Caledonian Pinewoods

Findings from the Caledonian Pinewood Recovery Project

Trees for Life

Acknowledgements

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One of the last surviving wild pine in a dying Caledonian Pinewood in Lochaber

Preface

Caledonian Pinewoods are among our oldest and richest habitats. They are characterised by wild Scots pines, descended from Scotland's once-vast ancient forests, and have been shaped and valued by people for centuries. They provide refuge for some of our rarest wildlife, yet cover only 1% of the Highlands today.

This report summarises key findings from the four-year Caledonian Pinewood Recovery project, the most comprehensive study of the health and resilience of Scotland's ancient pinewoods in 60 years. It builds on the landmark work of Harry Steven and Jock Carlisle in the 1950s, and pivotal efforts by the Forestry Commission in the 1990s. The report concludes that many of our pinewoods have never been so vulnerable, but also that recovery is possible if we start to move quickly. The time for action is now.

Restoring Caledonian Pinewoods could make a vital contribution to Scotland reaching net zero by 2045, and halting and reversing biodiversity loss by 2030. The UK Committee on Climate Change has made it clear that net zero can only be achieved and maintained if large-scale nature-based solutions to absorbing and securing atmospheric carbon are part of our response [5]. The Scottish Government have played a key role in recognising the need for transformative change in terrestrial ecosystems, committing to bold action by signing the Edinburgh Declaration on Biodiversity in 2020.

Solutions that tackle the two biggest threats to life on earth are rare and it is clear that the recovery of Caledonian Pinewoods can play a crucial role. We hope that the recommendations in this report will help guide their long-term recovery. To achieve this, leadership and resources from government will be vital, alongside support and understanding for those who manage the pinewoods. In the same way that only global cooperation and partnership will prevent the worst impacts of climate change, only a similar spirit of working together for mutual benefit will ensure that our pinewoods recover.

Executive summary

We collected ecological evidence from over 1,200 survey plots across 72 sites, and investigated barriers to improving management through questionnaires, one-on-one interviews, workshops, and discussion groups with stakeholders.

We found that despite concerted efforts in the 1990s, significant areas of Caledonian Pinewood are still declining, and 23% of what remains is critically threatened. Most Caledonian Pinewoods lack essential characteristics of health and resilience, meaning they cannot support their full range and abundance of wildlife, or adapt to the seismic changes that are impacting our ecosystems. Pressures on Caledonian Pinewoods are high, and impacts from artificially large deer populations are the biggest barrier to recovery. Dramatic improvements in health and resilience are taking place where these impacts are being effectively managed at landscape scale, demonstrating that large-scale recovery can be achieved.

Land managers recognise the importance of Caledonian Pinewoods but restoring them is not yet a key priority. Our study with stakeholders found this is primarily due to their culture, traditions, values, relationships, and past experiences, and uncertainty about the state of Caledonian Pinewoods and how they function. Government policy and incentives, perceived to favour new woodland planting over restoring and naturally expanding our Ancient Woodlands, are also a factor.

The future of Caledonian Pinewoods is uncertain. Poor health and resilience today means that catastrophic declines could take place in coming decades as the climate crisis and other threats intensify. On the other hand, we have an unprecedented and time-limited opportunity to turn the tide, returning health and resilience to Caledonian Pinewoods across the Highlands and restoring whole ecosystems in the process.

Caledonian Pinewoods

Scots pine (*Pinus sylvestris*) is a widely distributed conifer with a natural range spanning much of northern Europe, parts of northern Asia, and mountainous regions further south. In Britain, wild populations are generally considered restricted to the Scottish Highlands, though it is possible a few survive elsewhere [11]. These populations typically have high genetic diversity [7,9,17] and display a variety of different forms. Individual trees can be long lived, with the potential to reach over 560 years old in the Highlands [17]. Scots pine is light demanding but otherwise tolerates a wide range of growing conditions. In practice, this often confines it to places too stressful for more competitive tree species to grow, such as colder regions, rocky areas, or very acidic soils. Elsewhere, it behaves as a pioneer tree, typically surviving for a generation before being replaced by competitors.

Origins and history

Scots pine has been present intermittently in Scotland for millions of years, retreating to refuges or becoming locally extinct during ice ages and returning during warmer periods [4]. The current warm period caused glaciers to retreat across the Highlands around 11,700 years ago, with scattered Scots pine re-establishing at least 9,900 years ago [8]. Pine subsequently increased in abundance around Loch Maree in Wester Ross 9,300 years ago, and in parts of Assynt and the Cairngorms 8,800 years ago [3]. Recolonisation took place from at least two separate refuges, with pine initially spreading from the northwest and later from the south [4,12,16]. Caledonian Pinewoods are formed from the natural descendants of these wild Scots pine populations.

Scots pine continued to spread and formed extensive woodlands that at one time covered much of the Highlands, before starting to decline in different regions between 5,200 and 3,200 years ago [4]. Initial drivers of decline are contested, but subsequent decline was driven by a combination of felling, burning, and livestock grazing. Placenames derived from giuthas, the Gaelic word for Scots pine, suggest it remained widespread into historic times. However, woodland was becoming increasingly fragmented, with cover having fallen to around 20% by the year 1000 [1]. By the 1300s, pine timber was being imported to lowland Scotland from the Baltics, and from the 1500s to the 1800s Caledonian Pinewoods were progressively and extensively logged [10,13,15]. Those that recovered from logging were then subjected to two centuries of heavy browsing and grazing pressure following the Highland Clearances and advent of large-scale sheep farming.

Felling resumed at some sites during the First and Second World Wars, and the 20th century drive for commercial forestry resulted in many Caledonian Pinewoods being acquired by the state and underplanted with North American conifers. Additional areas were drowned by hydroelectric projects. However, concern about Caledonian Pinewoods was building, and surviving sites were identified, documented, and mapped in the 1950s by Steven and Carlisle, who published their findings in the landmark book The Native Pinewoods of Scotland in 1959 [14]. A symposium on Scottish Native Pinewoods in 1975 was followed by the introduction of the Native Pinewoods Grant Scheme in 1978 [8], which was administered by the Forestry Commission and intended to restore and expand Caledonian Pinewoods that were under private ownership. Success was limited and decline continued, with 25% of the Caledonian Pinewood mapped by Steven and Carlisle lost by the mid-1980s, primarily due to underplanting with commercial conifers and felling [3].

