Evaluating post-fire restoration methods for Pencil Pines (*Athrotaxis cupressoides*): the Lake Mackenzie Field Trial.

Compiled by Ben French

2022

Photo credit: Andy Szollosi

Summary

Pencil Pines (*Athrotaxis cupressoides*) are an iconic feature of alpine Tasmania and occur nowhere else on earth. These long-lived, slow growing trees have little resilience to fire, and are increasingly threatened by it under the changing climate. Pencil Pine stands which have burnt in recent decades have not recovered; hence intervention may be required to maintain Pencil Pine stands in the landscape in the long-term. With funding from NRE, a research team from UTAS implemented a field trial at Lake Mackenzie to explore intervention approaches. Between March 2019 and May 2020, 1439 interventions (data points) were established using a variety of methods. Stands burnt in the 1960's or 2016 fires were targeted. Environmental data were collected for each intervention both by on-ground observers and by drone survey. In December 2021 a full re-survey was undertaken and failed interventions removed. The 619 interventions that had living Pencil Pines at the time resurvey were left in place and require ongoing monitoring.

Project Description

Aim

We aimed to identify practical and effective approaches for restoring Pencil Pines after fire. Importantly we did not try to maximise the success of interventions we applied. Rather, we sought maximise the information gained from the project so that future interventions could be based on robust field data.

Objectives

1) Assess the effectiveness and practicality of the following interventions:
- protecting naturally occurring germinants from herbivores,
- sowing seed, and
- transplanting nursery-grown tube stock.

2) Determine how the following factors affect success:
- The use of tree guards.
- Method of seed sowing.
- Method of propagation for tube stock (seeds or cuttings).
- Genetic provenance of both tube stock and seed.
- Size and age of tube stock.

3) Determine where intervention is most effective, with regard to topographic position and fire history.

4) Develop a decision support tool to facilitate effective Pencil Pine interventions.

5) Gain practical insights regarding methods and materials to use.

6) Better understand the ecological constraints on Pencil Pine recruitment.

Justification/rationale/drivers for monitoring

- Pencil Pines are a Tasmanian paleoendemic of high conservation significance.
- They are also an iconic species highly valued by the public.
- Pencil Pine stands were identified in the recent Intergovernmental Panel on Climate Change (IPCC) report as an Australian ecosystem threatened by climate change, primarily through increased fire prevalence.
- The trial is scientifically robust and designed to be monitored in the long term.

- There was considerable investment of NRE resources to establish this trial, and given the slow-growing nature of the trees, results from the 2022 report must be considered preliminary. Ongoing monitoring will greatly increase the information gained with comparatively small investment.
- This establishment report is designed to facilitate ongoing monitoring.

Key stakeholders

- NRE funded this trial and have been closely involved in its establishment.
- The Tasmanian Parks and Wildlife Service, in particular the Great Western Tiers Field Centre, manage the land the trial is situated on and provided in-kind support in establishing it.
- A team from the UTAS Fire Centre established and re-surveyed the trial and are using the results in ongoing research.
- The Tasmanian Seed Conservation Centre at the Royal Tasmanian Botanical Gardens provided seed used for both the sowing interventions and to propagate tube stock for transplanting.
- Habitat Plants, a native plant nursery and restoration planting provider, were contracted to propagate tube stock for our study and provided expert advice on planting methods.

Source of funding for program

An NRE tender funded the establishment of this study by UTAS researchers. A funding source for ongoing monitoring is unknown.

Relationship to Other Monitoring

This is part of a broader UTAS post-fire restoration project at Lake Mackenzie. In addition to the Pencil Pine interventions implemented by Ben French this includes:

a) A *Sphagnum* restoration trial implemented by Scott Nichols. Field sites are separate to the Pencil Pine work, except for the "Eagle Valley" site at which both *Sphagnum* and Pencil Pine interventions were undertaken. An establishment report for this trial is being prepared for NRE.
b) Aerial photo surveys undertaken by Darren Turner, from which orthorectified images and digital surface models were constructed. These include a light aircraft survey of the entire Lake Mackenzie area and more detailed UAV (drone) surveys of each of the Pencil Pine and *Sphagnum* intervention sites. For the Pencil Pine project these were used to i) accurately locate each intervention ii) generate remotely sensed TRI data for each intervention, and iii) assign each Pencil Pine intervention to a topographic class. An Honours project by Morgan Harding in 2021 endeavoured to map fire severity based on outputs from this project, and has been reported on by Harding et al. (2021).
c) A re-survey of adult Pencil Pines burnt in the 2016 fires undertaken by Aimee Bliss. This built on Aimee Bliss's Honours project (Bliss 2017; Bowman et al. 2019), and provides an important context to our work. It has been published by Bliss et al. (2021).

