Managing bark beetle outbreaks in the 21st century

POLICY BRIEF

Tomáš Hlásny | Czech University of Life Sciences in Prague, Faculty of Forestry and Wood Science
Julia Haas | FOREST EUROPE Liaison Unit Bonn

Bark beetles and other biotic agents have devastated European forests with unexpected severity. The worst is likely still ahead of us. It is crucial to devise strategies to mitigate disturbance impacts across the entire forest value chain and increase the preparedness of all actors and institutions. However, every crisis presents an opportunity. Let's seize this one and use it to create resilient forestry sectors and forests fit for the future.

Photo: Forest Management Institute of the Czech Republic.

Context

Huge forest areas have been affected by bark beetles across Europe during the past few years, with damages exceeding pre-2000 levels by nearly tenfold[1]. The unprecedented scale of the damage turned the outbreaks into a pressing socio-economic issue. It concerns not only the forest-based sector and international timber markets but also the overall life quality of people, and raises questions about our ability to achieve climatic targets. These developments have prompted us to question the suitability of current management planning, silviculture, and forest protection practices, which were not designed to be implemented in such high-risk conditions. Accelerating climate change will intensify the outbreaks, cause their synchronous occurrence over large areas, and force them to expand to northern regions. These developments cannot only be addressed at the forest management level but require cross-sectoral and international cooperation with strong and clear policy support.

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Managing future forest risks faces many new challenges. Management must consider new interactions between disturbances, such as different chains of drought, wind, fire, pest outbreaks and diseases. Traditional methods of disturbance control and avoidance are no longer efficient, while operating in high-risk conditions has become the new norm. The proliferation of new technologies has the potential to revolutionize disturbance management, including mapping, forecasting, and spatial planning. Facing these challenges requires strengthened interface between science, policy and practice, and investments into training and education.

Management and policy principles

Replace isolated response actions with a comprehensive risk management strategy

Salvage and sanitary operations have been a cornerstone of bark beetle management in Europe; however, they represent only one element of a risk management strategy that can mitigate future outbreaks. Efficient management requires integrating silviculture and monitoring; developing storage and transportation capacities; workforce development and training; spatial planning and zonation; and post-disturbance restoration that mitigates future risks. The **emergency management cycle** consisting of the *Preparedness, Prevention, Response, and Recovery* phases can provide a practical framework for integrating these actions into consistent national risk management plans.

The report 'Living with Bark Beetles: Impacts, Outlook and Management Options[2]' under the EFI Science to Policy series and the follow-up review study[3] provide useful guidance for revising current outbreak management practices and related policies.

Risk management strategies must be comprehensive, not focusing on bark beetles, fires, or windthrows in isolation. These agents interact and measures taken to reduce one impact can increase others.

Foster cross-sectoral policy harmonization and international cooperation

Managing large-scale disturbances, such as bark beetle outbreaks, requires coordinated actions of multiple sectors and actors, including *inter alia* forestry, environment, transportation, finance, insurance, public safety, and the public. Contrary to singular fire and windthrow events, outbreaks typically last several years and can thus gradually deplete forest owners' resources, jeopardizing their ability to intervene. Well-prepared insurance, compensation, and subsidy programs can be instrumental in mitigating the impacts. Outbreaks and their environmental and market impacts do not respect the borders. Establishing communication and coordination platforms for states sharing outbreak-prone areas can increase management efficiency and help mitigate potential frictions.

The Czech experience with a country-wide outbreak of spruce bark beetle (2018-2023) can provide unique lessons for other countries, including adapting legislation, mitigating social impacts, and facing volatile timber prices and COVID restrictions. Platforms, such as the Forest Risk Facility (FoRISK) under FOREST EUROPE, can play a crucial role in sharing this knowledge with decision and policy-makers across Europe.