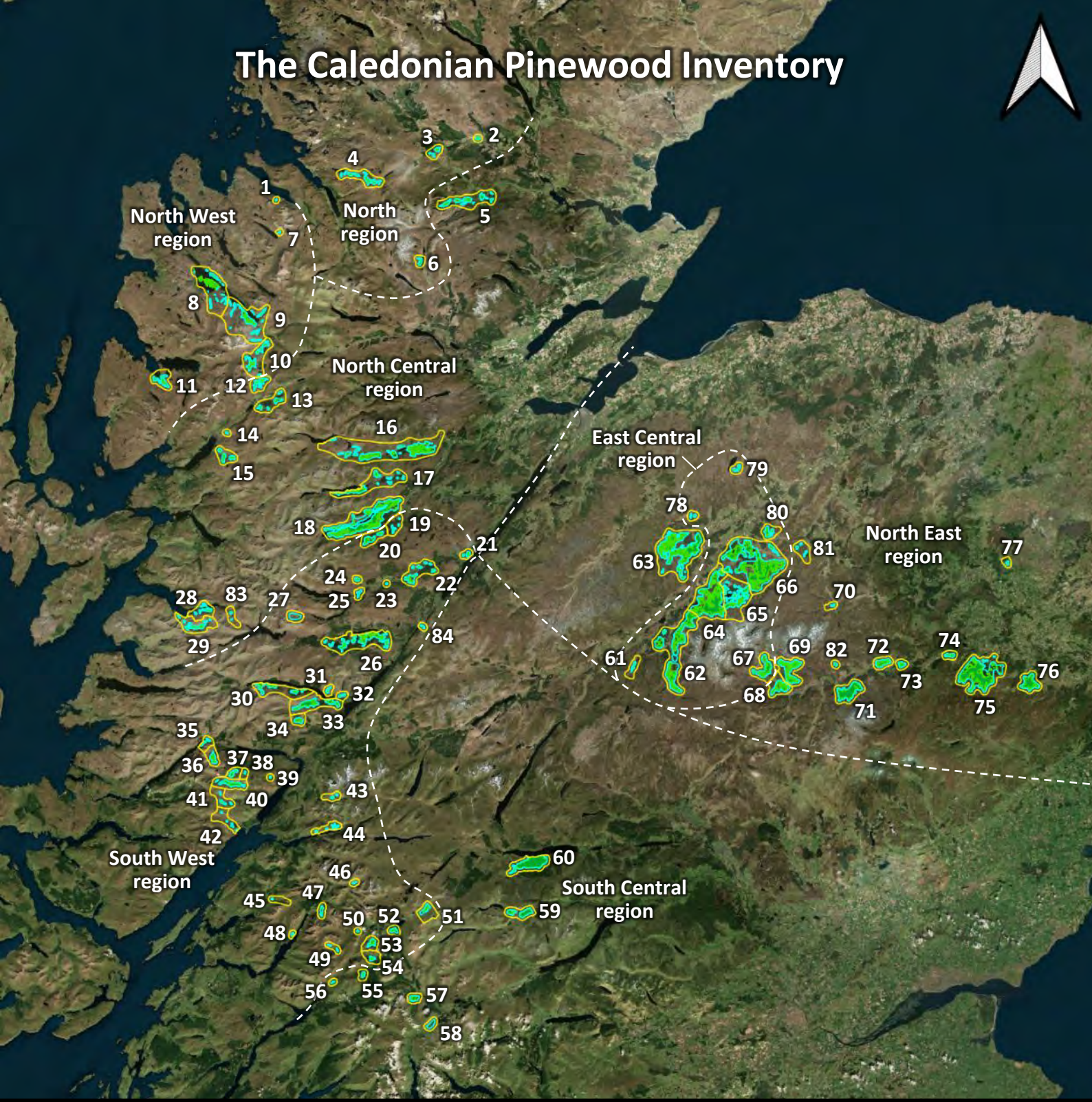
There was strong state support for Caledonian Pinewood restoration in the 1990s. A series of Caledonian Forest Reserves was established in state forests, and targeted management undertaken to reverse some of the damage caused in previous decades. This included felling planted non-native conifers from within relict pinewood, and reducing deer impacts through fencing. The Native Pinewoods Grant Scheme was replaced with improved Woodland Grant Schemes (1988-2003), which helped deer fence around 7% of Caledonian Pinewood. Combined with other exclosures, this meant between a quarter and a third of Caledonian Pinewood had likely been deer fenced by the end of the decade. However, the focus on restoration appears to have fallen away in the 2000s. By 2020, only another 2% of Caledonian Pinewood was deer fenced under successor schemes to the Woodland Grant Scheme, and most fences were breached, impairing or reversing recovery. The main exception was in Strathspey and upper Deeside, where land managers expanded landscape scale approaches to deer management, bringing populations down to levels compatible with Caledonian Pinewood recovery. This resulted in widespread regeneration and natural woodland expansion, allowing deer fences to be removed.

The Caledonian Pinewood Inventory

Building on the work of Steven and Carlisle in the 1950s, the Forestry Commission compiled a register of Caledonian Pinewoods in 1991. This was revised into the Caledonian Pinewood Inventory in 1994 and further updated in 1998 [6,10,15]. Today, the Inventory recognises 84 Caledonian Pinewood sites covering 17,882 hectares in the Highlands. 22 sites are part of the National Forest Estate, while most others are privately owned. Each site is mapped and divided into zones. Caledonian Pinewood forms a core zone, and this is typically surrounded by a 100m regeneration zone, where conditions may be suitable for natural woodland expansion. Beyond this, there is a 500m buffer zone where only trees of local origin should be planted.

