Why do some Psylloidea and Heteroptera occur regularly on snow?

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Certain species of Psylloidea and Heteroptera have been observed on snow in South Norway during many years, mainly at temperatures around zero. However, they do not belong to the exclusive group of winter active arthropods, which use the snow surface as a natural habitat during their life cycle. While most invertebrate groups occurring on snow are recruited from the air space below the snow or by hatching from winter-open rivers and brooks, Psylloidea and Heteroptera drop or blow down from trees. All the eight recorded species of Psylloidea hibernate on coniferous trees, and return to their host plant (which is often *Salix* sp.) at the end of the winter. Their occurrence on snow mainly in March and April indicates very early activity, long before their host plants have developed leaves. The presence of specimens of Psylloidea on the ice of a large lake (Furusjøen, Rondane) showed that they could also ble blown far away in late winter. *Kleidocerys resedae* (Heteroptera) occurs on snow mainly in November, when the animals drop down from birches to hibernate on the ground. *Gastrodes abietum* (Heteroptera) overwinters in cones high up in spruce trees. The species has no obligatory diapause, however, and especially during mild periods in early and late winter, active animals may drop down on the snow surface.

Key words: Psylloidea, Heteroptera, insects on snow, winter.

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INTRODUCTION

Many different arthropod groups can be recorded on snow, especially in mild weather. It is a challenge to understand why they occur on snow, and from which habitats they colonise the snow surface. Regarding the first question, we can divide the snow surface fauna into three main groups: a) Specialized, cold-adapted species, which are regularly active on the snow surface as a natural part of their life cycle, e. g. certain Collembola, Diptera, Mecoptera, Plecoptera and one species of Araneida (Ulfstrand 1968, Hågvar & Østbye 1973, Hågvar 1973, 1976, 2000, 2001, Jonsson & Sandlund 1975, Leinaas 1983). They use the snow surface for migration, copulation or feeding. b) Arthropods which can be observed rather regularly on the snow, but which do not belong to the exclusive first group, e. g. many species of Diptera and Araneida (Hågvar & Greve 2003, Hågvar & Aakra 2006). c) Casual visitors on snow. Especially during warm weather in early and late winter, spiders, beetles, various insect larvae etc. heated by the sun may crawl onto snow from snow-free patches, or flying insects may land on snow and made more or less immobile.

Regarding the second question, most arthropods on snow are recruited from the so-called subnivean air space below the snow cover. While some Collembola can migrate directly through the snow layers (Leinaas 1981), larger arthropods must find their way in the air spaces which are formed along tree-trunks and other vegetation penetrating the snow. A few Chironomidae and Plecoptera recorded on snow hatch from open, running water (Ulfstrand 1968, Hågvar & Østbye 1973 & Sandlund 1975). There is, however, little documentation whether the snow surface is colonized from trees.

During nearly forty years, since 1968, the author has observed that certain species of Psylloidea and Heteroptera occur rather regularly on snow. The insects belong to group b) above, and they are tree-living at least during some part of their life cycle. A preliminary note on Psylloidea on snow was given by Hågvar & Hågvar (1975). The paper documents the winter arthropod fauna on branches of spruce (*Picea abies* (L.) Karst.) in a locality close to Oslo, and makes it possible to compare the Psylloidea fauna on spruce with that of the snow surface.

Most collections on snow were made in localities not far from Oslo, but also in other localities in South Norway.

MATERIAL AND METHODS

The material presented here was collected mainly during 1968-72. During these years, several ski trips were usually made each month, sometimes more than one per week, under different climatic conditions. Although the sampling had a certain random character, it probably illustrates the species composition on snow and the main trends in phenology. Information about the sampling localities is given in Table 1. As far as information exists on temperature and weather conditions during sampling, these data are given below. Temperatures were partly measured at 1 cm, and partly about 1.5 m above the snow surface. Control measurements revealed that when the temperature at 1.5 m was 0 °C or below, the temperature close to the snow was very similar, within a few tenths of a degree. When temperatures at 1.5 m were above zero, the air temperature close to the snow surface would usually be between 0 and 3 °C.

A part of the Psylloidea material was collected 20 April 1968 on the snow-covered ice of the 1.7 km wide Lake Furusjøen at 852 m a.s.l. in Oppland county. A survey was made along a straight SW line across the lake, from Luseby on the East side to Rauddyrodden on the West side. All Psylloidea in a 4 m wide belt were collected, and counted for each 25 m. The purpose was to show that during winter Psylloidea can be spread by wind over considerable distances.

The nomenclature of Psylloidea follows Ossiannilsson (1992). Many species have changed name since the publication of Hågvar & Hågvar (1975), but synonyms are mentioned here.

