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Assessing long-term resilience of Scottish spruce forests to climate change and novel pests: *Ips typographus* as a case study

Policy Summary

Larval feeding galleries in Norway spruce bark caused by European spruce bark beetle (Ips typographus). Crown copyright © Forest Research.

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1 Policy Summary

1.1 Background

Sitka Spruce, *Picea sitchensis*, is a vital tree species for Scottish forestry in the current climate with few current pest or disease problems but it is unclear how Scottish forests might respond to further increases in pressure from climate change and pests. One potential threat is *Ips typographus* which has caused significant mortality of Norway spruce (*Picea abies*) in Europe. However, the co-interaction of a different spruce species (Sitka vs. Norway) and a substantially different climate (maritime Scotland vs continental Europe) leaves a significant evidence gap.

Bark beetles, particularly the European spruce bark beetle (*Ips typographus*), have a significant impact on spruce populations, often leading to tree mortality and altering forest dynamics. The ability of the beetle to produce multiple generations in a year is enhanced by warmer climates, whereas higher temperatures, lower precipitation and more frequent extreme events, such as windstorms, will affect tree health, providing ideal breeding grounds for beetle populations. It is unclear how Scottish Sitka spruce forests might respond to further increase in pressure from climate change and existing and new pests and their potential synergistic effects.

Therefore, there is a pressing need to investigate how climate change under different scenarios affects the potential for *Ips typographus* to become established in Scotland and what impact it would have on the Sitka spruce forests were the monitoring and eradication measures to be unsuccessful at some point in the future.

1.2 Key Research Questions

In this project, we have used a combination of literature review, expert solicitation, interactive workshop, climate and epidemiological modelling, and economics to address the following research questions:

- How will climate change affect the phenology of both *Ips typographus* and Sitka spruce, and how might this influence their interactions?
- How do abiotic factors like flooding and drought interact with biotic factors during the "epidemic phase" of *Ips typographus* outbreaks in Scottish forests?
- How will *Ips typographus* interact with Sitka spruce in Scotland's maritime climate, given that most existing research focuses on Norway spruce in different climatic conditions?
- How transferable are existing models (e.g., PHENIPS) to the specific conditions of Scottish forests and Sitka spruce?
- What are the long-term economic impacts, particularly indirect effects, of potential *Ips typographus* outbreaks on Scotland's forestry sector and rural economies.

1.3 Research Undertaken

In this project, we evaluated risk factors associated with the potential introduction of *Ips typographus* to Scotland under past, current and different future climate change scenarios.

We carried out an extensive literature review of existing research on bark beetle ecology, climate change, forest dynamics, and economic impacts. A two-day workshop was organised in Glasgow in May 2023, involving experts and policymakers to establish the state-of-the-art knowledge on *Ips typographus* and to discuss the implementation of the models. The workshop provided essential guidance to the approaches taken, including the identification of research gaps. The project analysed climate data from various sources, including HadUK-Grid and UKCP18 datasets for historical and projected climate conditions. We implemented and then integrated outcomes from four modelling approaches: (i) flight potential analysis was based on temperature thresholds, (ii) beetle phenology was addressed by a simplified PHENIPS model, (iii) potential losses during the "endemic" phase were assessed by Seidl et al. (2007) model, and (iv) drought potential and risk of an “epidemic” phase were assessed using Standardized Precipitation Evapotranspiration Index (SPEI). An analysis of six European locations with documented *Ips typographus* presence was used to compare with Scottish conditions.

We used Scotland’s division into three regions according to the Met Office classification (East, West, and North), and combined past climatic data (1960-2022) with the RCP 2.6 (best-case) and RCP 8.5 (worst-case) future climate projections (2023-2100). We carried out multiple simulations with different assumptions to test the robustness of the results. Finally, a literature review on the economic consequences of bark beetle outbreaks in other forest systems was carried out.

1.4 Main Findings

We have concluded that according to the best evidence, the potential for *Ips typographus* to be established in Scotland is currently moderate, with the risk of outbreaks currently low, but rising to moderate, then high within the next Sitka rotation (i.e. 30-50 years). Throughout the report, we associate low risk with sporadically occurring droughts, flights starting in July and occurring for less than 100 days, as well as one or no generation. Medium risk is associated with sporadic moderate to severe droughts, flights shifting to June and possibly for more than 100 days, as well as occasional years with 2 generations. When the number of generations increases from one to two or three, and combines with frequent prolonged and severe droughts, we associate it with a high risk.

We estimate that the risk of *Ips typographus* establishment and outbreaks in Scotland is likely to increase over time, particularly in East and West Scotland. These areas are at higher risk compared to North Scotland, which remains at lower risk throughout the century. Under both optimistic (RCP 2.6) and pessimistic (RCP 8.5) climate change scenarios, conditions are expected to become more favourable for *Ips typographus* development, with earlier flight periods and increased potential for multiple generations per year. In addition, climate change is likely to increase the frequency and severity of droughts, particularly in East Scotland, potentially increasing tree vulnerability to beetle attacks. The combination of improved

conditions for beetle development and increased tree stress could lead to a scenario characterised by large-scale outbreaks, especially after 2040.

While current risks are low, potential infestations could have significant direct and indirect economic impacts on Scotland's forestry sector and rural economies. We have carried out an extensive literature review on the economic impact of bark beetles and broadly divided the impacts as direct – associated primarily with consequences of forest loss and effort for removing damage, pest detection and control – and indirect – productivity and forest health loss, shifts in species, and environmental and social costs. With further information or scenario development, the methods identified here could be used to explore the potential economic costs of *Ips typographus* outbreaks.

1.5 Recommendations and Next Steps

Sitka spruce is favoured for its rapid growth, suitability for Scotland's current climate and soils, and for its contribution to timber production (for construction grade timber C16) and carbon sequestration, and so is a mainstay of the timber processing sector. However, there is growing apprehension about the potential consequences of overreliance on a single species. Our report has highlighted the potential risks to the industry if *Ips typographus* becomes established in Scotland over the next rotation and beyond. Given the trend that favours the beetle survival, reproduction, and impact on trees, our research highlights the importance of continuing surveillance, detection, and eradication actions as well as increased diversification of forests. However, all species, not just Sitka, will be up against significant pressures of climate change and pests and disease, and science and ongoing research will be critical in helping to find the best future forest solutions.

We have identified significant knowledge gaps which remain to be resolved by future work, including the ongoing research at Forest Research. The specific aspects of the interactions between *Ips typographus* and Sitka spruce, and the impact of the beetle on the Sitka trees, are uncertain, as most existing research focuses on Norway spruce. Existing models (e.g., PHENIPS) have been applied to Scottish conditions, but their transferability is limited due to differences in host species and climate. The study also identifies the need for finer spatial resolution analysis to account for local variations in climate and forest conditions.

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