Non-linear feedback processes and a latitudinal gradient in the climatic effects determine green spruce aphid outbreaks in the UK

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Abstract

The role of climatic fluctuations in determining the dynamics of insect populations has been a classical problem in population ecology. Here, we use long-term annual data on green spruce aphid populations at nine localities in the UK for determining the importance of endogenous processes, local weather and large-scale climatic factors. We rely on diagnostic and modelling tools from population dynamic theory to analyse these long-term data and to determine the role of the North Atlantic Oscillation (NAO) and local weather as exogenous factors influencing aphid dynamics. Our modelling suggests that the key elements determining population fluctuations in green spruce aphid populations in the UK are the strong non-linear feedback structure, the high potential for population growth and the effects of winter and spring weather. The results indicate that the main effect of the NAO on green spruce aphid populations is operating through the effect of winter temperatures on the maximum per capita growth rate (R_m). In particular, we can predict quite accurately the occurrence of an outbreak by using a simple logistic model with weather as a perturbation effect. However, model predictions using different climatic variables showed a clear geographical signature. The NAO and winter temperature were best for predicting observed dynamics toward the southern localities, while spring temperature was a much better predictor of aphid dynamics at northern localities. Although aphid species are characterized by complex life-cycles, we emphasize the value of simple and general population dynamic models in predicting their dynamics.