Excess seedlings from our trial were donated to Hydro Tasmania, who used them for restoration plantings in several "borrow pits" along both the Lake Mackenzie and Parsons falls roads. This differs from the UTAS trial in that the plantings are: i) not in wild areas, ii) planted on mineral soils, and iii) intended to rehabilitate degraded land rather than replace burnt Pencil Pine stands in the TWWHA. UTAS and HEC are monitoring these plantings for comparison with the present study.

The consultancy *Wild Ecology* are undertaking soil erosion and bog hydrology interventions in the Lake Mackenzie area. Some of their interventions are near our Pencil Pine sites, particularly "Unburnt South" and “Burnt North”. It is important that their infrastructure and equipment are not confused with UTAS material. The projects are otherwise unrelated.

Monitoring Schedule

Commencement Date

- Propagation of nursery stock commenced in 2018.
- The experimental design was developed from 2018 to 2019 in close consultation with NRE.
- Sowing and natural germinant interventions were established in Autumn 2019.
- Transplant interventions were established in Autumn 2019.

Duration of program

The final re-survey for the UTAS project was completed in December 2021. At this point failed interventions were removed and interventions with living Pencil Pines left in place. These should be monitored for several decades.

Frequency of survey

We suggest remaining interventions be re-surveyed every five years (next suggested survey December 2026), or following disturbance events.

Timing of survey

Re-surveys should be carried out between December and May. This is a very exposed location and field work is most feasible during settled weather.

Site Description

All trials are in the vicinity of Lake Mackenzie, a hydro impoundment near the northern edge of the Central Plateau, at the end of Lake Mackenzie Road. Interventions were established at five separate sites (Fig. 1) all of which must be accessed on foot.

The two northern sites (“Unburnt North” and “Burnt North”) are at the base of the prominent craggy hills immediately north of Lake Mackenzie. They are best accessed by parking near the boat launch area at the north end of the Lake Mackenzie dam wall. If the lake is low (~6.5m below full on the hydro lake levels webpage) it is possible to walk across the lakebed to the Sandy Lake Hut, then across the lakebed of the north arm of Lake Mackenzie to the sites. If water levels are higher it is necessary to walk around the lake, adding at least half an hour to the trip. Looking NNE from the Sandy Lake hut area, “Burnt North” centres on the visible stand of burnt Pencil Pines in the valley/creekline at the West (left) end of the obvious craggy hills north of the lake. “Unburnt North” sits a little above the lake level well east (right) of the summit of this escarpment.

The three southern sites are best accessed via the Blue Peaks Track, which begins at the car park at the southern end of the dam wall. After a short climb through eucalypts and scrub, there is a small creek crossing and the track leads to a grassy flat with sparse Pencil Pines and a large prominent burnt Pencil Pine immediately beside the track. From this point:

- “Eagle Valley” is accessed by leaving the track and moving southeast (left) across the flat. At the head of the flat, a short boulder scramble gets you within line of sight of the burnt stand, which is in a large *Sphagnum* bog.
- “Pine bog” is accessed by moving another 200m further along the Blue Peaks track and turning right (the large stand of burnt Pencil Pines at the centre of “Pine Bog” is visible from the track).
- Unburnt south is accessed by walking another 20 minutes or so along the Blue Peaks Track (passing a conspicuous stand burnt in 2016 on the right; this is one of the UTAS *Sphagnum*

intervention sites) until just outside the 2016 fire boundary. The site is spread out on the left side of the track, except for a cluster of natural germinant interventions, which are in the Pencil Pine grove to the right of the track.

Figure 1: Site map showing the location of each of the five sites. Burnt North and Unburnt North are best accessed by either walking around the northern lake shore, or if the lake is sufficiently low, cutting across the lakebed. Pine Bog, Eagle Valley and Unburnt South are best accessed via the Blue Peaks Track, from near the southern end of the dam wall.

Methodology

Overview

At the time of this report 619 interventions remain in the field and will require ongoing monitoring. These are the remnants of 1439 interventions which UTAS researchers and volunteers established over two field seasons (2019 & 2020). As each intervention was established it was assigned a uniquely numbered tag and environmental field data were collected. Sowing and natural germinant interventions were established in Autumn 2019. In Autumn 2020 transplant interventions were established and UAV surveys of each site conducted. All interventions were re-surveyed in December 2021, when failed interventions (those with no living Pencil Pine material) were removed.

Below we include details of the infrastructure used, environmental data collected and intervention methods. We also discuss the re-survey methods we used and make recommendations for future re-surveys.

Site Selection

The Lake Mackenzie area was appropriate for this study for several reasons.

