https://doi.org/10.17221/87/2025-JFS

# Balancing conservation and intervention: Managing forest diebacks in Slovakia's Tatra National Park

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**Electronic Supplementary Material (ESM)**

The authors are fully responsible for both the content and the formal aspects of the Electronic Supplementary Material. No editorial adjustments were made.

Table S1. Key SES variables in the TANAP bark beetle case with contrasting outcomes under laissez-faire and interventionist forest protected area management

| SES subsystem | SES variable (Ostrom 2007, 2009) | TANAP case characteristics | Conservation (laissez-faire) outcomes | Intervention outcomes |
|---|---|---|---|---|
| Resource system (RS) | RS1 – sector | mountain forest ecosystem (subalpine/alpine) | high exposure to uncontrolled disturbance | managed disturbance regime |
| | RS3/RS5 – size/productivity | spatial heterogeneity (core, buffer, altered forests) embedded within a transboundary and tourism-intensive landscape | outbreaks spread beyond protection zones and economic areas | spatial containment more feasible |
| | RS7 – predictability | low predictability under climate change | increased uncertainty and cascading effects | reduced uncertainty through action |
| | RS9 – location | high-elevation wind-prone region | strong amplification of wind–beetle interactions | disturbance interactions partially dampened |
| Resource units (RU) | RU1 – mobility | trees immobile; beetles highly mobile | rapid spatial spread of infestation | spread limited by substrate removal |
| | RU2 – growth/replacement rate | slow regeneration at high elevation | long recovery times after mortality | faster recovery potential |
| | RU4 – economic value | high value | large-scale loss of mature forest | partial preservation of forest structure |
| | RU7 – spatial distribution | spruce stand dominance | contagious mortality across stands | fragmentation of infestation patches |
| Governance system (GS) | GS1 – policy instruments | protection laws, zoning, permits | delayed or ambiguous implementation | clearer operational mandates |
| | GS5 – conflict resolution | fragmented, marked by media attention | escalating actor conflict and paralysis | reduced conflict through action |
| | GS7 – norms and strategies | conservation vs forestry legacies | ideological rigidity | pragmatic adaptation |
| | GS8 – monitoring and sanctioning | dual authority, overlapping mandates | delayed response to outbreaks | timely detection and response |
| Actors (A) | A1 – number of actors | high, heterogeneous | polarisation and distrust | improved coordination |
| | A5 – leadership | dual authority, overlapping mandates | governance stalemate | clearer responsibility |
| | A6 – norms/social capital | strongly contested | social conflict intensifies | greater legitimacy among locals |
| | A8 – dependence on resource | high for local communities | perceived livelihood and identity loss | partial livelihood protection |
| Interactions (I) | I1 – harvesting/response rules | post-windthrow decision-making | inaction reinforces beetle dynamics | action interrupts feedback loops |
| | I2 – information sharing | contested science | knowledge politicised | knowledge operationalised |
| Outcomes (O) | O1 – social performance | governance legitimacy | declining trust | increased acceptance |
| | O2 – ecological performance | forest resilience | threshold exceedance and regime shift risk | resilience maintained |
| | O3 – externalities | spillover effects | cross-border spread | reduced regional impacts |
| Feedbacks | – | ecology → governance | negative feedbacks amplify crisis | positive feedbacks enable learning |
| System properties | resilience | capacity to absorb disturbance | low, eroding | moderate, maintained |
| | thresholds | disturbance tipping points | frequently crossed | less frequently crossed |
| | transformability | capacity for reorganisation | delayed, reactive | enabled through adaptive management |

SES – Socio-Ecological Systems framework; TANAP – Tatra National Park; source: authors' own elaboration


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