



Bark Beetle Outbreaks in Slovenia Over the Last 30 Years: Patterns, Drivers, and Management Strategies

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ABSTRACT



Extensive outbreaks of native spruce bark beetles (Curculionidae: Scolytinae) have affected coniferous forests throughout Europe. Spruce bark beetle outbreaks have significantly impacted Slovenian forests as well over the past 30 years, with increasing frequency in the last decade where 11.672.070 m³ was salvage logged due to spruce bark beetles. The Alpine region has been recently particularly affected by climate changes, facing severe ecological and economic consequences. European spruce bark beetle (*Ips typographus* L.) outbreaks cause significant changes in landscape structure, reduce carbon storage, increase wildfire risk, accelerate soil erosion, alter water cycles, increase risk for invasive species, impact forest-based economies, and diminish the aesthetic and recreational value of forests. The management of bark beetles including preventive measures, proper response to outbreaks, and the restoration of damaged forests is therefore of crucial importance. This study analyses the spatial and temporal dynamics of outbreaks in Slovenia from 1995 to 2024. We present the research

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done in previous years verifying a combination of biotic and abiotic factors that precede an outbreak. Key environmental drivers, such as altitude, precipitation changes, and host tree composition and prior abiotic disturbance are shown to affect the probability of bark beetle outbreaks. The findings reveal a clear shift in outbreak patterns, with infestations spreading into higher elevations and drier regions, increasing the vulnerability of mountain forests. Integrated forest pest management approaches to mitigate future risks, emphasizing the importance of mixed-species stands, early detection systems, and climate-resilient forestry practices will be discussed. Effective bark beetle management requires a combination of prevention, suppression, and restoration strategies. Prevention focuses on altering forest conditions to reduce susceptibility, suppression targets existing infestations to limit further spread, and restoration aims to re-establish ecological integrity and resilience. An integrated approach combining all three strategies is essential for formulating a sustainable and adaptive management policy. This research provides information for sustainable forest protection in mountainous regions under accelerating environmental change.