- It is representative of Tasmanian alpine vegetation, has many Pencil Pine stands and is relatively accessible.
- Fires in 2016 burnt several Pencil Pine stands, attracting national and international media attention (Marris 2016; Mathieson 2017). At the time of project establishment these were the most recently burnt Pencil Pines in existence.
- The area also has numerous burnt Pencil Pine stands from the 1960's fires.
- It is part of the Tasmanian Wilderness World Heritage Area (TWWHA).
- It is a Conservation Area, and hence undertaking the trial here is administratively simpler than other parts of the TWWHA with higher levels of protection (ie. National Parks and State Reserves).

We selected five study sites in the Lake Mackenzie area. We sought to develop methods to rehabilitate burnt Pencil Pine stands (not create new stands) and hence targeted areas with fire-killed Pencil Pines. We selected three sites burnt in the 2016 fires (Burnt sites henceforth) and two which were not burnt in 2016, but contained dead Pencil Pines from the 1960's fires (Unburnt sites henceforth). We chose sites which were relatively accessible and which captured environmental variability. Sites did not have formal boundaries or fixed size; they were simply a tool to achieve geographic spread.

At each site we attempted to locate naturally occurring seedlings which we could use for our 'natural germinant' interventions. We only found them near living adult Pencil Pines, and mostly on *sphagnum*. We focused on seedlings which could feasibly have a tree guard built around them *in situ*. Seedings were sometimes found on their own, but more often they were located in clusters (sometimes >100 seedlings, sometimes two or three). In these cases, multiple seedlings were lumped together and treated as one intervention. We also targeted some single, isolated seedlings. After selecting intervention points we flipped a coin to determine which would be protected by tree guards and which would remain open.

Both sowing and transplant intervention points were selected from the parts of each site in which i) an adult pencil pine stem (dead or alive) was present within 5m, and ii) it was possible to construct a tree guard. Within areas that met these criteria we sought to representatively sample the range of topographic positions, substrate types and depths, ground cover, waterlogging, and vegetation that occurred. For transplant interventions the pick end of a mattock was used to probe the ground and locate intervention points with sufficient soil depth for transplanting. For both sowings and transplants, a pair of similar intervention points were chosen, and a coin flipped to determine which was protected by a tree guard. In this way we avoided any bias that could arise from preferentially placing tree guards on intervention points where they were easy to build.

Infrastructure

Caged interventions

Half of the interventions we established were enclosed within tree guards, protecting them from vertebrate herbivores (referred to as 'caged' interventions henceforth), while half were left open to herbivory (referred to as 'open' interventions henceforth). In the 2022 re-survey we found that open interventions had largely failed, and hence removed most of them. Of the 619 interventions now remaining in the field, 520 are caged (have tree guards).

Most tree guards were a 'tee-pee' design built from aluminium tubing, tie wire and stainless steel mesh, pegged down with mild steel jute pins (Fig. 2: this design referred to as "stainless" henceforth). We chose this design because it balanced the following requirements:

- Robust and long lasting. We anticipate it could be 20 years before plants outgrow these guards, and hence designed them to last.
- No galvanised components (zinc leaching was identified by DPIPWE as an environmental concern).
- Components relatively lightweight and easy to carry around rough terrain.
- Flexible construction options, allowing them to be used in varied terrain and shallow soil.
- Cost effective for the UTAS project (noting that cheaper materials may be more suitable for upscaled plantings).

To construct stainless tree guards four aluminium poles were pushed or hammered into the ground around an intervention point, bent to shape as necessary and bound together at the top with tie wire. Stainless steel chicken wire was wrapped around this structure, fastened to it with tie wire and pegged to the ground with jute pins.

As part of the trial we also tested other materials which could be used in future planting efforts. At each site we constructed a subset of ‘tee-pee’ tree guards using fibreglass poles and plastic coated (*longlife blue*) galvanised steel chicken-wire (Fig. 3: design referred to as “galvanised” henceforth). We also used some conventional plastic tree guard sleeves at each site, with either wooden or reinforcing steel (reo) stakes (Fig. 4: design referred to as “plastic” henceforth).

For natural germinant interventions (described below) which focused on groups of wild seedlings where they naturally occurred, tree guards often had to be individually tailored. In such instances we used stainless mesh and aluminum poles to construct larger cages, up to 1.5m diameter (Fig. 5: these varied designs collectively referred to as “tailored” henceforth).

