People or Environment: Elucidating the causal factors of the Scottish pine decline in the mid-Holocene

Curious12

Global Environmental Change

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Overview

The temporal dynamics and spatial distribution of the Scottish Caledonian Pine forest throughout the Holocene is hotly debated and it is not yet clear whether climate change and/or human influences have been the dominant drivers of changes in woodland cover through this period, particularly woodland contraction. The maximum pine extent, discerned from pollen and macrofossil records, occurred during the early to mid-Holocene (Bennett 1984) and appears generally consistent across northern Scotland and likely reflects favourable growing conditions during this period. However, between 7000 and 4000 yrs BP, pine populations in some areas show marked reductions. While some areas show a permanent and often abrupt decline in pine pollen (Bennett 1995; Tipping et al. 2006; Wilson et al. 2013), others suggest more stable woodland coverage with limited contraction (Froyd & Bennett 2006, Bennett 1996), a later decline (Wilson et al. 2013) or spatially heterogeneous population contraction (Davies et al. 2017). Tree-ring dated death dates of remnant sub-fossil pine extracted from both peat bogs and lakes emphasise the variability of the so-called “pine decline”: ~6800 yrs BP for the Cairngorm high elevations (~550 masl – Wilson et al. 2013), ~6600 yrs BP for Rannoch Moor (~350 masl – Bridge et al. 1990), ~5500 yrs BP at lower elevations in the Cairngorms (~280 masl – Wilson et al. 2013) and 5000-4000 yrs BP in the Flow Country in far northern Scotland (Gear and Huntley 1991; Moir et al. 2010), with multiple declines ~6200 and 4200 cal BP in other northern sites (Tipping et al. 2008).

Regional climatic change and anthropogenic impact are the two main arguments advanced to explain range contraction in pine. However, it remains unclear whether there are regionally coherent trends that could be explained by climatic mechanisms, whether the extent and magnitude of human pressures were sufficient to account for widespread decline, and why some populations appear more resilient. The aim of this project is to undertake new meta-analyses of the timing, extent and rate of pine decline and high resolution multi-proxy studies using dendrochronology, pollen, stomata, dung fungi and faecal biomarkers to test competing causal hypotheses and resolve current uncertainty over possible causal factors. The tree-ring data can provide not only climate information for the centuries leading up to the decline and woodland die-off but also date the decline phase itself. Coprophilous fungal spores and faecal biomarkers can quantify changes in large herbivore biomass and potentially be used to identify animal type and change over woodland transitions (Baker et al. 2013, Harrault et al. 2019). These novel proxies can be used with palynological, stomatal evidence to understand whether the demise of pine coincides with intensified upland management and a shift from wild herbivores to domesticated stock.

Methodology

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Key Words

- Scots pine
- Scotland
- decline
- anthropogenic
- environmental change

The project will adopt a dual scale strategy by applying (1) a ‘meta data’ approach to characterise groups of sites with similar responses based on existing palaeoecological records, and (2) from these, select representative sites to conduct new high-resolution multi-proxy analyses to test hypothesised drivers of decline. The analyses will target ‘marginal’ upland environments in the Scottish Highlands where pine growth was highly sensitive to changes in the local environment and profuse amounts of remnant stem pine material are found in peat deposits. Previous fieldwork has already identified potential sites in Loch Einich (Cairngorms), North of Ben Alder and Glen Corrour (central Scotland) and remote sensing and ground-truthing will look for at least one further western site. We anticipate that these will be characteristic of regional trends. The project will focus on at least four locations from east to west across Scotland.

Fieldwork at each site:
1. Map the location and stratigraphy of the peat sequences; sample 20-50 pine disks across each pine remnant zone in the sequence. In some locations there might be evidence for more than one pine woodland phase, and each will be sampled accordingly.
2. Extract intact peat cores through the pine horizons for laboratory analysis of vegetation, herbivore and land-use dynamics.

Lab work:
1. Dendrochronology: Sample disks will be slowly air dried, sanded and polished. Ring-width and density will be measured to allow crossdating between trees to create a pine phase chronology and to understand recruitment/mortality dynamics. These parameters will also provide information of summer temperatures and possibly water table depth. Living samples have already been sampled in the northern Cairngorms by St Andrews for modern analogue calibration.
2. Microfossils: High-resolution subsampling and analysis of dung fungi, biomarkers for climate (leaf wax n-alkanes) and faeces (sterols) (including DNA to identify SE67BTC44 pine haplotypes in time and space), stomata and pollen to provide independent lines of evidence for anthropogenic, climatic and herbivore impacts, and to provide complementary evidence of changes in woodland composition and abundance associated with pine growth and demise.
3. Chronology: The sub-fossil pine chronologies will be anchored in time by radiocarbon dating (ca. 2 radiocarbon dates per pine woodland phase and site. Further funds will be sought through application(s) to the NRCF steering Committee. All supervisors will support the student in writing these applications to increase the chance of success) and comparison will be made with previous sub-fossil pine chronologies developed from lake sediment preserved tree archives (Wilson et al. 2011) from the northern Cairngorms and Glen Affric. The peat sequences will be dated using a combination of radiocarbon and possibly tephra. Funds to support tephra-dating will be sought via an application to the QRA new research workers’ award.