Each Caledonian Pinewood is assigned a biochemical region based on analysis of chemicals in tree resins believed to reflect underlying genetic distinctiveness. Seven different biochemical regions are recognised: North, North West, North Central, North East, East Central, South Central, and South West.

The Caledonian Pinewood Inventory



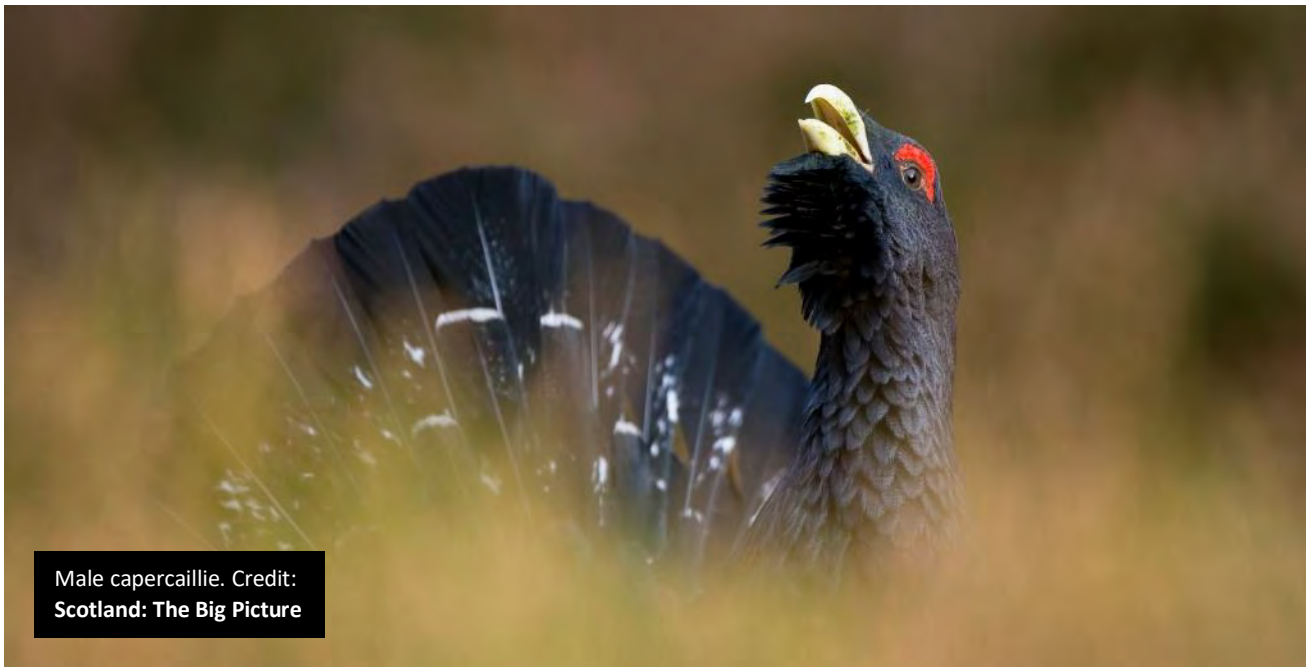
Caledonian Pinewood | regeneration zone | buffer zone | biochemical region (approx.)

1. Ardessie
2. Strath Oykel
3. Glen Einig
4. Rhidorroch
5. Amat
6. Strath Vaich
7. Coir a' Ghamhna
8. Loch Maree Islands
9. Beinn Eighe
10. Loch Clair
11. Shieldaig
12. Easan Dorcha
13. Achnashellach
14. Taodail
15. Attadale
16. Glen Strathfarrar
17. Glen Cannich
18. Glen Affric
19. Guisachan
20. Cougie
21. Achnaconeran
22. Dundreggan
23. Achlain
24. Ceannacroc
25. Bunloyne
26. Glen Garry
27. Glen Loyne
28. Loch Hourn
29. Glen Barisdale
30. South Loch Arkaig
31. Achnasaul
32. Dark Mile
33. Glen Mallie
34. Glen Loy
35. Loch Shiel
36. Callop River
37. An Slochd
38. Dubh Uisge
39. Gleann Sron a Chreagain
40. Conaglen
41. Glen Scaddle
42. Glen Gour
43. Glen Nevis
44. Loch Leven
45. Glen Ure
46. Allt Chaorunn
47. Allt Mheuran
48. Ard Trilleachan
49. Glen Kinglass
50. Loch Dochard
51. Crannach
52. Doire Darach
53. Gleann Fuar
54. Allt Coire Bhiochair
55. Allt Broighleachan
56. Glen Strae
57. Coille Coire Chuilc
58. Glen Falloch
59. Meggernie
60. Black Wood of Rannoch
61. Glen Tromie
62. Glen Feshie
63. Kinveachy
64. Rothiemurchus
65. Glenmore
66. Abernethy
67. Glen Derry
68. Glen Lui
69. Glen Quoich
70. Glen Avon
71. Ballochbuie
72. Crathie
73. Creag Ghiubhais
74. Torphantrick
75. Glen Tanar
76. Glen Ferrick
77. Breda
78. Baddengorm
79. Lochindorb
80. Carn Na Loine
81. Glen Brown
82. Allt Cul
83. Lochourn River
84. Glen Buck

Wildlife

Caledonian Pinewoods span two climatic zones. Those in the east are examples of boreal forest, characterised by harsh snowy winters and warm dry summers, while those in the west are examples of temperate rainforest, characterised by mild wet winters and warm moist summers. Boreal Caledonian Pinewoods are generally larger and less fragmented than those in the temperate rainforest zone. They are key refuges for iconic wildlife like capercaillie, as well as rare wildflowers, fungi, invertebrates, and lichens [10,15]. Sites in the west are more fragmented and have lost more of their charismatic species, but still support rare invertebrates, bryophytes, and lichens.

