Plant Health Centre
Scotland's Centre of Expertise

Scottish Government
Riaghaltas na h-Alba

Evidenced-based impacts of severe weather events on forestry pests in Scotland: a meta-analysis

Policy Summary



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Forest Research

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Windblow at Broadford, Isle of Skye, Scotland.
Grant MacIntosh

Policy Summary

Background

This review assesses how forest insect pest species respond to severe weather events which are defined here as wildfires, drought, windthrow, and flooding. Climate change is a significant driver of more frequent and intense severe weather events which disrupts habitats, alters host availability and reshapes pest dynamics. The review focuses on key pest groups that are already present in Scotland or represent important future threats, including bark beetles (e.g. *Ips typographus* and *Dendroctonus micans*), defoliating moths (e.g. oak and pine processionary moths and spruce budworms), jewel beetles (e.g. *Agrilus* spp.) and sap-sucking insects such as adelgids and aphids. To explore how forest insects will respond and what current evidence is available on how best to manage any potential changes we have conducted a systematic literature review and a meta-analysis of the available evidence.

Key Research Questions

This review and meta-analysis had the following objectives:

1. Systematically review the current literature how forest pest species that are present in Scotland, or are likely to establish, respond to severe weather events.
2. Conduct a meta-analysis of the published evidence to elucidate how species biology and ecology might change in response to severe weather events.
3. Establish broadly applicable case studies to visualise how future management might occur in Scotland.
4. Identify potential evidence-based management recommendations for Scottish land managers and policy makers.

Research Undertaken

A systematic literature review and meta-analysis was conducted in accordance with PRISMA (Preferred Reporting Items for Systemic reviews and Meta-Analyses) guidelines (Page et al. 2021). Pre-defined search terms were developed by using a combination of software that develops subject specific keyword strings and subject area expertise. Studies concerning forest pests' responses to severe weather events were sought for targeting two key concept areas; (i) key forest pests and invertebrates' biology and ecology, and (ii) their responses to severe weather events. Relevant studies were identified by searching the online database Scopus using a set of predefined search terms. The meta-analysis compared results across studies using a standardised measure of effect size. The findings were then checked for reliability by exploring sources of variation between studies and assessing potential bias using methods such as sensitivity analyses and visual inspection of result patterns. The initial search identified 1319 articles of which, 1283 were removed during screening. Thirty-six were accepted for use for case studies, and only 8 were deemed to have suitable data for the meta-analysis of which 22 individual "studies" were extracted for use in the analysis. Species considered in the review included bark beetles (*Ips*, *Dendroctonus*), defoliating moths (*Thaumetopoea* spp. and *Choristoneura fumiferana*), jewel beetles (*Agrilus* spp.), and sap-sucking insects such as adelgids and aphids.

Main Findings

Only a small number of studies have examined pest responses to storms, droughts and wildfires with evidence concentrated to certain regions and taxonomic groups. Across the literature, the strongest evidence was available for bark beetles and defoliating moths, while evidence for jewel beetles and sap-sucking insects was comparatively limited. Severe weather can affect pest populations in different ways depending on species, host condition and local context and findings were often inconsistent. Importantly, where no meta-analytic result was produced (e.g. drought and bark beetles), this reflects a lack of suitable evidence for the analysis rather than evidence of no effect.

Wildfire

- Based on the available evidence bark-boring beetles appear to decline after fire, but the overall effect is modest and not statistically robust with responses depending heavily on whether species are adapted to fire-prone systems and on fire severity.
- Wildfires likely directly reduce bark beetle numbers by killing individuals but provide weakened hosts that can act as breeding material for populations to recover. This variability means wildfire cannot be assumed to either suppress or promote bark beetles without considering species ecology and site conditions.

Drought

- Drought appears to favour certain leaf-eating insects by increasing feeding and growth rates. This is likely linked to changes in foliar chemistry in stressed trees and to warmer temperatures accelerating insect development.
- There are few studies that reinforce this observation, and there is limited understanding of how repeated or prolonged droughts influence population dynamics.

Storm and Windthrow

- Storms and windthrow can generate large volumes of damaged timber that provide suitable breeding material for bark beetles which likely contribute to increased populations. However, a small sample size meant the meta-analysis did not detect a statistically significant overall effect.
- Variation among studies was high, partly because key variables such as, host species, disturbance severity, time since the event and follow-up management, are inconsistently reported. As a result, firm generalisations remain difficult.

Recommendations and next steps

Overall, severe weather can alter pest risk in important ways, but the evidence is not yet strong enough to support highly specific, species-by-species rules. Further targeted research is needed to refine guidance, but particular attention should be given to windthrown spruce, drought-stressed broadleaves vulnerable to defoliators and post-fire stands. From a management perspective, several precautionary steps are justified:

- Pest monitoring should be strengthened around all types of severe weather event by utilising trapping networks, ground surveys and online reporting systems.
- Post storm and wildfire management should prioritise reducing the availability of high-risk breeding material. This may involve prioritising removal or treatment of damaged trees in strategic areas, including high-value stands and sites near transport routes. Sanitation felling and targeted thinning can limit the build-up of stressed hosts.
- During drought periods, where defoliator risks may rise, managers should ensure that appropriate control measures can be deployed rapidly if thresholds are exceeded.
- Increasing structural and tree species diversity should remain a key long-term strategy. Mixed-species and mixed-age forests are generally more resilient to both extreme weather and pest outbreaks than uniform monocultures.

Despite these recommendations significant knowledge gaps remain. Few quantitative studies directly link specific severe weather events to changes in priority pests under Scottish or comparable conditions. Future work should prioritise use of existing datasets, together with standardised survey design, reporting, and metadata collection to improve comparability across time and place. Targeted field studies following severe weather events, alongside controlled experiments and mesocosm studies, are also needed to improve understanding of how drought, storms, wildfires, and flooding influence forest pest populations and tree health over time.

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