Project Timeline

Year 1

• Sep 2020: late summer fieldwork of Loch Einich site where >40 samples have already been extracted.
• The Loch Einich tree-ring samples will be prepared, measured and crossdated over the winter period.
• Review and collate data for meta-analysis of previous palaeoecological studies for Northern Britain for 9000-2500 yrs BP, using the European Pollen Database, records held by supervisors and by contacting previous researchers to request additional datasets.
• Remote sensing to identify new sites to be ground truthed in the spring of 2021 as part of new site selection strategy

Year 2

• Finalise fieldwork at Corrour, Ben Alder and at least one western site
• Tree-ring and soil sample lab work
• Analyses of pollen, stomata and dung fungi from peat cores, followed by biomarker analysis once key horizons are identified
• Write up of meta-analysis review.

Year 3

• Continued lab work to finalise data development by middle of year 3
• Writing up of individual site stories

Year 3.5

Final analyses to bring all the different data sources together leading towards final write up by the end of 2024.

Training & Skills

Dendrochronology: Fieldwork methods including mapping and stratigraphic profiles; laboratory methods including crossdating and the measurement of ring-width and Blue Intensity; calibration methods for converting tree-ring variables to estimate of temperature and hydroclimate (Wilson).
Peat samples: High-temporal resolution pollen, fungal spore and charcoal analyses, sample processing for radiometric dating, and multivariate analysis of palaeoecological time-series (Davies, Bennett); biomarker processing and analysis (McClymont)
Remote sensing: Aerial photographs and remote sensing methods will facilitate the identification of new sample sites using distinct spectral properties of known bog pine sites (in house training St Andrews).

References & further reading

Baker AG, Bhagwat SA & Willis KJ. 2013 Do dung fungal spores make a good proxy for past distribution of large herbivores? Quaternary Science Reviews 62: 21-31.
Bennett, K.D., 1984. The post-glacial history of Pinus sylvestris in the British Isles. Quaternary Science Reviews, 3(2-3), pp.133-155.
Bennett, K.D. 1995, Post-glacial dynamics of pine (Pinus sylvestris L.) and pinewoods in Scotland, Our pinewood heritage, pp. 23-39.
Bridge, M. C., Haggart, .A. & Lowe, .J., 1990, The History and Palaeoclimatic Significance of Subfossil Remains of Pinus Sylvestris in Blanket Peats From Scotland, The Journal of Ecology, 78(1), p. 77.
Davies AL, Smith MA, Froyd CA & McCulloch, R. D. 2017 Microclimate variability and long-term persistence of fragmented woodland. Biological Conservation 213, Part A: 95-105.
Froyd, C.A. & Bennett, K.D., 2006, Long-term ecology of native pinewood communities in East Glen Affric, Scotland, Forestry, 79(3), pp. 279-91.
Gear, A.J. & Huntley, B., 1991, Rapid changes in the range limits of Scots pine 4000 years ago, Science (New York, NY), 251(4993), p. 544.
Harrault, L., K. Milek, E. JardÃ©, L. Jeanneau, M. Derrien and D. G. Anderson 2019 Faecal biomarkers can distinguish specific mammalian species in modern and past environments. PLOS ONE 14(2): e0211119.
Moir, K., Leroy, S.A.G., Brown, D. & Collins, P.E.F., 2010, Dendrochronological evidence for a lower water-table on peatland around 3200-3000 BC from subfossil pine in northern Scotland, The Holocene, 20(6), pp. 931-42.
Tipping, R., Davies, A. & Tisdall, E., 2006, Long-term woodland dynamics in West Glen Affric, northern Scotland, Forestry, 79(3), pp. 351-9.
Tipping, R., P. Ashmore, A. L. Davies, A. Haggart, A. Moir, A. Newton, R. Sands, T. Skinner and E. Tisdall 2008. Prehistoric Pinus woodland dynamics in an

upland landscape in northern Scotland: the roles of climate change and human impact. Vegetation History and Archaeobotany 17(3): 251-267.Wilson, R., Loader, N.J., Rydval, M., Patton, H., Frith, A., Mills, C.M., Crone, A., Edwards, C., Larsson, L. & Gunnarson, B.E., 2011, Reconstructing Holocene climate from tree rings: The potential for a long chronology from the Scottish Highlands, The Holocene, 22(1), pp. 3-11.
Wilson, R., Cunningham, L., Edwards, K., Davies, S., and Twiddle, C. 2013. Final Report for Leverhulme Trust funded project RELiC (Reconstructing 8000 years of Environmental and Landscape change in the Cairngorms)

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