Caledonian Pinewood vegetation can be divided into different structural layers. Larger trees like Scots pine and birch typically dominate the tree canopy, while smaller trees and shrubs like rowan, juniper, holly, and eared willow can be prominent in the understory below. The field layer is generally dominated by blaeberry and cowberry in denser areas, or ling heather where the canopy is more open. Mosses carpet the ground, and specialised wildflowers like creeping lady's-tresses orchid and twinflower sometimes occur too. Soils are usually very acidic and support communities dominated by fungi and micro-invertebrates.



Male capercaillie. Credit: **Scotland: The Big Picture**

Invertebrate communities of Caledonian Pinewood have not been systematically surveyed, but wood ants can be abundant amongst the vegetation, building large nests on the forest floor and scaling trees to feed on aphid honeydew. Caterpillars, an important food source for many birds, are most abundant on blaeberry and native trees, and small flies that feed on plants and fungi were found to be the most numerous insects in the canopy at Abernethy [15]. Old growth features such as standing deadwood, fallen logs, and old trees support rare insects and lichens, and holes excavated by woodpeckers can provide nesting and roosting sites for birds, bats, and other wildlife [15].

Birds and mammals in Caledonian Pinewood include conifer specialists like crossbills and red squirrels, which are specially adapted to prise open pine cones and feed on their seeds, and capercaillie, which feed on the shoots of trees and dwarf shrubs. Pine martens are important predators that feed on birds and small mammals, as were wildcats before recent declines. The largest mammals that occurred in Caledonian Pinewood are now extinct in Scotland, including elk, lynx, wolves, and brown bear. Consequently, some species like roe and red deer no longer have natural predators besides people.

A wood ant nest at the base of Caledonian pine in Glenmore

Creeping lady's-tresses orchid growing in Glen Affric

Green hairstreak butterfly on Blaeberry at Beinn Eighe

Rainforest liverworts and filmy ferns growing on Scots pine in Glen Kinglass

The Caledonian Pinewood Recovery Project

The Caledonian Pinewood Recovery (CPR) project was a four-year project to improve our understanding and management of Caledonian Pinewood across the Scottish Highlands. It was run by Trees by Life and took place in two phases.

The first phase ran from March 2018 to March 2021. It was supported by five project partners: Scottish Land and Estates, Woodland Trust Scotland, NatureScot, Forestry and Land Scotland, and Scottish Forestry; and funded by the Esmeé Fairbairn Foundation, Woodland Trust Scotland, Ernest Kleinwort Charitable Trust, Garfield Weston Foundation, HDH Wills Charitable Trust, and the Paul and Louise Cooke Endowment, as well as generous donations from individual supporters of Trees for Life. It aimed to:

- Assess the overall ecological health and future resilience of Caledonian Pinewood sites.
- Collaborate with site owners and managers to understand ongoing work and identify feasible next steps towards securing long-term recovery.
- Understand and collate views on any barriers to better site management and share these with project partner organisations.

Trees for Life employed two dedicated project staff: Fiona Holmes as Project Manager, and James Rainey as Project Officer. Fiona had experience in rural land management, and James in ecological survey work. The first phase of work was interrupted during the early stages of the COVID-19 pandemic. Outputs included 52 site reports, a Pinewood Workshop held over two days in March 2020, an End of Project Report containing health and resilience and barriers analyses, and presentations to key groups to disseminate results.

The second phase ran from May 2021 until the end of 2021. It was funded by Forestry and Land Scotland and aimed to assess the health and resilience of Caledonian Pinewood sites across the National Forest Estate and identify management actions that could secure recovery. This phase was managed and carried out by James Rainey, Senior Ecologist at Trees for Life. Outputs included shapefiles presenting results at polygon and site levels, a summary report with detailed information on polygons and sites appended, and presentations to Forestry and Land Scotland staff to disseminate results.

Surveying Caledonian Pinewood at Beinn Eighe

What we did

Health and resilience concepts

Healthy Caledonian Pinewoods have capacity to support the full range and abundance of associated wildlife, while resilient Caledonian Pinewoods can recover after disturbance and sustain their health during change. We identified four characteristics of healthy and resilient Caledonian Pinewoods as described in Appendix 1. These are:

1. Diversity, which is the range and quality of Caledonian Pinewood habitat components, and the genetic variability within tree species. Diverse Caledonian Pinewoods are healthier as they can support more wildlife, and more resilient to threats from disease and climate change as they can better resist and adapt to change.
2. Continuity, which is the maintenance of diversity over time through regeneration of its component parts. The ability of Scots pine and other trees to naturally regenerate is essential for resilience, as this allows Caledonian Pinewood to recover from disturbances which are expected to become more frequent and intense due to climate change.
3. Mobility, which is the ability of Caledonian Pinewood species to move through the landscape. It is critical that wild Scots pine and other trees can regenerate outside current woodland boundaries, as this will allow them to track changes in their bioclimatic envelopes caused by climate change.
4. Connectivity, which is the scale of Caledonian Pinewood and its components parts in the landscape, and how well joined up they are. Well-connected Caledonian Pinewoods are better able to absorb negative impacts and recover after disturbance as species can recolonise more readily.

Securing Caledonian Pinewood health and resilience is more important today than ever, as threats from climate change, introduced tree diseases, and introduced plants are increasing.

Surveying Caledonian Pinewood health and resilience

We surveyed Caledonian Pinewoods using a bespoke methodology to gather detailed field data relevant for assessing diversity, continuity, mobility, and threats, as described in Appendix 2. This incorporated Woodland Herbivore Impact Assessments [2]. Between May 2018 and September 2021, field data was gathered from 1,223 half-acre plots spread across 72 sites – 71 on the CPI and one additional. Over 800 miles were travelled by foot during the survey. Plots were located both within Caledonian Pinewood and in the surrounding regeneration zone. Each health and resilience characteristic was assessed and analysed, along with key threats. We weighted results such that each Caledonian Pinewood site was represented equally. See Appendix 3 for details.

