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Climate Change And Insect Pests: Monitoring And Surveillance Of The Migratory Phase For Smart Crop Protection

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The Rothamsted Insect Survey

There are close to 5000 aphid species in the world of which about 100 are major crop pests. Aphids have a high reproductive rate and a very short generation time compared to most other insect groups, requiring an effective decision support system to monitor populations and predict outbreaks.

Since 1964, the Rothamsted Insect Survey (RIS) has operated a 12.2 m suction-trap network to monitor the aerial fauna migrating at the landscape scale (https://www.rothamsted.ac.uk/insect-survey). Suction-traps can be thought of as upside-down hoovers which indiscriminately catch small to medium-sized insects (≤5 mg), particularly aphids.

Fig. 1. The Rothamsted Insect Survey's 12.2 m suction-trap used to sample aphids.

Currently, 16 traps are in operation in the UK which are used to monitor aphids daily during the growing season for the agri-industry, transferring knowledge of pest incidence to farmers, consultants and levy boards in a bid to reduce the prophylactic use of insecticides and therefore resistance. As our food chains have become global, so too have both the suction-trap network and the dominant pest aphid species. Currently, there are 129 traps in 17 countries and many of the species which are common in the UK are common on other continents (e.g. *Aphis fabae*; *Myzus persicae*; *Rhopalosiphum padi*, *Sitobion avenae*). The broader activities of the RIS have been reviewed over the years and readers may like to consult Taylor (1986), Harrington (2014) and Storkey *et al*. (2016) for more information.

Overview of Recent RIS Climate Change Science Highlights

Here, I give a brief understanding of the impact of climate change on aphids in context of RIS science over the last 15 years.

The UK has a temperate maritime climate. Although temperatures below around -5°C may be severe enough to kill the mobile stages, aphid eggs can survive below −27°C, the lowest temperature ever recorded in the UK (Strathdee *et al*. 1995).

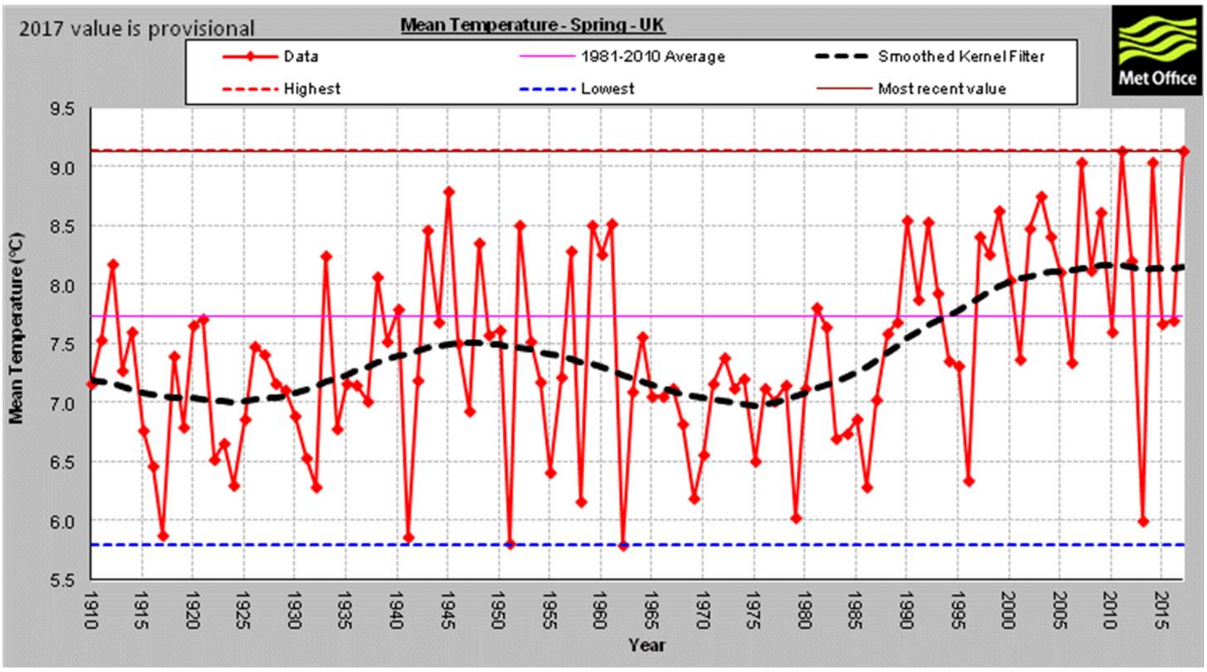

Fig. 2. Mean springtime temperature from 1910 to 2017. Source: The Met Office under Crown Copyright Licence http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

It is evident that there has been an upswing in spring temperatures since the RIS began recording in 1964 (Fig. 2), and this has the effect of advancing aphid first flight dates. Harrington *et al*. (2007) showed that aphid first flight dates across Europe were related to mean temperature. Their projections suggested that first records of aphids in suction-traps are likely to advance 8 days over the next 50 years on average. This rate of change is conservative in relation to the likely change over the UK. Here, flight phenologies have advanced at a rate of 0.7 days per year when averaged over species (Bell *et al.* 2015). Taken over the lifetime of the RIS, this is a dramatic change that equates to more than a month's advance.