RESULTS

Psylloidea

Psylloidea were recorded on snow in several localities in South Norway, covering various forest types and altitudes. A single record is also from far north in Alta, Finnmark. The specimens were found throughout the winter from November to May, but mainly in March and April. The animals were often found to be alive, although this was not checked systematically. In the following, records on snow of eight different species are presented. Information on host plants and winter habitat is according to Ossiannilsson (1992).

Trioza urticae (Linné, 1758)

Host plant: *Urtica* sp. (nettle). Winter: On conifers. The records were from lowland localities, not far from cultural landscapes which probably contain its host plant. *Locality 1*: Sognsvann: 1 individual 26 November 1971, -0.5 °C, overcast and calm. 4 ♂♂ 10 February 1972 at similar conditions, but snowing. At that sampling, many more Psylloidea were observed on snow. 4 individuals 12 March 1971, -2 °C, calm and snowing. *Locality 2*: Valler: 5 individuals in spruce forest 3 March 1968, -4 °C. *Locality 4*: Frogn: 7 ♂♂ and 1 ♀3 March 1972.

Table 1. Localities in Norway where Psylloidea and Heteroptera were sampled on snow. Symbols for county parts are according to Økland (1981).

Loc.	Name	County	Altitude (m)	Dominant trees
1	Nordmarka	Buskerud (BØ), Akershus (AK)	200-500	Spruce, some pine and deciduous
2	Bærum	Akershus (AK)	100-200	Spruce and deciduous, some pine
3	Nordstrand	Akershus (AK)	100	Pine and deciduous, some spruce
4	Frogn	Akershus (AK)	50-100	Mixed forest
5	Hurdal	Akershus (AK)	200-400	Spruce, some pine and deciduous
6	Vegglifjell	Buskerud (BV)	700-900	Spruce, some pine and birch
7	Furusjøen	Oppland (ON)	850-900	Pine, some birch
8	Alta	Finnmark (FV)	100-200	Pine and birch

Bactericera curvatinervis (Foerster, 1848)

Syn.: *Trioza curvatinervis* Foerster.
Host plant: *Salix* sp. Winter: On conifers. *Locality 4*: Frogn: 1 ♀ 3 March 1972.

Bactericera striola (Flor, 1861)

Syn.: *Trioza striola* Flor.
Host plant: *Salix* sp. Winter: On spruce. *Locality 4*: Frogn: 1 ♂ 3 March 1972.

Bactericera femoralis (Foerster, 1848)

Syn.: *Trioza femoralis* Foerster.
Host plant: *Alchemilla* sp. Winter: Usually on conifers. *Locality 7*: Near Furusjøen: 1 ♂ in pine (*Pinus silvestris* L.) forest 17-20 April 1968.

Cacopsylla brunneipennis (Edwards, 1896)

Syn.: *Psylla klapaleki* Sulc.
Host plant: Salix sp. Winter: On conifers. *Locality 1*: Sognsvann: 2 ♀♀ 10 February 1972, -0.5 °C, calm and snowing. Krokskogen: 3 ♀ ♀ 12 April 1968. 1 ♂ and 3 ♀♀ 9-13 April 1971, on sunny, warm days with up to 10 °C. *Locality 2*: Kolsåsen: 1 ♀ 24 January 1971, 0.5 °C, foggy, slight wind and snowing. Dælivann: 8 ♀♀ 9 February 1972, -0.5 °C, calm and cloudy. 4 ♀♀ 5 March 1972, 0 °C, faint wind and snowing. Dalbo: 2 ♀♀10 April 1968. *Locality 4*: Frogn: 5 ♀♀ 3 March 1972. *Locality 7*: Near Furusjøen: 1 ♂ and 9 ♀♀ in pine forest 17-20 April 1968, and 30 ♀♀ on the snow-covered ice of Lake Furusjøen 20 April 1968. *Locality 8*: Mattisdalen: 2 ♀♀ 22 March 1971, -2 °C. Clearly, this species is widespread in Norway and often occurring on snow, especially in March and April. According to Ossiannilsson (pers. comm.), the low number of males is due to high autumn mortality in this sex.

Cacopsylla palmeni (Löw, 1878)

Syn.: *Psylla palmeni* Löw and *Psylla nigrita* (Zetterstedt).
Host plant: *Salix* sp. Winter: A few recorded on branches of spruce by Hågvar & Hågvar (1975). *Locality 2*: Dalbo: 1 ♀ 10 April 1968. *Locality 7*: Furusjøen: 4 ♂♂ and 2 ♀♀ in pine forest 17-20 April 1968, and 11 ♂♂ and 25 ♀♀ on snow-covered ice of Lake Furusjøen 20 April 1968.

Cacopsylla elegantula (Zetterstedt, 1838)

Syn.: *Psylla elegantula* (Zetterstedt).
Host plant: *Salix* sp. Winter: On conifers. *Locality 1*: Krokskogen: 1 ♂ and 1 ♀ 12 April 1968. *Locality 7*: Furusjøen: 4 ♀♀ in pine forest 17-20 April 1968, and 3 ♂♂ and 1 ♀ on snow-covered ice of Lake Furusjøen 20 April 1968.