Adopt 'resilience thinking' in risk management

Bark beetle outbreaks and other disturbances are inevitable, and their frequency and severity will increase in the following decades in many countries. Resilient forests can absorb and recover from such impacts; resilient forestry sectors can absorb large amounts of salvaged wood and operate under fluctuating timber prices and labour availability; and resilient societies can learn to live with large-scale environmental transformations and changing provisioning of ecosystem services. Resilience must not be seen as an elusive scientific concept but as a major policy and management framework for dealing with increasing risks and limited knowledge of future environmental, market, and societal trends[4,5]. Adopting *resilience thinking* enables us to see natural disturbances as opportunities for creating new, resilient forests and implementing reforms that enhance the forestry sector's capacity to adapt and recover from future shocks more efficiently.

Policy recommendations

- **Learn and anticipate, not only respond.** Knowledge exchange across Europe and thorough assessment of good-practice examples and shortcomings of disturbance management are essential for preparing anticipatory crisis plans and gaining their support across sectors. These plans will perform better than any ad-hoc solution; if lucky, they will never need to be used.
- **Replace "one-size-fits-all" solutions** with approaches tailored to different social and ecological contexts. Consider that natural disturbances are detrimental to most ecosystem services[6] but essential for biodiversity and natural processes*. Actions supporting natural dynamics including dead wood retention and natural recovery, should be promoted on sites with high conservation values, while risks should be actively managed on sites where commodity production is the primary objective. Data-driven zonation with differential management priorities within the zones is essential for managing large-scale outbreaks. Cases when salvage logging is not economically viable and sanitation logging is unlikely to suppress outbreaks need to be specifically considered in management decisions. Such approaches differ from uniform management practices applied in many countries, and their implementation requires legislative changes coordinated across sectors.
- **Reconcile silviculture and forest protection** and combine them in an integrated risk management strategy. Silviculture practices promoting long rotation periods, high growing stocks, and low age and species diversity create high-risk conditions, which cannot be mitigated by actions, such as salvaging, sanitation and beetle trapping. However, active risk reduction measures can help reach management objectives in diverse, climate-adapted, and resilient forests. Under climate change, risk reduction and resilience matter more than maximized productivity.
- **Mitigate negative effects of game.** In many European countries, large wild herbivores pose a significant threat to forest regeneration and can compromise natural and main-aided forest adaptation. They can decimate replanted disturbed areas and alter the species composition of the emerging regeneration, often leading to the dominance of spruce. Therefore, active game management is crucial for restoring disturbed areas, creating forests adapted to future climatic conditions, and reducing future risks.

* The report "Living with Bark Beetles" and its follow-up review study[3] made a clear distinction between interventions in wood production-oriented forests and forests managed for biodiversity and conservation values, the two end-members of the management continuum in Europe. The report highlights the importance of natural disturbances for creating habitats for various forest-dwelling species, maintaining natural processes, and enhancing landscape heterogeneity. It also outlines situations where intervention against bark beetles is justified in high conservation-value forests, such as when new species invade, when native bark beetles expand their range, when individual monumental trees or old-growth remnants need to be protected, or when focal species of conservation are directly threatened by the disturbance.

