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EARLY WARNING SYSTEM FOR INSECT MIGRATION USING WEATHER RADARS

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Abstract

Prediction of weather systems has been the principal aim of weather radar since its early history. With polarimetric radar it is however possible to differentiate bird migration, insect migration and drizzle. Migrating insects can cause considerable damage to crops if they are not controlled in time and there is therefore need for pest-insect early warning systems. Rotating tow-nets, yellow sticky traps and suction traps are used for monitoring insects whenever a migration is underway. Our preliminary results suggest that polarimetric Doppler weather radar can be used to detect migrating insects.

Keywords: polarimetric radar, bird-cherry aphid, pest insects, monitoring, rotating tow-net, early warning system.

Introduction

Large numbers of insects migrate to Finland during the growing season, comprising mostly aphids, butterflies and moths. Pest species migrating in large numbers can cause serious damage to crops. It is therefore essential to be able to inform farmers of the approaching problem as soon as possible. The early warning system consists of three channels: public media, web services and SMS-messages.

The aim of the study was to devise an early warning system for impending migration: direction of migration and the quantity of expected insect types. The early warning system was designed by the Finnish Meteorological Institute and the University of Helsinki in co-operation with MTT Agrifood Research Finland.

Materials and Methods

The University of Helsinki operates a polarimetric Doppler weather radar at the Kumpula Campus in Helsinki. The radar transmits microwave pulses directed by a scanning antenna in a circular beam one degree wide. The echoes are received and a signal processor calculates various parameters. In addition to reflectivity and radial speed, the radar system also supplies information on polarimetric properties of the scatterers. Insects in the atmosphere are an important source of echoes on the radar frequency band employed (C-band, 5.6 GHz). In this study the received echoes were analysed to obtain data on airborne migrating insects. The data produced by several other Doppler radars were also analysed. The radar network consisted of: i) Kumpula radar, ii) an additional Doppler weather radar situated 32 km north of Kumpula, and iii) Doppler weather radars of the Finnish Meteorological Institute network. All the radars used the same frequency band as the polarimetric radar.

The migrating insects were monitored with continuous catchment and alarm catchment. From May to the beginning of July airborne insects were collected using six rotating tow-nets and yellow sticky traps. Rotating tow-nets and yellow sticky traps were used at five of the monitoring sites. At one site there was only a tow-net. The monitoring was supplemented with two suction traps, one in Jokioinen (south-western Finland) and the other at Viikki in Helsinki. When favourable weather conditions for insect migrations were estimated, an alarm was given by the Finnish Meteorological Institute and the University of Helsinki and yellow sticky traps were deployed.

Selecting the monitoring fields

Air flows between the south-east and south-west were most likely to carry migrating insects to Finland and we therefore selected fields that were open towards the south. Our aim was to position the yellow sticky traps in a circle of about 20–60 km from the polarimetric radar in Helsinki (Kumpula) (Figure 1).

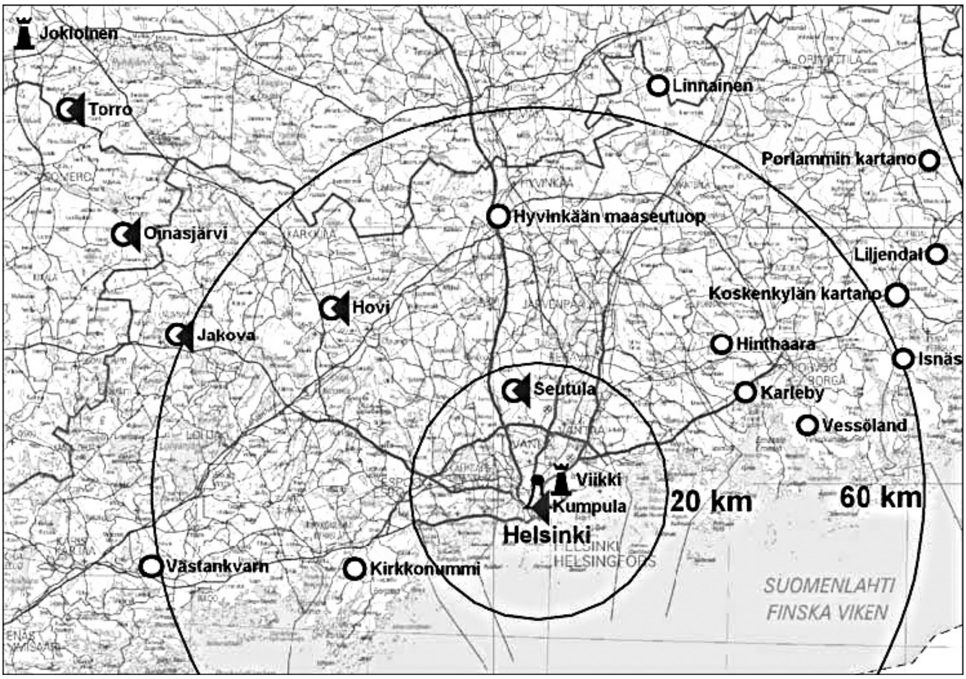

Figure 1. Circles indicate the sites of yellow sticky traps and triangles the sites of rotating tow-nets. Suction traps were located in Helsinki and Jokioinen

