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Changing patterns in insect pests on trees in The Netherlands since 1946 in relation to human induced habitat changes and climate factors—An analysis of historical data

Leen G. Moraal*, Gerard A.J.M. Jagers op Akkerhuis

Alterra Wageningen UR, Centre for Ecosystem Studies, Droevendaalsesteeg 3, 6708 PB Wageningen, The Netherlands

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ABSTRACT

In The Netherlands, insect pests on trees and shrubs are being monitored continuously since 1946. During these years, almost all insect pest populations showed marked changes, which may be the result of changes in forest management, shifts in forest composition, climate change and the arrival of new pests from the Mediterranean region or from other continents. In order to generate hypothesis about possible relationships between species ecology and environmental factors, we have analyzed 61 years of population development of the 98 most abundant species in the database while paying attention to life history traits and preferred host plants. The 22 species with infestations lasting a few years only were excluded from the analysis. Of the remaining 76 species, 18 were present over the entire observation period of 61 years. Of the other species, 27 showed a decline and 31 showed an increase. On coniferous trees most species showed decreasing populations. Increasing populations were found most on deciduous trees. Not directly climate-related factors such as changes in forest age, tree composition and forest management were identified as the most important causes for the fluctuations in pest insect populations. Climate change is a possible driver of the population increase in *Thaumetopoea processionea*, *Haematoloma dorsatum* and of the population decrease in *Euproctis chrysorrhoea*. The recently increasing exotic species *Eupulvinaria hydrangeae* and *Pulvinaria regalis* were exclusively found on trees in cities, presumably in relation to the higher temperatures of the urban habitat.

1. Introduction

A range of processes has changed the Dutch landscape and its habitats. During the last decades the forests have undergone a management shift towards a more sustainable form, with increasing proportions of indigenous broadleaved trees. In addition, the age distribution of existing forests changed because the majority of forest in The Netherlands has been planted between 1850 and 1935. Furthermore, new pests invaded The Netherlands (Moraal et al., 2004). For many years, the levels of aerial nitrogen deposition from industrial and agricultural sources have shown an increase (Van der Eerden et al., 1998), which may have affected the quality of trees as food for herbivore insects (e.g. Flückiger and Braun, 1998; Port et al., 1995; Thomas and Schafellner, 1999). Meanwhile, Europe has experienced an increase in annual temperature, which across the continent amounts to about 0.8 °C. The winter temperatures increased more than summer temperatures and the yearly averages and winter temperatures since about 1990 were amongst the warmest in the instrumental record (IPCC, 2007). Recent studies on insects have shown examples of effects of climate change on ranges and population development of insects and the relationships with functional traits (Bale et al., 2002; Battisti, 2006; Evans et al., 2002; IPCC, 2007; Musolin, 2007; Parmesan et al., 1999; Ward and Master, 2007). In The Netherlands, responses to climate change on abundance and geographical distribution have been suggested for a range of species. Visser and Holleman (2001) determined the response of *Operophtera brumata* egg hatching and *Quercus robur* bud burst to temperature. They showed that there has been poor synchrony in recent warm springs, which is due to an increase in spring temperatures without a decrease in the incidence of freezing spells in winter. This means that changes in temperature patterns may affect ecosystem interactions more strongly than changes in mean temperature.

Aukema (2003) reported that between 1980 and 2002, seventeen new species of Heteroptera reached The Netherlands by natural range expansion of a southern distribution. Another examples are the thermophlic *Phaenops cyanea* and *Phloeosinus bicolor* which were observed in 1997 and 2004 respectively for the first time in The Netherlands (Moraal, 2008, 2010). Climate change has also caused phenological changes in Microlepidoptera populations

* Corresponding author.
E-mail address: leen.moraal@wur.nl (L.G. Moraal).