- **Make use of natural forest dynamics.** The high capacity of many forests to recover and adapt without or with a limited human intervention has often been underestimated, although natural recovery can provide many ecological and economic benefits. Given the expanding outbreak areas and limited human resources, it becomes crucial to incorporate both the promotion of natural dynamics in certain landscape segments and active adaptation and restoration in other areas. The emerging spatial mosaics can vitally contribute to forest resilience and reduce future risks. Forest management should actively embrace structural and compositional diversity created by natural disturbances and incorporate advanced regeneration, survivors, deadwood patches and other elements into the emerging forest generation. To garner support for such measures, it is crucial to implement anticipatory education, training, and awareness initiatives.
- **Keep the future in mind.** Post-disturbance treatment and restoration determine the forest's fate into the future, including vulnerability to future disturbances. Therefore, establishing climate-adapted and resilient forests on disturbed sites is a paramount yet often overlooked risk management component. This may require unpopular actions, such as planting currently less valued yet low-risk species, substantial game reduction, and adapting species composition to future climatic conditions through assisted migration. The changes in forest composition must drive corresponding transformations of forest-based industries. They can serve as a powerful incentive for forest managers to adapt their practices.
- **Keep up with emerging technological trends.** Forest risk management must keep up with the ongoing digital transformation. Satellite and close-range remote sensing, Artificial Intelligence, Dynamic Simulation Models, Horizon Scanning tools, and other emerging technologies can vitally support disturbance monitoring, risk assessment, spatial planning, and forecasting in operational conditions. These technologies can be particularly useful in assessing future site suitability and selecting species for replanting disturbed areas. National research organizations, forest protection services, extension services (e.g., https://forext.eu/), and other bodies need to be engaged in adopting and adapting existing solutions to local natural, logistic, and human resource settings.

Resources

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RESONATE
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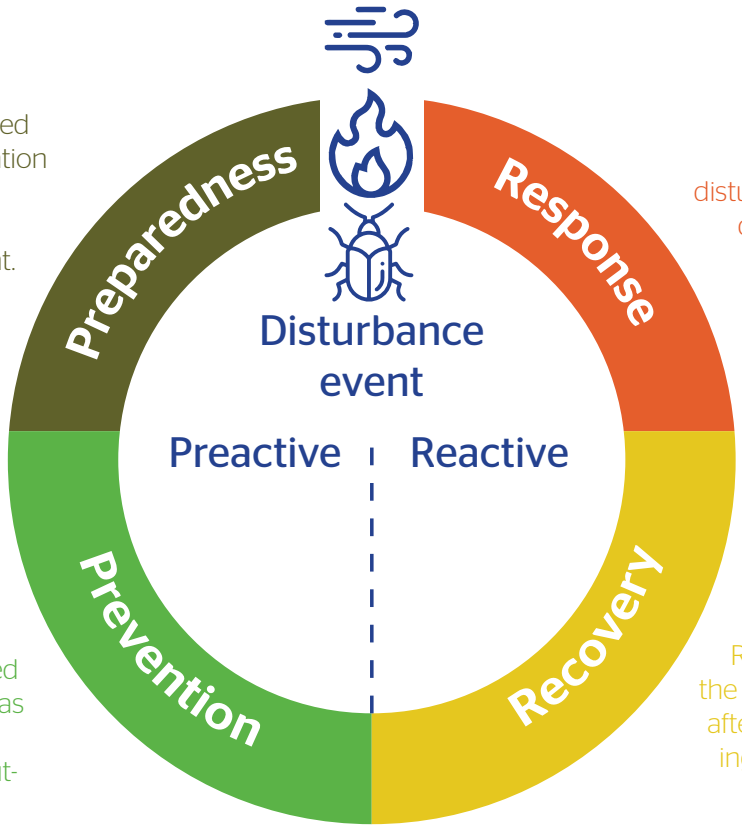
Technical annex: Biotic risk management toolbox

This appendix is an updated version of the toolbox published in the report Living with bark beetles: Impacts, outlook, and management options (Hlásny et al. 2019) and the follow-up study Bark beetle outbreaks in Europe: State of knowledge and ways forward for management (Hlásny et al. 2021). For clarity, actions in the toolbox are organized around the four phases of the Emergency Management Cycle: Preparedness – Prevention – Response – Recovery. The phases do not need to be sequential, and the same action can be applied in different parts of the cycle. For example, post-disturbance recovery actions can determine the efficiency of future preventative actions. Salvage and sanitation logging can be applied both to prevent the build-up of bark beetle populations and respond to the ongoing outbreaks by salvaging dead trees to mitigate economic losses. All phases require a high level of preparedness in terms of human and technical resources, legislation, improved education and training, cross-sectoral crisis plans, and other aspects.



