Improving climate-based predictions for the future of long-lived conifers

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On the edge: Resilience of Tasmania's threatened pencil pine in an age of rapid global change

Rapid climate change and intensifying wildfire threaten fire-sensitive montane conifers. Using a multiproxy palaeoecological approach and species distribution modelling, this study reconstructs Holocene (~11,700 years) fire, vegetation and hydroclimate dynamics for *Athrotaxis cupressoides*. Results show that moisture drives long-term resilience, while limited regeneration and increasing fire risk constrain persistence, with projected contraction of climate space under future warming.

Research context

Rapid climate change and intensifying wildfire activity are reshaping montane ecosystems globally, threatening long-lived, fire-sensitive species - particularly relict Gondwanan conifers confined to high-elevation refugia. *Athrotaxis cupressoides* (pencil pine), endemic to Tasmania and listed as vulnerable, exemplifies this risk due to low fire tolerance and limited dispersal. As a long-lived subalpine conifer, it provides a model for understanding climate-disturbance interactions over long timescales. Linking millennial-scale ecosystem dynamics with present-day distributions improves predictions of persistence and supports conservation under future climate change.

Research approach

- Multiproxy palaeoenvironmental reconstruction (Holocene):
  - Fossil pollen → vegetation change
  - Charcoal → fire history
  - Speleothem record → hydroclimate
- Integrated with species distribution modelling (SDM):
  - Current climatic suitability
  - Future projections

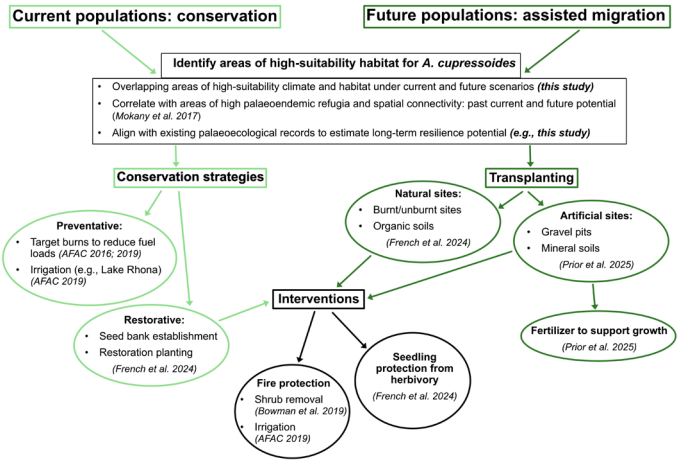

Figure 1: Conceptual framework linking long-term ecosystem dynamics with conservation planning. Persistent moisture supports resilience and recovery, while increasing fire and drying constrain regeneration. Integrating palaeoecology, species distribution modelling, and contemporary management identifies refugia and informs conservation under climate change. Light green indicates current populations; dark green shows projected future populations.

Key findings

- Moisture availability controls long-term dynamics
- Under wet conditions, *A. cupressoides* recovers after fire
- Under dry conditions, fire limits recruitment and drives decline
- Long-term ecosystem legacies shape current distribution
- Climate projections indicate range contraction and fragmentation – (SSP2-4.5, SSP5-8.5, 2030-2050)

Management implications

- **Prioritise** fire refugia and moisture-stable areas for persistence
- **Protect** climatically suitable habitats projected to remain stable
- **Target** conservation toward regions with long-term resilience
- **Integrate** palaeoecological insights into modelling and planning

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