Cacopsylla corcontum (Sulc, 1910)

Syn.: *Psylla corcontum* Sulc.
Host plant: *Sorbus aucuparia* L. Winter: On conifers. *Locality 1*: Krokskogen: 1 ♂ 12 April 1968.

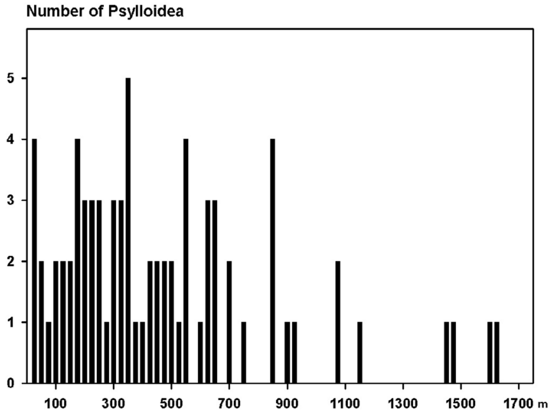

Figure 1. Occurrence of Psylloidea along a 1700 m long transect on the snow-covered ice of Lake Furusjøen near Rondane. The number of Psylloidea was counted for each 25 m, in a 4 m wide belt.

Additional records

Some records of non-identified specimens of the family Psyllidae are added here to confirm their occurrence especially during late winter, and during different years. *Locality 2*: Kolsåsen: 2 individuals 1 November 1970, -1 °C, on newly fallen snow. Valler: 1 individual 2 April 1968, 0.5 °C, and 2 individuals next day, 2 °C, on newly fallen snow. *Locality 5*: Skrukkelia: 1 individual 25 March 1975. On 28 March 1975, 18 individuals were collected below *Salix caprea* L. trees at 2 °C, in calm weather while snowing. The animals had probably been activated by sunshine one hour earlier. *Locality 6*: Lake Sørkjevatn: 7 individuals on the snow-covered ice about 750 m from the shore, 14 April 1995. Some of them jumped when being collected. Probably about 5 °C. Votnedalen: 1 individual 25 May 1985, about 10 °C and snow-free patches.

Figure 1 shows the number of Psylloidea collected along the 1700 m long transect across Lake Furusjøen. Animals were recorded more or less throughout the transect, although mainly in the eastern half. This indicates a long-distance transport of Psylloidea by wind from trees at the Eastern side.

Heteroptera

Among Heteroptera, two species of Lygaeidae are frequently found on snow. Data on biology are from Southwood & Leston (1959). As for Psylloidea, the animals were often found to be alive, although this was not checked systematically. The following observations illustrate typical situations.

Kleidocerys resedae (Panzer, 1797)

Host plant: mainly *Betula* sp. Winter: On the ground, or in cracks in the bark of conifers. Most observations on snow are from November. *Locality 2*: Kolsåsen: 10 individuals 1 November 1970, -1 °C and calm. Animals were observed several places below its host tree, partly when snowing. Valler: 1 individual 3 November 1970, -3 °C, faint wind and snowing. 2 individuals 14 November 1970, -3 °C, calm and cloudy. Dalbo: 30 ♀♀ and 18 ♀♀ 4 November 1968, -3 °C. Some juveniles were also found. The animals were found on freshly fallen snow, on about 30 m^2 below a large birch, and had probably been activated by a period with sun and higher temperature (around 0 °C) earlier the same day. They showed movements when being touched, and 3 specimens enclosed in a glass survived 3 nights outdoor at -10 °C. Dælivann: 11 ♂♂ and 4 ♀♀ below birches 14 November 1968, -6 °C. 12 juveniles were also found. About half of both adults and juveniles seemed to be alive. 6 ♂♂ and 8 ♀♀ below birches 21 November 1968 at -1 °C were all dead. *Locality 3*: Nordstrand: 1 individual below its host tree 8 December 2005, 0 °C, calm and cloudy.

Gastrodes abietum Bergroth, 1914

Host plant: Spruce, where it stays between the scales in the cones during winter. It is called the spruce-cone bug. The species occurs on the snow mainly during early and late winter (November/December and March). *Locality 1*: Krokskogen: 1 individual 15 November 1970, -1 °C, calm, snowing. Sognsvann: 1 individual 26 November 1971, -0.5 °C, calm and cloudy. 19 individuals 9 December 1971, -1 °C, calm, sunny. These animals were probably activated by the warming sun. *Locality 2*: Kolsåsen: 1 individual 1 November 1970, -1 °C and calm. 1 individual 20 December 1968, 0 °C. 1 individual 23 February

1969, -2 °C. Dalbo: 1 individual 10 November 1968, 0 °C. Several individuals were observed 12 March 1970, -1 °C. 1 individual 18 March 1970, 2 °C. Valler: 1 individual 14 November 1970, -3 °C, calm and cloudy. 1 individual 27 March 1969. 2 individuals in a fallen cone 28 March 1969.