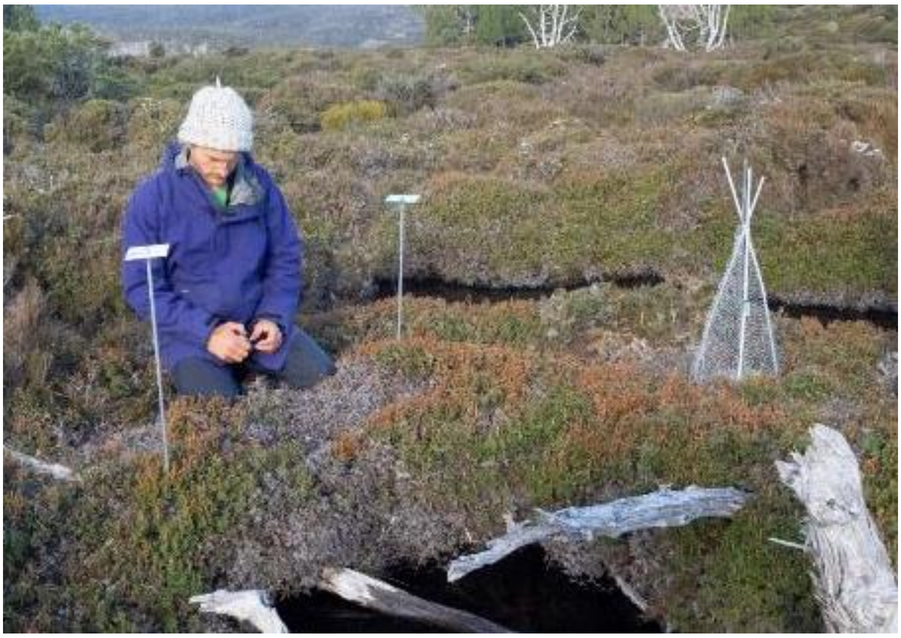

Figure 2: Example of a stainless tree guard (right) which we used for most of our caged interventions, and a typical open intervention (left). Poles are lengths of aluminium tubing, pushed or hammered into the ground. Mesh on the tree guard is stainless steel chicken wire.

Figure 3: Example of a galvanised tree guard, which we used for a subset of transplant interventions at each site. Poles are flexible fibreglass rod, pushed or hammered into the ground. Mesh is *longlife blue* (plastic coated) galvanised chicken wire.

Figure 4: A typical plastic tree guard, which we used for a subset of transplant interventions at each site. Stakes are either timber (as pictured) or reinforcing steel (reo). Mesh is an industry standard plastic tree guard sleeve (bought from Geotas), pegged to the ground with jute pins.

Figure 5: An example of a 'tailored' tree guard design used to protect natural germinants where they occurred. These varied in shape and size and were constructed using aluminium tubing, stainless steel mesh, tie wire and jute pins.

Open interventions

Half of the interventions we established were not protected by tree guards (referred to as 'open' interventions henceforth). These largely failed; hence only 99 of the 619 interventions remaining *in situ* are open.

At establishment, open interventions were marked with a pair of aluminium tubing posts and perspex markers to make them visible in UAV- based orthophotos (Fig. 2). This also made them easy for field observers to re-locate. Two posts were positioned with the intervention point located in the exact centre between them. Spacing varied because of the rocky terrain, but posts were typically between 30 centimetres and 1 metre from the intervention point.

Perspex squares were affixed to the top of each post. These squares varied in colour, and the colours used for each intervention were recorded with the field data. Each square had a small hole drilled in its centre and was affixed to a post by inserting a tech screw through this hole and into the end of the aluminium tubing. The tubing was then crimped securely around the screw using a swaging tool.

For natural germinant interventions, most open interventions were encircled by several aluminium posts to mark the boundary of the surveyed area (Fig. 6). Perspex markers were attached to just two of these posts. At the Eagle Valley site, open natural germinant interventions were marked only using a standard pair of posts.

.

Figure 6: An example of an 'open' natural germinant intervention, with posts encircling the surveyed area.

Environmental data collection

The same environmental data were collected for each intervention point, regardless of intervention type. After an intervention point was selected a 50x50cm quadrat was positioned with the point at its centre and an image of the quadrat captured using a handheld camera. Ground cover was assessed by estimating the percentage of the quadrat occupied by several cover classes. These included woody and herbaceous vegetation, living and dead *sphagnum*, rock and bare soil. Scats within the quadrat were identified and counted but not removed. Soil depth was measured using a steel probe. Adult Pencil Pine stems within five metres of the intervention point were classified according to their status (live or dead) and fire history (unburnt, burnt in the 60s, burnt in 2016), then counted. A detailed explanation of each environmental variable can be found in the data file. Images of each quadrat are also available in the data repository.

Establishing 'sowing' interventions (March 2019)

A total of 300 sowing interventions were established: 60 at each site. Almost all of these were removed during the 2021 resurvey because there was no evidence of germination. A handful were left in place because very small live seedlings were present (Fig. 7). However, all sowing interventions with seedlings present were located near living adult Pencil Pines, and seedlings of similar size were also present in the surrounding environment. This suggests that these few seedlings germinated from naturally occurring seed.