Traps

Tow-nets were attached to a vertical bar, and they rotated freely on tripods such that their inlets were always directed against the wind. Horizontal cloth bags caught the insects that fell into a sample bottle filled with 70% alcohol (Figure 2). Sites for tow-nets were chosen between Jokioinen and Helsinki such that they were evenly located and easy to reach by monitoring personnel. The traps were set about 2 m from the ground on the fields. The Kumpula Campus tow-net was located on the roof of the building about 25 m above the ground. The site is surrounded by parks and water areas at the edge of the city centre.

Figure 2. Rotating tow-net being prepared

The tow-net traps were set up on 8th May 2007 and removed on 2nd July 2007. Sample bottles were changed twice a week, usually on Mondays and Thursdays. There were 16 samples from each site except Kumpula, from which there were 20. All the samples were taken to MTT Jokioinen where the trapped insects were photographed and identified.

Yellow sticky traps (190 x 320 mm) were continuously located at the same sites as the rotating tow-nets during the monitoring period. They were changed at the same time as the sample bottles of the rotating tow-nets. Sticky traps were fastened to a 65 cm metal stick stuck into the ground. The traps were fastened level with the vegetation. Traps were placed around field edges so that they would not hinder regular field work done by farmers.

Yellow sticky traps for alarm catching were set evenly in the Uusimaa area. During the alarm catching period the traps were replaced every second day, enabling frequent assessment of trapped insects. Sticky traps were photographed after removal and placed in a freezer to kill the insects. After freezing, traps were covered with transparent plastic for examination and storage.

After the freezing phase, sticky traps were examined under the microscope. The most important agricultural insect pests, such as bird-cherry aphids (*Rhopalosiphum padi*), flea beetles (*Phyllotreta* spp.) and diamond-back moths (*Plutella xylostella*) were sorted and identified to species level, but most of the insects were simply identified to family level.

Insects kept in the sample bottles (catches from rotating tow-nets) were also examined under a microscope. The preservation liquid was decanted into a counting dish (sector dish) to enable easy sorting of insects and species identification. The level of identification was the same as for sticky traps.

Results and Discussion

Beetles and radar

Flea beetles caused considerable damage to oilseed rape in spring 2007. Daily catches of flea beetles in spring 2007 showed no significant peaks during favourable meteorological conditions for wind assisted migration. These observations indicated that a large number of the flea beetles in spring 2007 originated from domestic populations.

Airborne insects in southern Finland were caught by a suction trap during 1988–1989 at 160 m above ground level /Kurppa, 1989 a/ and it was established that beetles accounted for less than one percent of the catches. As the radar levels were usually above 100 m altitude, the abundance of flea beetles in the fields was not necessarily associated with significant radar echoes.

At the radar site and in Viikki near the coastline, flea beetles were not recorded before the migration episode at the end of May, in contrast to observations made in Jokioinen. The large number of beetles in the coastal traps was probably related to near surface winds blowing from mainland Finland. The radar echoes at that time showed a near surface maximum connected with the outflow from land areas and a step-like change to much weaker echoes at this height over the sea.

In Sweden flea beetle migration from Finland was recorded on the eastern coastline /Solbreck personal comm./, but the role of forced landing in the water and the subsequent wind-drift should be taken into account regarding such observations on migrating beetles.

Moths and radar

Diamond-back moths were observed in June near the radar site in Helsinki, but the first preliminary observations were made already at the end of May at the radar site 32 km north of Helsinki. The moths were caught in sticky traps near the coastline month on May 28th and in the Kumpula tow-net during the first days of June. The number of moths caught in the study area did not however exceed the current alarm limit. Numerous diamond-back moths were observed by farmers on May 30th in Haukivuori, southern Savo /Piirainen personal comm./, and moths were also seen in the nearby areas of Joroinen, Juva, Pertunmaa and Mäntyharju in early June. These localities in eastern Finland are 200–300 km NE from our study area, and the warmest air mass from the south or southeast during the migration period was flowing from a little further east.