Prepardeness: Actions aimed at capacity building, education and training, strategic planning, legislation, and infrastructure development.

Response: Actions taken directly in response to the disturbance, such as salvaging dead trees and subsidizing response measures.

Prevention: Measures aimed at reducing the risks, such as increasing forest resilience and reducing the risk of outbreaks.

Recovery: Actions restoring the forests and forestry sector after disturbances and adapting them to changing conditions and future risks.

Figure 1: The four phases in the crisis management cycle for disaster risk reduction. Adapted from Lindner, M. and Schuck, A. (2020). Towards holistic forest crisis management - adapting to changing disturbance regimes in Europe. EFI Policy Brief 08_2020. https://sure.efi.int/sites/default/files/2020-08/Policy%20Brief_Towards%20holistic%20forest%20crisis%20management.pdf

Photo: Forest Management Institute of the Czech Republic.

PREPAREDNESS		
#	Tools & Measures	Description
1.1	Improving education	Key forestry subjects such as forest protection and silviculture need to reflect fully on the most recent understanding of changing forest risks and new management and governance concepts responding to changing socio-ecological conditions. Accordingly, training modules for decision- and policy-makers should be developed and training systematically organized.
1.2	Strengthening international collaboration	The transboundary scale of outbreaks and the potential introduction and spread of invasive pests require strengthened international collaboration, data, and knowledge sharing, improved pest monitoring, and crisis management systems.
1.3	Increasing knowledge transfer from science to policy and practice	Intensifying outbreaks question the efficiency of traditional approaches to their control and prevention. Knowledge transfer from science to policy, legislation, and practical management needs to be strengthened, and best practice examples developed and shared among the countries. Platforms strengthening the science-policy-management interface need to be established, and their actions integrated within the workplans of national forestry agencies.
1.4	Developing effective crises management plans	Outbreaks occurring at national or supranational scales require well-prepared cross-sectoral responses (forestry, environment, finance, transportation, public safety, etc.). Our current preparedness for such complex actions is low, and legislation supporting cross-sectoral response actions is missing in most countries. Such plans need to be prepared prior to outbreaks or other large-scale disturbances to maximize their efficiency and reach support from all actors.
1.5	Developing zonation for nature conservation areas	Adequate buffer zones need to be established around nature conservation areas to better control and monitor beetles` migration between non-intervention forests and adjacent managed forests. This will help increase management efficiency and reduce friction between the involved actors.
1.6	Maintaining multi-stakeholder dialogue and building relationships with local communities	Dialogue must be maintained with all stakeholders involved in outbreak management or otherwise concerned with the forest to increase the efficiency of measures, acceptance of the final outcome, and mitigate the risk of conflicts.
1.7	Improving and/or establishing systems for monitoring forest susceptibility to disturbance and changes in pest populations	The current ability of most of the EU countries to detect changes in biotic risks and take coordinated transboundary actions is low. Timely and efficient implementation of management actions requires early detection of susceptible forest conditions, quantitative modelling and sampling of pest densities, and detecting the appearance of new pests. The quality of management decisions vitally depends on the quality of incoming information.
1.8	Maintaining sufficient levels of well-trained professionals	Forestry employment levels are decreasing, yet the increasing risks require a sufficient workforce. Maintaining well-trained and experienced forestry personnel on site is essential.
1.9	Supporting advanced regeneration	Maintaining a vigorous advanced regeneration facilitates a faster recovery of forest cover after disturbances, reduces demand on seedlings production, and labor-demanding planting and regeneration protection.
1.10	Maintaining sufficient nursery capacity	Increased demands on forest reproductive material of non-spruce species and provenances after large-scale disturbances may exceed the existing capacity of nurseries and result in insufficient restoration of disturbed areas. Nursery capacities need to be increased, and their production adapted to forest adaptation needs.
1.11	Developing and maintaining an adequate forest road network	A sufficient forest road network is needed for small-scale interventions, resilience-oriented management, as well as efficient detection and removal of infested trees.
1.12	Increasing timber storage capacities	Sufficient facilities for timber storage can provide a supply buffer after windthrows and bark beetle outbreaks by preventing large quantities of timber from flooding the market.