The seeds we used were provided by the Royal Tasmanian Botanical Gardens, having been collected in the wild in 2015. We obtained seed from several provenances (details in the data file). Seed viability varied slightly between provenances (based on RTBG data). We adjusted the number of seeds sown such there were 15 viable seeds per sowing intervention (17-20 total seeds, depending on provenance).

We divided the 300 interventions between three different sowing methods. These were : i) sprinkling seed directly onto the undisturbed ground surface; ii) scratching vegetation off with a mattock (to mimic an animal dig) and sprinkling seeds on the disturbed surface, and; iii) digging a small pit (5cm deep), tipping seeds into the hole, then replacing a handful of soil.

Figure 7: A young seedling, with cotyledons visible, found during the 2021 resurvey. In a few cases these were found on our sowing interventions, however only near living adult Pencil Pines. They were also occasionally found within transplant interventions and were present in the surrounding environment. It seems likely these germinated from wild seed rather that our sowings. Interventions with these seedlings were left in place nonetheless.

Establishing 'natural germinant' interventions (March 2019)

Once natural germinant intervention points were chosen (methods described above in *site selection*) half were protected from herbivory. Tailored tree guards were used, except at Eagle Valley, where stainless tree guards were used, and Pine Bog, where both stainless and plastic tree guards were used. The remaining half were left open to herbivores and marked using aluminium posts.

All seedlings within the tree guard footprint or marker post perimeter were counted. Seedlings were mostly very small (0.5 to 2cm). Where there were many seedlings exact counts were not practical, so the counts were estimates only. The largest and smallest seedlings in each intervention were measured to the nearest millimetre.

Establishing 'transplant' interventions (Feb-April 2020)

We contracted Habitat Plants, a nursery in Liffey, to propagate Pencil Pine tube stock to be used for the transplant interventions. We worked with the NRE technical reference group to agree on nursery procedures which were cautious from a biosecurity perspective and reasonably practical (details provided in the Nursery Methods document attached to the 2022 report). Half of the tube stock were propagated from seed (referred to as 'seedlings' henceforth), which was provided by the Royal Tasmanian Botanical Gardens. The other half were propagated from cutting material (referred to as 'cuttings' henceforth) which Habitat Plants collected from wild Pencil Pine stands. We sourced both seed and cutting material from several genetic provenances, and each individual tube was labelled to reflect this.

Tube stock propagated for this project were quite small at the time of transplanting, and we were concerned that this could limit their success. To test this idea we purchased an additional 100 Pencil Pine seedlings from Habitat Plants which predated the project and were hence larger, albeit not grown according to the same strict phytosanitary standards. We planted these at the Pine Bog site (referred to as 'single transplants' henceforth) to compare their success with the younger individuals.

The 2020 field season was focused solely on establishing transplant interventions. We split the field season into two discrete phases. These were:

i) a site selection and data collecting phase, in which we selected intervention points, distributed tree guard materials, collected environmental data and dug planting holes.
ii) a planting phase, in which we transported, measured and planted tube stock, and erected tree guards and markers.

We chose this approach because it minimised:

i) the equipment, briefing steps and task switching necessary in any given field day,
ii) the time we had to care for live plants in the field, and
iii) the time elapsed between the first and last plantings, reducing the potential confounding influence of weather variability across the planting period.

After an intervention point was selected and environmental data recorded (described above), a mattock was used to remove a small area of surface vegetation and dig a rectangular planting hole. Loose soil was then placed back in the hole and the vegetation re-assembled. Each hole was assigned a uniquely numbered tag, and either tree guard or marker materials left in place beside it.

In the planting phase each hole was re-opened using a mattock. We planted a pair of young Pencil Pines: one seedling and cutting ('transplant pair' henceforth). These were randomly selected from a tray, and their provenance and height recorded. Height was measured in the tube after inverting it to remove the loose pine bark mulch. A coin was flipped to determine which end of the rectangular hole the seedling and cutting would be planted in. They were then planted at their respective ends of the rectangular hole using the dislocated soil to firmly bed them in. The vegetation we had removed was used as a mulch after planting (Fig. 8). Height was not re-measured once individuals were in the ground.

We erected a tree guard or pair of open markers around each transplant pair using the uniquely numbered tag to distinguish the cutting from the seedling. Tree guards were positioned, and tags affixed with stainless tie wire, such that the cutting was always located between a post to which the tag was affixed and the centre of the area protected by the tree guard. For open interventions, the tag was affixed between the tech-screw and Perspex square on one of the two markers. These were placed such that the cutting was always located between the tagged marker and the intervention centre point (the exact central point between the two markers).

Single transplants (at Pine Bog only) were positioned in the centre of the rectangular hole. Tree guards had the tag affixed at the apex of the tee-pee, helping to distinguish them from the transplant pairs.