The barriers analysis

We investigated any barriers to securing better pinewood management using questionnaires, one-to-one interviews, workshops, and discussion groups. The questionnaire was promoted via Scottish Land and Estates and the Association of Deer Management Groups to their members, and emailed directly to many landowners, managers, agents, and foresters. 38 responses were received and analysed. 20 one-to-one interviews, with an assurance of anonymity, were conducted over telephone to allow people to speak freely and specifically about their experiences of what influences pinewood owner or manager behaviour. Interview notes were coded and analysed. We convened a two-day Pinewood Workshop attended by around 30 stakeholders, mostly drawn from those involved in managing privately owned Caledonian Pinewoods, and recorded notes from discussions. See Appendix 4 for details.

What we found

Health and resilience

Most Caledonian Pinewoods lack essential characteristics of health and resilience. This means they cannot support the full range and abundance of associated wildlife, and their ability to recover after disturbance or adapt to change is compromised, leaving them vulnerable to climate change. High herbivore impacts, primarily from deer, are the main barrier to recovery, and dramatic improvements in Caledonian Pinewood health and resilience are taking place where deer populations are being effectively managed at landscape scale. Localised improvements were also found inside deer fences, but recovery is now widely impaired or being reversed as most deer fences have been breached. Our findings show that the future of Caledonian Pinewood across the Scottish Highlands largely depends on effective landscape scale deer management being expanded beyond Strathspey and upper Deeside.

Our full analysis of Caledonian Pinewood health and resilience is presented in Appendix 3, and seven key findings are summarised below. Units for results have been simplified as described in Appendix 3, Section 4. Terms including selective and blanket overbrowsing are defined in the Glossary.

1. **Pressures on Caledonian Pinewood were high, and some pressures reinforced others**:
    - Herbivore impacts, primarily from deer, were determined as High or greater in 63% of Caledonian Pinewood. Levels of herbivore impact are the main barrier to improving diversity, continuity, mobility, and connectivity.
    - Non-native trees, primarily Sitka spruce, were recorded in 32% of Caledonian Pinewood and considered abundant in 7%. They were 3 times more widespread and 18 times more abundant on the National Forest Estate than elsewhere. Most were young and not yet causing significant impacts, but pressure will increase in future without targeted management. Selective overbrowsing was favouring recruitment of non-native over native tree species. The non-native plant *Gaultheria shallon* is in the early stages of becoming invasive.
    - Evidence of historical fire was widespread, but recent fires were typically small and contained. Blanket overbrowsing following a destructive fire prevents woodland recovery.
2. **Caledonian Pinewoods remain important for old growth features, but wider diversity was suppressed by levels of herbivore impact**:
    - Caledonian Pinewoods generally had low canopy and understory cover, but old growth features – important for many rare and specialised species – were widespread.
    - Caledonian Pinewood plots could have at least twice as many tree species regenerate successfully if not for overbrowsing, and selective overbrowsing was suppressing more tree diversity overall than blanket overbrowsing. Tree species most severely impacted by overbrowsing are especially important for leafy lichens, pollinators, and berry-feeding animals.
    - Selective browsing of Scots pine over birch regeneration by deer was associated with shifts from Caledonian Pinewood to birch dominated woodland over time. This was a regional phenomenon, with Caledonian Pinewoods in South West region impacted most.
    - Heavy browsing and grazing was widely suppressing growth of key wildflowers and berry-producing subshrubs such as blaeberry, dog rose, and honeysuckle. This favoured dominance of unpalatable purple moor grass and bracken.
    - Suppression of tree diversity and growth of key species in the field layer is expected to cause cascading effects on a wide range of dependent species over time.

Photo taken along an effective deer fence, showing mixed natural regeneration and recovering continuity inside (right)

Photo taken along an effective deer fence, showing the dramatic recovery of dwarf shrubs such as Blaeberry inside (right)

3. **Caledonian Pinewood continuity was improving in some areas, but almost a quarter was critically threatened and will be lost without urgent action**:
    - Improvements in Scots pine continuity were taking place in 27% of Caledonian Pinewood, while 23% was considered critically threatened.
    - Improvements could be disrupted if levels of browsing were to increase inside fences.
    - Continuity is uncertain in areas where canopy cover is currently high because Scots pine regeneration is light demanding. Outcomes will depend on levels of herbivore impact when the canopy becomes more open in future.
    - While chronic overbrowsing by deer is the main threat to continuity, some areas were critically threatened by competing non-native conifers planted in the 20th century.
4. **Most Caledonian Pinewood lacks mobility, but exceptional natural expansion is taking place where effective landscape scale management is underway**:
    - Mobility was classed as good in 26% of the regeneration zone, mainly within deer fences or where effective landscape scale deer management was being carried out.
    - Mobility was classed as absent in 51% of the regeneration zone, mainly outside deer fences in areas where effective landscape scale deer management was not being carried out.
    - Exceptional mobility was noted in East Central region, where effective landscape scale deer management is now widespread. Here, occasional Scots pine regeneration was taking place over 5km from the nearest known seed source.
5. **Most Caledonian Pinewoods are small and fragmented, but there is potential to reconnect them by restoring Ancient Woodlands and facilitating woodland expansion**:
    - Almost all Caledonian Pinewoods are too small to support the full range of diversity. Only 11% of sites exceed 500 hectares in size, while over half are smaller than 50 hectares.
    - Many sites are internally fragmented, with patchy Scots pine cover and a scattered distribution of key diversity features.
    - Landscapes that support Caledonian Pinewood also support other kinds of Ancient Woodland, and some Caledonian Pinewoods are part of larger Ancient Woodland complexes. Maintaining and enhancing connectivity between Caledonian Pinewoods and other Ancient Woodlands is critical to securing and restoring diversity.
    - Although woodland expansion is important to enhancing connectivity in the long term, restoring Ancient Woodlands damaged by underplanting with non-native conifers is the best way to enhance Caledonian Pinewood connectivity across the National Forest Estate.
    - Large Scots pine plantations provide a degree of connectivity between Caledonian Pinewoods in the Cairngorms, and this could be enhanced by allowing plantations to develop old growth features over time.
6. **Health and resilience of Caledonian Pinewoods varied between regions, with those in the South West most threatened**:
    - Health and resilience were poorest in South West region, where 43% of CPI sites are located and high herbivore impacts most widespread. 34% of Caledonian Pinewood in the South West is critically threatened, and more tree diversity was suppressed by overbrowsing than elsewhere. Sites were also particularly vulnerable to climate change due to very poor mobility and connectivity combined with their southerly distribution.
    - Health and resilience were greatest in East Central region, where the extent of Caledonian Pinewood is largest and effective landscape scale deer management widespread. More Caledonian Pinewood was recovering continuity and diversity here than elsewhere, and mobility and connectivity were exceptionally high.
    - Recovery was generally taking longer in western Caledonian Pinewoods, where young Scots pine grew slowly and could take around 30 years to establish above browse height.