The moths that arrived in eastern Finland were able to lay eggs, which were however effectively controlled by a rainy period that caused high mortality among the progeny. The second generation migrated westwards on July 7th. Those insects probably originated from more eastern or southeastern areas, where the migration at the end of May was characterised by more favourable air currents than those present in eastern Finland.

Diamond-back moth migration has been studied using entomological radar /Chapman et al., 2002/, and the University of Helsinki weather radar echo monitoring was once used for near real time warning of a huge immigration episode of the species. Both radar systems are able to detect individual moths and consequently the radar observations can be more reliably related to the migration of the moths. In spring 2007 the moths were not very abundant near Helsinki and their significance in radar echoes was further reduced by numerous other insect species in the air during the warm period of southeasterly flows. However, the second generation migration was spotted by the weather radars in July in a warm southeasterly flow between two precipitation areas. Some other larger insects, probably noctuid moths, were seen in this warm air at nearly 4 km altitude, reaching the freezing level.

Aphids and radar

The main immigration of bird-cherry aphids occurred in Finland from May 24th to 28th 2007. Hundreds of aphids were trapped in tow-nets during this period. The maximum number was 166 at Oinasjärvi, roughly 80 km northwest of Helsinki (Figure 3). During the same time domestic bird-cherry aphids were still on the overwintering host (*Prunus padus*). In the Kumpula tow-net the first two aphids appeared already in the sample from May 14th to 16th and were probably extremely long-range migrants. This period had flows from the south and southwest and long range migrant butterflies (Red admiral, *Vanessa atalanta*) were also observed in Finland.

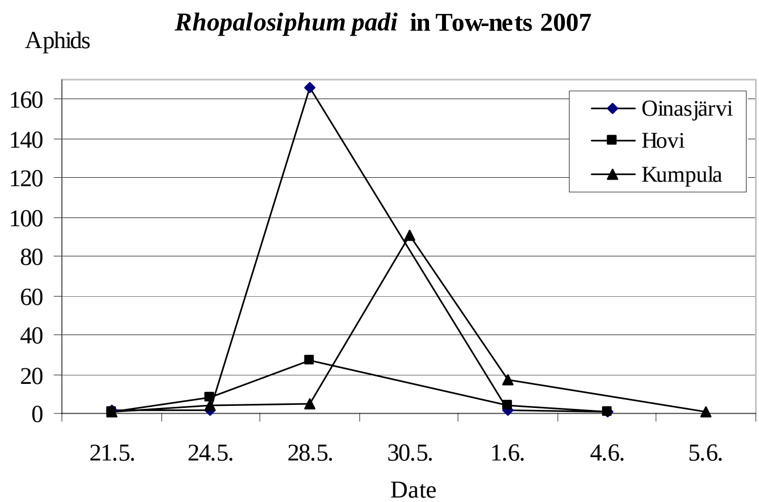

Figure 3. High numbers of R. padi were caught in tow-nets late May

Bird-cherry aphids are not necessarily easily detected in the radar echoes because of their small size. They are much weaker scatterers than certain other insects that migrate at the same time /Nieminen et al., 2000/. On the other hand, if the echoes are mainly caused by these aphids, the migration must be considered substantial. Field observations are very important to verify the radar-assisted warnings for this species. The maxima in field observations of bird-cherry aphids at the end of May 2007 seemed to coincide with maxima for radar echoes over the Gulf of Finland. A cloud of echoes could even be followed in time-lapse images crossing the Gulf of Finland in the southeasterly flow. Moreover, the first period in mid-May was related to significant insect migration detected by the radar.

The bird-cherry aphid is the most important insect pest of cereals in Finland and thus the effect of the aphids can be disastrous if the numbers of migrating aphids during the beginning of the growing season are high /Kurppa, 1989 b/. Control is needed if aphids are found on every fifth plant at the shoot or sprouting phase. When the plants are already at the straw phase the economic threshold is 5 aphids/plant and when the plant is producing ears it is 10–20 aphids/plant. In Finland chemical control is usually needed only in years when aphid attack is severe. The best time for application of pesticide is shortly after the aphids migrate and land on the cereal crop.

Conclusions

1. It is apparent that although bird-cherry aphids are small they can be detected using radar when they occur in large numbers. Diamond-back moths were also detected with radar. Radar and field trap monitoring of pest insects are important after the aerial migration has begun. Since many harmless species also migrate, vigilance and awareness of the incoming insects are important.

2. In order to be prepared and avoid crop losses a functional early warning system for migrating pest insects is needed. This system also helps to reduce chemical control if carried out early enough after migration has begun. This preliminary study concentrated only on a small area and more polarimetric radars are needed to develop a national system.

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