PREVENTION		
#	Tools & Measures	Description
2.1	Developing early-warning systems and integrating them in outbreak management	Development and maintenance of early-warning systems based on near-real-time weather data, automated beetle monitoring, and/ or remote sensing data help identify high-risk areas and plan targeted preventative measures.
2.2	Coordinating beetle management across the landscape	Effective management of outbreaks is often complicated in multi-owner landscapes. Plans for coordinated management actions across property boundaries is needed to mitigate the risk of outbreak expansion.
2.3	Decreasing landscape-scale host connectivity	Reducing landscape-scale connectivity of susceptible forest stands and complexes can help contain the spread of beetles. This requires using spatial planning tools and coordinating forest owner actions.
2.4	Use pheromone traps to monitor pest populations	Pheromone traps can efficiently monitor beetle populations and inform management about the optimal timing and intensity of control measures.
2.5	Maintaining compositionally and structurally diverse stands	Mixed stands with a complex vertical and horizontal structure are less likely to generate outbreaks and exhibit a higher survival rate than monospecific stands with homogeneous structures. Maintaining forest compositional and structural diversity is paramount for managing risks under climate change.
2.6	Reducing risks by shortening forest rotation period	Tree vulnerability to wind and bark beetle damage increases with age and tree size. Reducing the area of susceptible age classes reduces the overall outbreak risk. However, undesired effects may occur, such as increased harvest levels, reduced carbon stock, and the loss of habitats related to the presence of mature trees. Therefore, rotation reduction has to be balanced with other risk reduction measures, mainly the change in species composition. Collateral effects must be carefully considered.
2.7	Increasing host tree resistance by thinning	Silvicultural treatments that reduce competition between trees can increase tree vigor and resistance against bark beetles and keep bark beetle population below the epidemic threshold.
2.8	Reducing outbreak risks by sanitation felling	Removing infested trees from the forest while the beetle brood is still inside can reduce beetle populations and decrease outbreak risks. Removing wind-felled trees to prevent a build-up of beetle populations can also be considered if it is conducted timely and without incurring excessive collateral damages. However, the ability of salvage and sanitation logging to prevent or suppress the outbreaks in conditions when bark beetle development is accelerated by climate change and host tree resistance is compromised, remains unclear.
2.9	Preventing beetle spread from felled trees and logs	Mechanical or chemical treatment of infested logs, combined with timely removal, can prevent beetles from leaving the trees and infesting live trees. New approaches, such as bark scratching and fumigation, need to be developed and tested for efficiency, cost-benefit ratio, and collateral effects.
2.10	Creating habitats for natural enemies of bark beetles	Bark beetles have a number of natural enemies (birds, predatory beetles, etc.). Creating diverse stands with favourable habitat conditions for natural enemies can keep beetle populations in the endemic phase and reduce outbreak risks.

