom come into direct contact with the pollutants. Only adults of *Petrova resinella* have exposed life habits since the other stages development remain for almost two years inside the resin gall, which presumably prevents heavy direct contamination.

Parasitic species of Hymenoptera are known to be sensitive to dust, which may reduce parasitism of insect herbivores in polluted areas (see Finney & Fisher 1964). Führer (1985) has suggested that, if a parallel is drawn with pesticides, it can be assumed that entomophagous insects in general are more threatened by air contaminants than phytophagous ones. The distinctive galls of *P. resinella* on the shoots of pines seem to be under heavy parasitization pressure. Wolff & Krausse (1922) and Escherich (1931) have listed more than forty species of insect predators, mostly those belonging to Ichneumonidae. Unfortunately, however, nothing is yet known about the response of these parasitoids to air pollution.

References

Alstad, D. N., Edmunds, G. F., Jr. & Weinstein, L. H. 1982. Effects of air pollutants on insect populations. Ann. Rev. Entomol. 27: 369–384.

Baltensweiler, W. 1985. "Waldsterben": forest pests and air pollution. J. Appl. Entomol. 99: 77–85.

Boullard, B. 1973. Interactions entre les pollutants atmosphériques et certains parasites des essences forestierès (champignons et insectes). La Forêt Privée 94: 31–37.

Charles, P. J. & Villemant, C. 1977. Modification des niveaux de populations d'insectes dans les jeunes plantations de pins sylvestres de la forêt de Roumare (Seine-Maritime) soumises à la pollution atmospherique. Comt. Rend. Acad. d'Agric. France 63: 502–510.

Crooke, M. 1951. A contribution to the knowledge of the genus Evetria Hbn. (Lepidoptera, Tortricoidea). Forestry 24: 127–143.

Dässler, H. G. 1963. The effects of SO_2 on the terpine content of spruce needles. Flora 154: 376–382.

Douwes, P., Mikkola, K., Petersen, B. & Vestergren, A. 1976. Melanism in Biston betularius from north-west Europe (Lepidoptera: Geometridae). Entomol. Scand. 7: 261–266.

Eidmann, H. H. 1961. Über die Entwicklung von Evetria resinella L. Entomol. Tidskr. 82: 60–63.

Escherich, K. 1931. Die Forstinsekten Mitteleuropas. Dritter Band. Berlin, 825 pp.

Finney, G. L. & Fisher, T. W. 1964. Culture of entomophagous insects and their hosts. In: Debach, P. (ed.). Biological control of insect pests and weeds, pp 255–328. New York, 844 pp.

Führer, E. 1985. Air pollution and the incidence of forest insect problems. J. Appl. Entomol. 99: 371–377.

Gasow, H. 1925. Beitrag zur Kenntnis des Kiefernharzgallenwicklers (Evetria resinella L.) und des