Bell *et al*. (2015) went beyond looking at first flights to consider also the duration of the flight season, last flights and annual abundances for 55 species of aphid. Phenology and annual abundance were shown to be linked to a large-scale weather pattern, the North Atlantic Oscillation (NAO), a measure of the atmospheric pressure difference between the Azores and Iceland, as well as the accumulated day degrees above 16°C. The NAO determines whether the UK is likely to have a warm wet winter or a cold dry winter and 16°C is the average flight threshold across all species studied.

In a comprehensive analysis of over 10,000 time-series, Thackeray *et al*. (2016) showed using a new analysis technique, how temperature affected three trophic levels, building on their earlier work which highlighted differences in the rate of phenological change between primary producers, primary consumers and secondary consumers (Thackeray *et al*. 2010). The RIS contributed time series for these analyses, underpinning our understanding of rates of change in primary consumers. Thackeray *et al*. (2016) showed that precipitation was never significantly linked to aphid flight phenologies but there was a range of responses to temperature: 25% of all first flight records showed evidence that warmer temperatures drive first flights that are earlier, irrespective of when in the year warming happens. 42% of these warmer-earlier responses were significant. For the majority of first flight records (70%), warmer temperatures may be associated with earlier or later first flights, depending on when in the year warming happens: 30% of these records showed a warmer-earlier tendency that is significant, but <1% of these records showed warmer-later tendencies that are significant. Around 4% of all first flight records showed evidence that warmer temperatures resulted in later first flights, irrespective of when in the year warming happens.

Spatial synchrony is a measure of correlation over space, much like temporal autocorrelation is a measure of correlation over time. If these are combined, spatio-temporal synchrony tells us concurrently about the correlation over time and space. This is important because variation in climate changes over these two domains. Under increasing temperatures, particularly in winter, aphid phenology changes according to location and year. Sheppard *et al*. (2015) showed how spatio-temporal phenological synchrony was changing, driven by synchrony in winter climate, for a group of important pest aphids. In short, the long-term synchrony in aphid populations is in decline because of the increasing variability of winter temperatures between years and over space.

How Temperature Drives Changes in Aphid Phenotypes

During autumn, winged forms of the main vector of barley yellow dwarf virus (BYDV) increase in abundance. *Rhopalosiphum padi*, the bird cherry–oat aphid, either host-alternates between grasses and its winter host the bird cherry tree (sexual) or remains on grasses all year round (asexual), moving between cereals and field margin grasses according to availability. These two different life cycle strategies bring different BYDV transmission risks: asexual - high risk because they remain in the cereal system; sexual - low risk because they leave the system to reproduce sexually on bird cherry trees. The two forms also conveniently produce two different colour phenotypes (Lowles 1995) which can be used to estimate primary infection risk when dissected (Fig. 3). When average December to February temperatures are between 2 and 5°C the proportion of *R. padi* that are cereal colonisers is low in the following winter at around 10% of the sample population. As average temperatures rise above 5°C, the proportion of cereal colonisers the following winter increases dramatically, exceeding 50% when temperatures surpass 6.5°C. With this simple test, BYDV is predicted to be high in the autumn following warm winters.

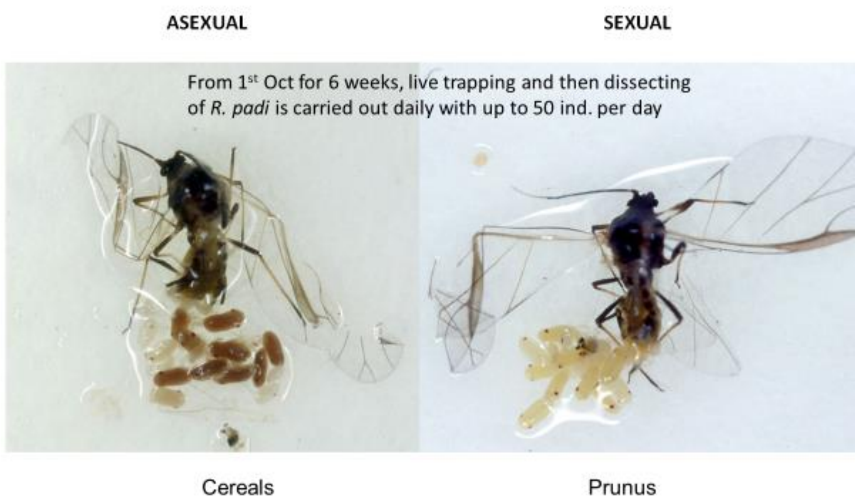

Fig. 3. *Rhopalosiphum padi* colour phenotypes indicating asexual and sexual lifecycle type

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