Figure 8: Images sequence showing transplant methods. A seedling and a cutting were planted at opposite ends of a rectangular hole (top) and firmly bedded in place with the soil from the hole (middle). Vegetation which had been cut away was then used as a mulch layer (bottom).

Resurvey and removal of failed interventions (Nov-Dec 2021)

We conducted the final re-survey for the UTAS project over about 10 field days in November and December 2021. With a team of 3-5 people, we re-visited every intervention point and recorded the state of both the Pencil Pines and the infrastructure. We left interventions in place where they contained living Pencil Pines and removed all other infrastructure. We describe our re-survey methods in detail in the hope they can be adapted for future re-surveys.

The field team was familiar with each site and hence we were able to locate most interventions by memory and an on-ground visual search. Printed maps of each field site, with interventions marked were also used (waypoints for each intervention can be found in the data file).

On approaching each intervention point we:

1) Located the uniquely numbered tag and recorded the number.
2) Recorded the infrastructure type and the state it was in (intact or not). If it was not intact we recorded the nature of the failure.
3) Identified the intervention type, either by looking up the tag number (in a printed list of the establishment data), or by recognising differences in the infrastructure (the types of ID tags used and the colour of Perspex disks differed between transplant and sowing interventions). For future re-surveys, a printed list should be used.

After these steps the re-survey method differed for each intervention type.

For transplant interventions

We attempted to locate each individual transplanted Pencil Pine (one individual for single transplants, two for transplant pairs). For transplant pairs we used the position of the tag (as described above in “establishing transplant interventions”) to determine the location of the seedling and the cutting respectively. Single transplants (Pine Bog only) were a seedling located at the centre of the intervention.

For each transplanted individual we recorded the below data (workflow illustrated in figure 9, with examples in figures 10 to 14):

- Presence or absence. If an individual was not visible a jute pin was used to dig around gently in the soil in its expected location. To ensure this digging effort was consistent we dug only as thoroughly as could be achieved when poking a jute pin through the mesh of a stainless tree guard (even for open interventions). Individuals were recorded as absent only if no trace of them was found after digging. No further data were recorded for absent individuals.
- For present individuals we recorded whether they were alive (any part of the plant living) or dead (no living material).
- For both living and dead individuals we recorded whether they were “intact” (protruding above the surrounding vegetation, or if not protruding, showing no evidence of having missing shoot ends) or had been “broken” (not protruding above the surrounding vegetation, and shoot ends missing). Dead shoots were sometimes snapped off but still present (Fig. 11), and these were recorded as “intact”, reflecting the fact that they had not been consumed by a herbivore.
- For living, intact individuals we estimated how much of the shoot material was alive (still succulent). Those with >=90% living foliage were recorded as “healthy”. Those with <90% living foliage were recorded as “damaged”.
- For damaged plants, the % of shoot material still alive was visually estimated to the nearest 10%.

- For healthy plants the size of the plant (longest axis of the shoot) from base (measuring tape gently pressed to the ground at the base of the shoot) to tip was measured to the nearest half centimetre using a measuring tape. This coarse resolution of measurement was used because we measured caged plants by inserting the tape through the mesh (ie. not opening the tree guard).