Kiefernknopfentriebwicklers (Evetria buoliana Schiff.). Allgem. Forst- u. Jagdzeit. 101: 213–220.
Gilbert, O. L. 1970. Some indirect effects of air pollution on bark-living invertebrates. J. Appl. Ecol. 8: 77–84.
Hågvar, S., Abrahamsen, G. & Bakke, A. 1976. Angrep av furuskuddmøll (Exoteleia dodecella L.) på Sørlandet. Mulig sammenheng med sur nedbor. (Summary: Attack by the pine bud moth (Exoteleia dodecella L.) in southernmost Norway. Possible effect of acid precipitation). SNSF-project IR 15/76: 1–19.
Heliövaara, K. & Väisänen, R. 1986. Industrial air pollution and the pine bark bug, Aradus cinnamomeus (Heteroptera, Aradidae.) J. Appl. Entomol. 101: 469–478.
Hynninen, V. 1983. Rahkasammalsiirrosten (sammalpallojen), männyn versojen ja seinäsammalen raskasmetallipitoisuudet Harjavallan kaupugissa ja lähiympäristössä. Manuscript, Department of Botany, University of Helsinki, 99 pp.
— & Lodenius, M. 1986. Mercury pollution near an industrial source in Southwest Finland. Bull. Environm. Contam. Toxicol. 36: 294–298.
Juutinen, P. 1962. Tutkimuksia metsätuhojen esiintymisestä männyn ja kuusen viljelytaimistoissa Etelä-Suomessa. (Referat: Untersuchungen über das Auftreten von Waldschäden in den Kiefern- und Fichtenkulturen Südfinnlands): Commun. Inst. For. Fenn. 54(5): 1–80.
Kangas, E. 1932. Tutkimuksia kaasutuhoista Imatran valtionpuistossa. (Referat: Untersuchungen über die Rauchschäden im Imatra-Staatspark). Silva Fenn. 23: 1–34+6 append.
Karhu, N. 1982. Tuloksellista ympäristönhoitoa Kemiran Harjavallan tehtailla. Kemira 3: 26–31.
Katayev, O. A., Golutvin, G. I. & Selikhovkin, A. V. 1983. Changes in arthropod communities of forest biocoenoses with atmospheric pollution. Entomol. Rev. 62: 20–35.
Laaksovirta, K. 1973. Ilman saastuminen Harjavallassa. Ympäristö ja Terveys 4: 539–552.
— & Silvola, J. 1975. Effect of air pollution by copper, sulphuric acid and fertilizer factories on plants at Harjavalta, W. Finland. Ann. Bot. Fenn. 12: 81–88.
Löyttyniemi, K. & Piisilä, N. 1983. Hirvivahingot männyn viljelytaimikoissa Uudenmaan – Hämeen piirimetsälautakunnan alueella. (Summary: Moose (Alces alces) damage in young pine plantations in the district Uusimaa – Häme). Folia For. 553: 1–23.
Materna, J. 1973. Criteria for the characterization of pollution damages in forests. Proc. Int. Clean Air Congr. III, Düsseldorf, pp. 121–123.
Mikkola, K. 1975. Frequencies of melanic forms of Oligia moths (Lepidoptera, Noctuidae) as a measure of atmospheric pollution in Finland. Ann. Zool. Fenn. 12: 197–204.
Mjöberg, E. 1909. Om hartsgallvecklaren (Retinea resinella L.). Skogsvårdsföreningens Tidskr. 1909, H. 3: 101–110.
Oppermann, A. 1985. Rinden- und holzbrutenden Insekten an emissionsgeschädigten Fichten und Kiefern. Holz-Zentralblatt 111: 213–217.
Przybylski, Z. 1968. Results of consecutive observations of effect of SO_2, SO_3, and H_2SO_4 on fruit trees and some harmful insects near the sulfur mine and sulfur processing plant at Machow near Tarnobrzega. Adv. Agric. Sci. Warsaw 15: 131–138.
Schnaider, Z. 1973. Secondary pests of Douglas fir and white pine recorded in Silesia during years 1966–1969. Sylwan 117: 25–31.
Scott, T. M. 1972. The pine shoot moth and related species. For. Comm. For. Record 83, pp. 1–14.
Sierpinski, Z. 1966. Schädliche Insekten an jungen Kiefernbeständen in Rauchschadengebieten, in Oberschlesien. Arch. Forstwes. 15: 1105–1114.
— 1970. Owady szkodliwe wystepujace w drzewostanach sosnowych na terenach uprzemyslowionych i ich znaczenie gospodarcze. (Summary: Pest insects occurring in pine stands in industrialized areas and their economic importance). Wiadomosci Ekol. 16: 298–305.
— 1972. Die Bedeutung der Secundären Kiefernschädlinge in Gebeiten chronischer Einwirkung industrieller Luftverunreinigungen. Mitt. Forstl. Bundesversuchsanstalt. 97: 609–615.
Templin, E. 1962. On the population dynamics of several pine pests in smoke-damaged forest stands. Wiss. Zeitschr. Techn. Univ. Dresden 11: 631–637.
Villemant, C. 1980. Influence de la pollution atmosphérique sur les microlépidoptères du pin en forêt de Roumare (Seine-Maritime). Acta Oecologia / Oecol Appl. 1: 291–306.
— 1981. Influence de la pollution atmosphérique sur les populations d'aphides du pin sylvestre en forêt de Roumare (Seine-Maritime). Environm. Pollut. Ser A. 24: 245–261.
Wentzel, K. F. 1965. Insekten als Immissionsfolgeschädlinge. Naturwissenschaften 52: 113.
Wolff, M. & Krausse, A. 1922. Die forstlichen Lepidopteren. Jena, 337 pp.
Ympäristökonsultit Oy 1980. Harjavallan ympäristöilman perustutkimus. 22 pp. + 2 append.

Total of 40 references