DISCUSSION

Psylloidea

The recorded species of Psylloidea leave their host plants during autumn, colonise coniferous trees for hibernation, and migrate back to their host plants in spring (Ossiannilsson 1992). All of them, except *Cacopsylla elegantula*, were found on branches of spruce during winter near Oslo by Hågvar & Hågvar (1975). The two most common species on spruce branches, *Trioza urticae* and *Cacopsylla brunneipennis*, were also among the most common species on snow. There is no doubt that Psylloidea on snow were recruited from coniferous trees.

The density of Psylloidea on spruce branches remained high from November to February, but dropped to about one fourth in March (Hågvar & Hågvar 1975). In this month, both the air temperature and the day length increases markedly. However, in large parts of Norway, the ground may be snow-covered during both March and April, and at higher altitudes even in May. The majority of recordings on snow in March and April coincides with the observed density reduction on spruce trees.

The high Psylloidea population on spruce from November to February proved that hibernating, passive individuals were able to withstand shaking of the branches due to wind. There were also very few observations of Psylloidea on snow during that part of the winter, indicating wind tolerance. However, if the branches are shaken hard enough by hand, hibernating Psylloidea drop off. In Locality 2, 60 individuals of *Trioza urticae* were shaken down from low branches of spruce 3 December 1970.

The following observations indicate that in March and April, hibernating Psylloidea start to be active, even at temperatures around zero. Firstly, animals were sometimes moving their legs – even jumping – during sampling on snow. Secondly, many records on snow were made in calm weather, indicating that animals had dropped off due to own activity and not due to wind. Records during calm snowfall showed that animals had newly dropped down. Thirdly, although many samplings were made in overcast weather, field notes indicate that short, sunny periods could activate the animals and make them fall off. Fourthly, the wind transport onto the ice of Lake Furusjøen in April, indicates that the animals at this time had lost their «winter grip». Similarly, the animals recorded 750 m from land on the ice of Lake Sørkjevatn illustrates wind transport in April.

Heteroptera

The records of *Kleidocerys resedae* on snow during early winter (November) represent individuals which are leaving their host tree (birch) for hibernation. In the autumn of 1968, when 48 individuals dropped down on the snow below a large birch on 4 November, the trees shed their leaves unusually late, and the first snow came early. The presence of juveniles on snow 14 November 1968 shows that at least some individuals reach the adult stage very late. An increasing fraction of dead animals on snow throughout November 1968 indicated disadvantages by leaving the host tree late.

Gastrodes abietum hibernates high up in spruce trees, hiding between the scales in large, old cones. There is no obligatory diapause, merely a facultative resting stage (Southwood & Leston 1959). Depending on temperature, they are more or less active, and individuals may drop down on the snow, mainly during early and late winter. The closely-related species *Gastrodes grossipes* (DeGeer, 1773), which lives on pine, can also be found on snow. One record was from Locality 6 at 17 April 2003.

A special segment of the «snow surface fauna»

Psylloidea and Heteroptera represent a special segment of the snow surface fauna, based on the following two criteria:

1. They are nearly the only invertebrates on snow which have arrived from trees. An exception is subadult spiders of *Philodromus* sp., which on very warm days at the end of the winter may send out flying threads from their hibernation sites in trees and land on snow (Hågvar & Aakra 2006). Although several spider species hibernate on branches of spruce (Hågvar & Hågvar 1975), this fauna largely remains on the trees and very rarely drop down on the snow. Also the collembolan *Vertagopus westerlundi* Reuter may migrate from subalpine birch trees down to the snow surface in mild periods during winter (Leinaas & Fjellberg 1985).

2. Psylloidea and Heteroptera end up on snow by casual dropping or due to wind, and not by seeking the snow surface actively. This separates them from the other regularly occurring invertebrates in group b), which actively migrate up to the snow surface from the subnivean air space (see Introduction).

Differences in ecology explain the differences in time when Psylloidea and the two Heteroptera species are found on snow. However, it is difficult to understand why Psylloidea start to leave the coniferous trees long before their host plants have developed treeleaves. Since Psylloidea represent roughly 20 % of the invertebrate biomass on spruce branches during winter (Hågvar & Hågvar 1975), they are included in the winter food of goldcrests and tits (Palmgren 1932, Haftorn 1956, Gibb 1960). Whether early leaving may have an anti-predator function, is unknown. It is also an open question whether their wind transport in late winter has any ecological function, and whether they may survive staying on or in snow until snow melt.

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