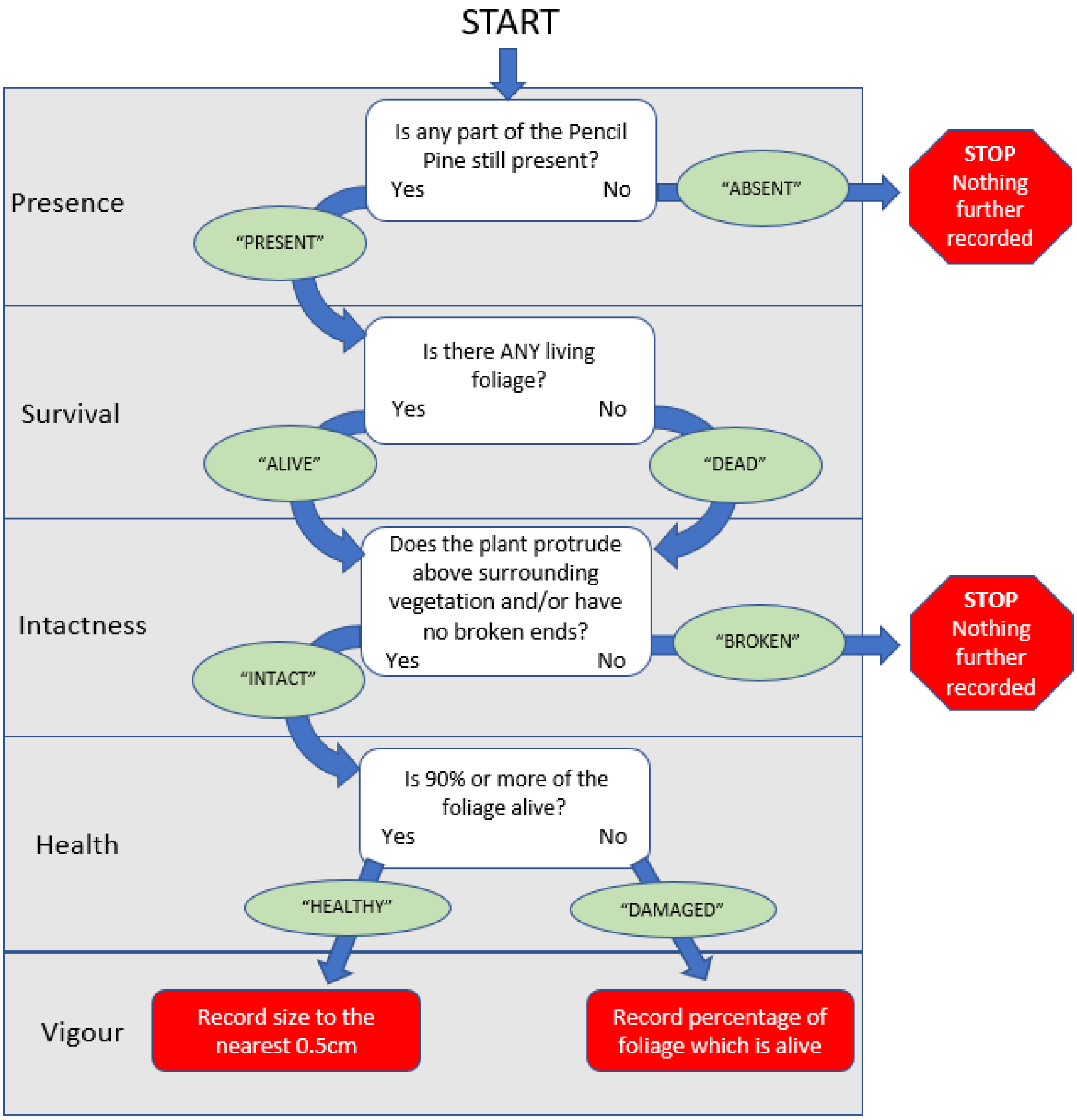

Figure 9: Flow chart showing the approach used to re-survey all transplanted interventions in November and December 2021. This approach was followed for each transplanted individual after using the tag to determine its expected position and recording propagation method (cutting or seedling).

Figure 10: Example of a transplanted individual classified as Present, Dead and Broken in the 2021 re-survey. No further data was recorded. If the other transplant within this intervention was also dead or absent the infrastructure would have been removed.

Figure 11: Example of a transplanted individual classified as Present, Dead and intact in the 2021 re-survey. No further data was recorded. If the other transplant within this intervention was also dead or absent the infrastructure would have been removed.

Figure 12: Example of a transplanted individual classified as Present, Alive and Broken (did not protrude above the surrounding vegetation and was missing shoot tips) in the 2021 re-survey. No further data was recorded. Because this individual was alive, infrastructure would have been left in place regardless of the state of the other transplanted individual within this intervention.

Figure 13: Example of a transplanted individual classified as Present, Alive, Intact and Damaged (<90% of the shoot is alive) in the 2021 re-survey. The percentage of the shoot that was alive was estimated to the nearest 10% (10% alive in this case). Because this individual was alive, infrastructure would have been left in place regardless of the state of the other transplanted individual within this intervention.

Figure 14: Example of a transplanted classified as Present, Alive, Intact and Healthy (>90% of the shoot is alive) in the 2021 re-survey. The size of the shoot from base to tip was recorded to the nearest 5mm using a measuring tape inserted through the tree guard (145mm in this case). Because this individual was alive, infrastructure would have been left in place regardless of the state of the other transplanted individual within this intervention.

For sowing and natural germinant interventions

These interventions were carefully inspected for living Pencil Pine seedlings. If seedlings were present:

- they were counted, measured and photographed.
- if there were too many seedlings to measure and photograph each one (some natural germinant interventions have >100 seedlings) the size of the largest and the smallest seedlings was recorded, and some representative photographs taken of the seedlings present at that intervention.
- If there were any living individuals present, infrastructure was left in place and maintenance undertaken as necessary.

Infrastructure maintenance and removal (interventions of all types)

For intervention points which did not contain any living Pencil Pines all infrastructure was removed. Tree guards and posts were pulled out by hand and piled at a central point. Materials were then sorted into their component parts. A cordless drill was used to remove tech screws from marker posts, allowing tags and perspex markers to be recovered. Tree guards were deconstructed: tie wire was cut off and bagged, mesh flattened and rolled together, jute pins consolidated in boxes/bags. Poles were straightened by hand and bundled together using duct tape. All material was packaged in bulker bags. These were subsequently helicoptered out by PWS Great Western Tiers and stored at their depot in Deloraine.