The remains of an old Scots pine amongst mature non-native conifers. This tree was probably killed by the competing trees within the last few years. Urgent action is needed to save surviving wild Scots pine threatened by plantations.

7. **Management to reduce pressures and improve health and resilience is having mixed success**:
    - Efforts have been made to restore state-owned Caledonian Pinewoods that were underplanted with non-native conifers. In many places, the recovery process is underway and young woodland has re-established following removal of the conifer crop. However, non-native conifer regeneration remains widespread, and some areas have failed to recover due to overbrowsing of native tree regeneration.
    - Deer fencing has been the main technique used to restore Caledonian Pinewood since the 1990s. An estimated 30-44% of Caledonian Pinewood has been deer fenced within at least 256 exclosures, including most Caledonian Pinewood on the National Forest Estate.
    - Compared with unmanaged areas, Caledonian Pinewood inside deer fences showed improved characteristics of health and resilience, and dramatic recovery was evident where fences remained effective after several decades. However, most exclosures have now been breached by deer, resulting in widespread recovery impairment or reversal. In some cases, slow-growing Scots pine regeneration that had taken decades to develop was being killed or had already died due to deer impacts within fences.
    - Overbrowsing was recorded in 63% of Caledonian Pinewood inside deer fences, and in over half of Caledonian Pinewood inside recent deer fences. This was mostly selective overbrowsing. 35% of critically threatened Caledonian Pinewood was located inside deer fences.
    - Effective landscape scale deer management without the use of fences is underway at most sites in East Central region, and some sites in North East and North West regions. These areas showed the greatest improvements in health and resilience at landscape scale, and benefits extended to other habitats including montane scrub and tall herb vegetation.
    - Some areas of Caledonian Pinewood have been damaged by inappropriate cultivation and planting, and some has been destroyed through recent infrastructure development.

Barriers to better management

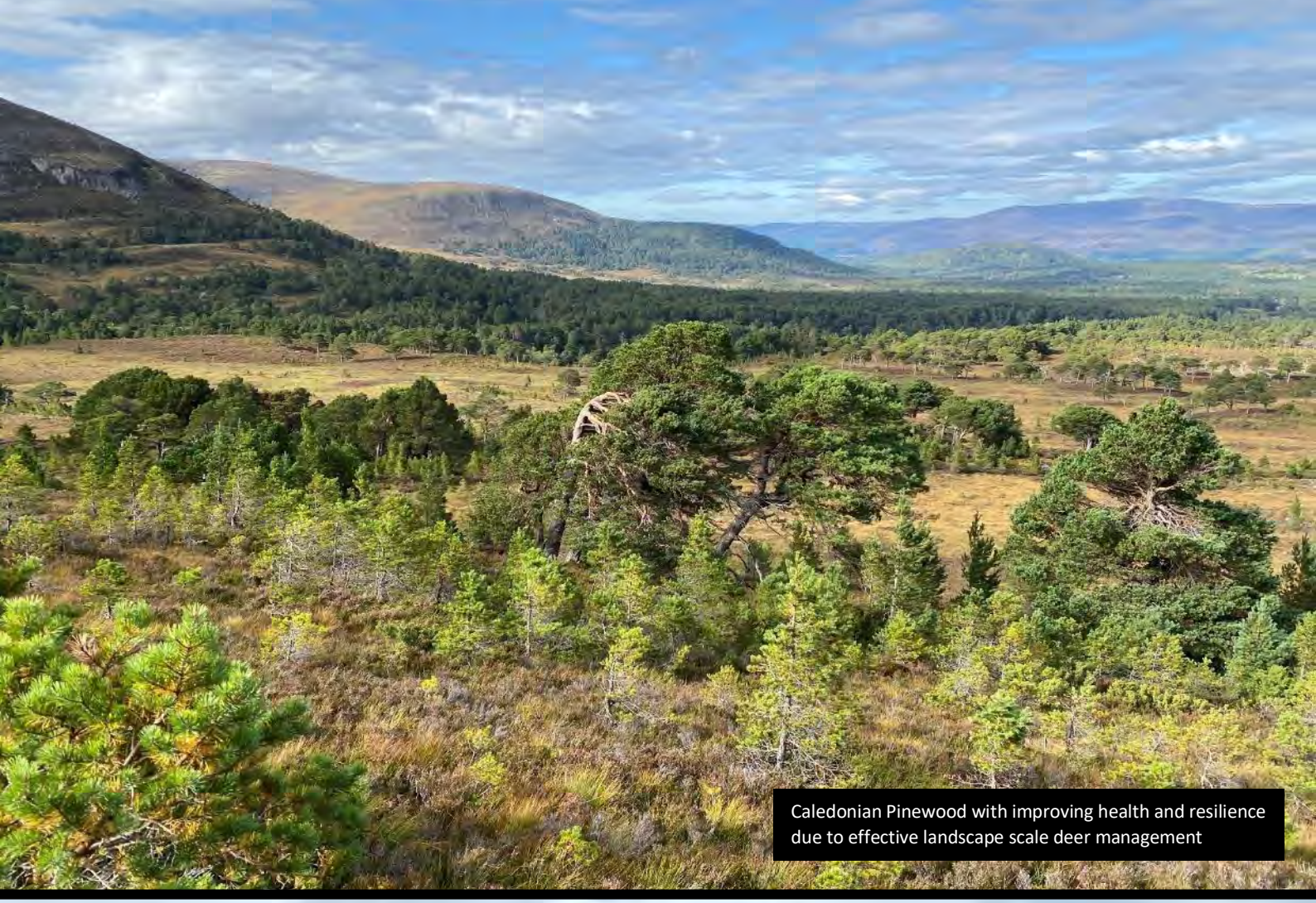
There was near consensus amongst stakeholders that Caledonian Pinewoods are important, including for ecological, cultural, and historical reasons. Despite this, Caledonian Pinewood management was generally not a priority, with focus instead directed towards other land uses. This was primarily due to the culture, traditions, values, relationships, and past experiences of stakeholders, and their uncertainty about the state of Caledonian Pinewoods and how they function. Additionally, government policy and incentives were perceived to favour planting new woodland over restoring and naturally expanding existing woodland. Barriers to better pinewood management could be overcome through:

- Relationship building between different groups of stakeholders.
- Improved communication about the state of Caledonian Pinewoods and their management requirements, and policy that aligns with and prioritises these management requirements.
- Consistent messaging from Scottish Government, public sector agencies, and environmental non-governmental organisations (ENGOs).

Our full analysis of barriers to securing better pinewood management is presented in Appendix 4.

Other findings

Over the course of the project, we found inaccuracies in the Caledonian Pinewood Inventory (CPI), including offset errors, mismapping, and omissions. We also identified additional Caledonian Pinewood sites not recorded on the Inventory. Most of these have been reduced to tiny fragments and are critically threatened. Several lost Caledonian Pinewoods were also documented.



Caledonian Pinewood with improving health and resilience due to effective landscape scale deer management

An almost lost Caledonian Pinewood, where most of the old trees that died were not replaced because natural regeneration was overbrowsed for centuries

Towards health and resilience

Based on our findings, we make the following five recommendations about Caledonian Pinewood management:

1. **Expand effective landscape scale deer management**. Managing deer populations at landscape scale to levels compatible with diverse tree regeneration would be the single most effective way to secure and enhance Caledonian Pinewood health and resilience. Reduced deer impacts would also benefit blanket bogs, montane scrub, tall herb vegetation, and other Ancient Woodlands.
2. **Extend the effective lifespan of deer fences in the west**. Until effective landscape scale deer management is established more widely, deer fences will remain an important tool to manage herbivore impacts. However, decades of Caledonian Pinewood recovery are now at risk because most deer fences have been breached. This is a particular issue in the west, where Scots pine regeneration establishes slowly. Repairing breached fences, and adopting proactive deer management within fences, is required if progress is not to be reversed.
3. **Complete the program of Ancient Woodland restoration across the National Forest Estate**. Some areas of Caledonian Pinewood and associated Ancient Woodland underplanted with non-native conifers are yet to be restored, and remnant wild trees are now critically threatened. Completing the program of Ancient Woodland restoration is the best way to safeguard diversity and enhance Caledonian Pinewood connectivity across the National Forest Estate.
4. **Remove non-native tree and shrub regeneration and eradicate Gaultheria**. Where present, non-native trees and shrubs should be removed from Caledonian Pinewood and the surrounding regeneration zone to reduce risks from disease, invasion, and competition. The non-native plant *Gaultheria shallon* should be eradicated before it becomes a serious problem.
5. **Regenerate and expand Caledonian Pinewoods naturally**. Natural regeneration and expansion help maintain genetic diversity, distinctiveness, and structural variability that contribute to the health, resilience, and character of Caledonian Pinewoods. Cultivation and planting can damage these attributes and increase disease risk, so should not be undertaken in normal circumstances.

To enable effective management, we make five further recommendations:

6. **Prioritise Caledonian Pinewood management**. While stakeholders are united in recognising the importance of Caledonian Pinewood, other land uses continue to take priority. Caledonian Pinewood will need to become a priority for all stakeholders to secure restoration success.
7. **Build stronger relationships between stakeholders and provide consistent messaging**. Building stronger relationships between different stakeholder groups could help secure better Caledonian Pinewood management. Past mistakes could be avoided by acknowledging different starting points and objectives at the outset of discussions, being mindful of assumptions made about others, developing consistent messaging between ENGOs, the public sector, and Scottish Government, and agreeing common standards and timeframes for delivering action.
8. **Align policy and incentives with management recommendations**. Restoration will be more successful and conflict between stakeholders reduced if policy and incentives can be better aligned with recommended Caledonian Pinewood management.
9. **Target resources towards South West region**. Caledonian Pinewoods are most threatened in South West region. Focused relationship building, policy interventions, and resourcing in this region are key to improving the state of Caledonian Pinewood as a whole.
10. **Revise and expand the Caledonian Pinewood Inventory**. The Caledonian Pinewood Inventory was last revised 25 years ago. Without a further update, important areas could be lost or inappropriately managed due to lack of recognition.

Glossary

Ancient Woodland: areas understood from historical sources to have been continuously wooded since the mid-1700s. Many Ancient Woodlands are documented on the Ancient Woodland Inventory.

Biochemical region: areas assigned to Caledonian Pinewoods based on the chemical composition of Scots pine resins, which is believed to reflect underlying genetic distinctiveness. The following regions are recognised: North, North West, North Central, North East, East Central, South Central, and South West.

Blanket overbrowsing: feeding on tree shoots sufficient to arrest regeneration of all tree species.

Caledonian Pinewood: woodland formed from wild populations of Scots pine and other trees, naturally descended from those that recolonised Scotland after the ice age.

Caledonian Pinewood Inventory: a map and documentation of known Caledonian Pinewoods compiled by the Forestry Commission in 1994 and updated in 1998. It recognises 84 Caledonian Pinewoods scattered across the Scottish Highlands, and includes the Caledonian Pinewoods themselves, along with surrounding regeneration and buffer zones.

Connectivity: the scale of Caledonian Pinewood and its components parts in the landscape, and how well joined up they are. One of the four characteristics of healthy and resilient Caledonian Pinewood.