RESPONSE		
#	Tools & Measures	Description
3.1	Reducing economic losses by salvaging dead trees	Salvaging of infested, windfelled, or otherwise damaged trees primarily aims to recover economic losses. In large-scale events, spatial planning of salvage harvests can be applied to salvage the most valued stands before timber quality deteriorates. Planning tools that consider transportation networks, disturbance distribution, and stand characteristics can be applied to increase salvaging efficiency. The negative impacts of salvaging on forest regeneration, soil, and biodiversity need to be considered and weighed against the value of salvaged wood.
3.2	Reducing outbreak expansion by sanitary removal of infested trees	Detection and removal of infested trees can be applied to prevent outbreak expansion, particularly if infestation spots are small. Hazard-rating and spatial planning models can optimize sanitation felling, reduce the connectivity of host trees and beetle populations, and preferentially treat areas serving as hubs for beetle dispersal.
3.3	Reducing planned harvests	Reducing planned harvests can free up capacities for logging of beetle-killed trees and mitigate the adverse effects of a temporary timber surplus on the market.
3.4	Subsidizing response measures	Responses to a large-scale bark beetle outbreak may require substantial investments, which could exceed the forest owners` capacity. Subsidizing timber transport, storage, and other components of outbreak management can mitigate economic impacts and increase the efficiency of response actions.
3.5	Considering “no management” as a possible response option	Not intervening needs to be considered as a possible response option in situations where salvaging is not economically viable, sanitary felling, beetle-trapping, and other measures do not hold the promise of containing the outbreak, and collateral effects could be severe (for example, in steep slopes). Spatial planning tools can help optimize intervention planning with regard to logistics, human resources, level of risk, and economic and ecological considerations.
3.6	Increasing multi-stakeholder dialogue and communicating response strategies to the public	Maintaining a dialogue with stakeholders involved in outbreak management will improve the efficiency of control measures and the acceptance of final outcomes. Communicating management strategies and progress to the general public will raise awareness and reduce the risk of negative responses.

RECOVERY		
#	Tools & Measures	Description
4.1	Fostering diverse stands	The recovery phase provides opportunities to influence the tree species composition of the next forest generation and reduce forest vulnerability to future disturbances. Enrichment planting and assisted migration can be applied to create species compositions adapted to foreseen climate conditions and new risks.
4.2	Supporting advanced regeneration	Advanced regeneration should be spared during salvage logging as it facilitates faster recovery and restores the microclimate. Vigorous regeneration layer also reduces the costs of planting and seedlings protection.
4.3	Harnessing early-successional species	Regeneration of early-successional species such as birch, poplar, and larch can swiftly establish a new canopy. Ecological benefits of these species should be maximized, while commercially more important species can be planted later. Maintaining early successional species for an extended period can help increase the age diversity of the new forest.
4.4	Taking benefit of natural recovery processes	Forests have a high capacity to recover from disturbances naturally. Low-cost natural recovery can be considered in areas where fast recovery is not essential, and locally relevant ecosystem services can be provided by naturally regenerating species. Combining natural recovery with an active adaptation of species composition in different areas can create resilient forest landscapes.
4.5	Planting seedlings on disturbed sites	Planting tree seedlings leads to a quicker recovery of tree cover and gives more control over the tree species composition. Adapting species composition to future climates through targeted species selection and assisted migration is paramount for reducing future risks.
4.6	Protecting forest regeneration	Regeneration protection against browsing by animals and competing vegetation improves tree growth rate and tree quality. In many countries, active game management is essential prerequisite of successful forest recovery and adaptation.
4.7	Integrating disturbance legacies into the recovering forest	Disturbance legacies, such as surviving trees, advanced regeneration, and standing and downed deadwood, should be integrated into the recovering forest rather than being removed. Such legacies support the regenerating tree cohort and increase structural diversity of the recovering forest.
4.8	Maintaining multi-stakeholder dialogue	Maintaining dialogue with stakeholders involved in outbreak management makes it possible to track changing risk perceptions and responses, and adapt management and communication strategies accordingly.
4.9	Establishing forest insurance programs for forest owners	Forest owners can be insured against certain kinds of forest damage and loss of future income in some countries (e.g. Finland and Norway). This provides an effective distribution of economic risk from disturbances among forest owners, and can enhance their recovery from disturbance events.
4.10	Subsidizing recovery measures	Recovery from large-scale outbreaks (or disturbances, in general) may require substantial investments, which may exceed the capacity of forest owners. Subsidizing recovery actions, such as planting of desired tree species and protecting regeneration, can be vital for the successful recovery of both forests and forest owners.