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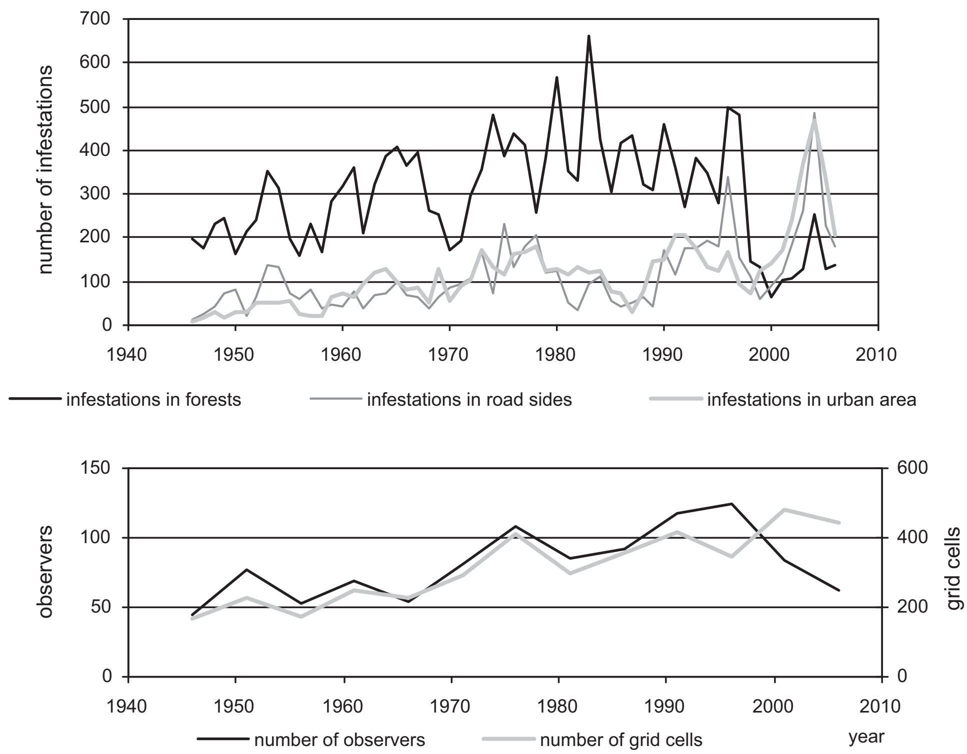

Fig. 1. Background information about the insect pest observation data. The figure shows the yearly numbers of infestations in forest, roadside and urban habitat in combination with the number of different grid cells (determined as five-years averages) and the number of observers (determined every fifth year).

in The Netherlands. For all species, the average observed peak dates have become more than 11 days earlier in the last decades, especially as the result of higher spring temperatures (Ellis et al., 1997).

Although there is much interest for climate change in recent years (e.g. Lawton, 1995), it is not the only factor influencing arthropod populations (Harrington and Stork, 1995). How can we determine the most important aspects in this concert of human induced changes and climate factors on insect populations?

Searching for answers to the latter question, we analyzed 61 years of monitoring data of insect pests on trees and shrubs of a programme which, since 1946, monitors these insects in The Netherlands.

To generate hypothesis about the factors inducing population changes over time, we included in the analysis information about taxonomic order, insect life history traits and food plant preferences. Insect herbivores can only complete their life-cycle successfully if they are adapted to their host plants and to the (climatic) environment (Bale et al., 2002). Based on earlier analyses of our pest insect database by Moraal et al. (2004) and Siepel (2006), the aim of the analysis was to generate hypothesis about how pests showing different ecological properties are affected by climatic factors and factors related to human activity such as changes in forest management.

2. Materials and methods

2.1. Properties and limitations of the data base

In the monitoring programme, volunteers have continuously observed pest insects in forests, nature reserves, urban environment and roadside plantings all over the country. Most observers were professionally involved in tree management. The monitoring has resulted in a database, which presently includes more than 32,000 records of almost 350 pest species. The pest species belong to the Lepidoptera, Coleoptera, Hymenoptera, Diptera, Hemiptera and Acari. A record in the database includes the following information: insect species, tree species, habitat type (forest, roadside or urban environment), national grid reference, the degree of infestation (light, moderate or heavy) and an estimation of the area infested. Local observations on infestations are registered in the database using a grid with a spatial resolution of 5 km $\times$ 5 km.

As can be concluded from Fig. 1, both the numbers of observers and the number of grid cells varied over the years. Temporal patterns in the number of grid cells are roughly followed by the number of infestations. The number of infestations in roadside plantings and urban area is increasing since 2000. The activity and spatial distribution of the volunteers varied not necessarily in close correlation to local pest infestations. As a result, corrections based on numbers of observers and/or grid cells would cause artefacts in the data due to local/temporal overcompensation. To avoid such undesirable effects this study focused on untransformed infestation data.

2.2. Selection of species and the creation of pattern groups

The database contains information on almost 350 pest species. We selected species with at least 35 infestations, resulting in a shortlist of 98 species. We focused on infestations irrespective of the degree. We consider this measure the best intermediate between only spatial sampling on the one hand (grid cells, extreme flattening of the data), and the inclusion of the degree of infestation on the other hand (extremely variable data). As a basis for comparing the historical population patterns of species with few or many infestations, we uniformly scaled their yearly numbers as the percentages of their total numbers during the entire 61-year period. We regard these percentages as the "relative abundances". This scaling allowed an effective comparison of temporal patterns in infestations. In Fig. 2 we give an example of *Diprion pini* and *O. brumata*, showing decreasing and increasing numbers of infestations, respectively.