Continuity: the maintenance of Caledonian Pinewood diversity over time through regeneration of its component parts. One of the four characteristics of healthy and resilient Caledonian Pinewood.

Critically threatened Caledonian Pinewood: Caledonian Pinewood with low canopy cover where large decreases in Scots pine cover are expected due to insufficient regeneration.

Deer fences: barriers intended to exclude deer from the area within them. However, in reality most deer fences have been breached and deer have got inside.

Diversity: the range and quality of Caledonian Pinewood habitat components, and the genetic variability within tree species. One of the four characteristics of healthy and resilient Caledonian Pinewood.

Effective deer fences: deer-proof barriers that successfully exclude deer from the area within them.

Effective landscape scale deer management: reducing deer numbers across large areas to levels compatible with successful tree regeneration without the use of fencing. In general, red deer densities of less than 5 deer per km^2 in and around Caledonian Pinewood allow some tree species to regenerate successfully, while densities of less than 3 per km^2 allow diverse tree regeneration to take place.

Exclosure: the area inside a deer fence.

Habitat component: species and structures that benefit many other species within the habitat. For example, old growth features are a habitat component of Caledonian Pinewood, as without them many species could not survive.

Health: the capacity of Caledonian Pinewood to support the full range and abundance of associated wildlife.

Mobility: the ability of Caledonian Pinewood species to move through the landscape. One of the four characteristics of healthy and resilient Caledonian Pinewood.

National Forest Estate: land owned by the Scottish Government and managed by Forestry and Land Scotland.

Natural regeneration: trees that self-seed or otherwise propagate themselves without the use of planting.

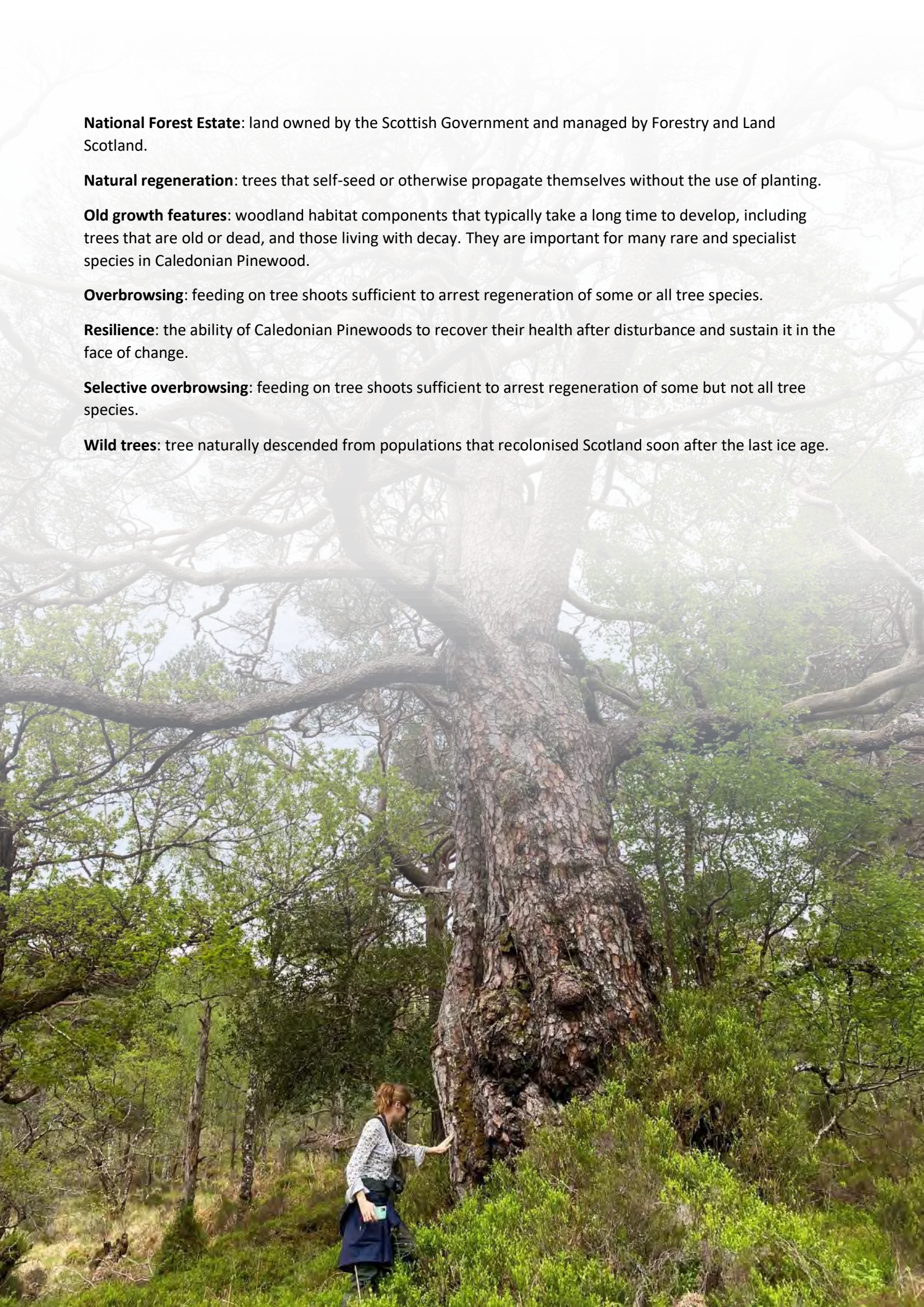
Old growth features: woodland habitat components that typically take a long time to develop, including trees that are old or dead, and those living with decay. They are important for many rare and specialist species in Caledonian Pinewood.

Overbrowsing: feeding on tree shoots sufficient to arrest regeneration of some or all tree species.

Resilience: the ability of Caledonian Pinewoods to recover their health after disturbance and sustain it in the face of change.

Selective overbrowsing: feeding on tree shoots sufficient to arrest regeneration of some but not all tree species.

Wild trees: tree naturally descended from populations that recolonised Scotland soon after the last ice age.



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