For interventions which contained living Pencil Pines infrastructure was left in place, and any necessary maintenance undertaken. When constructing both stainless and galvanised tree guards a skirt of excess mesh was left in place and pegged to the ground to prevent digging animals (Fig. 15 top). On re-survey we observed no cases of digging animals being an issue, even for plastic tree guards which did not have skirts. However there were many cases where vegetation had grown through the mesh of the skirt over the course of the trial. This made tree guards very difficult to remove in some cases, especially in *sphagnum*, where doing so damaged the freshly grown moss. We were concerned that over a few more years retrieving tree guard materials would become impossible, or would require major damage to the vegetation. Hence, we addressed this issue by rolling up the skirts of all tree guards left in the field, using a few spare jute pins to peg them in place (Fig. 15 bottom).

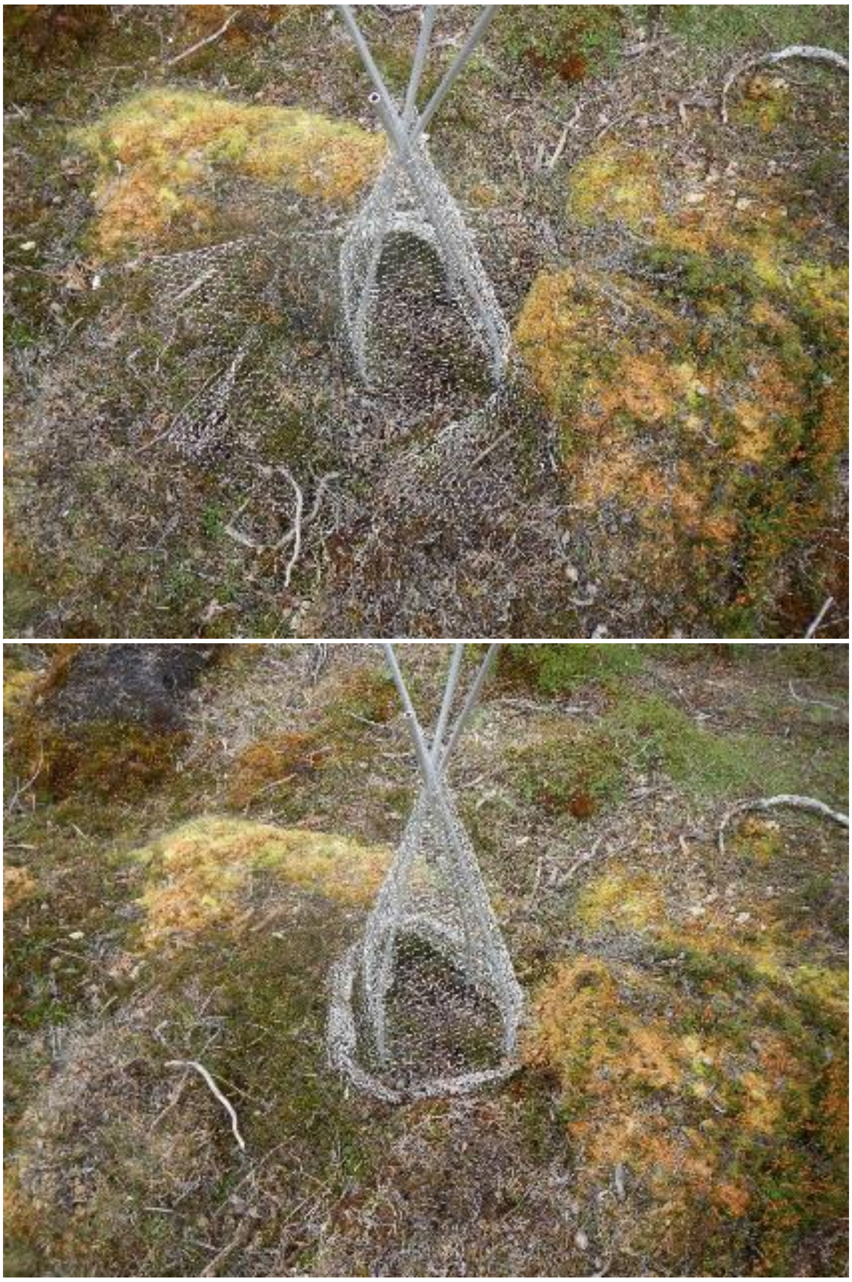

Figure 15: Two images of the same stainless tree guard, before (top) and after (bottom) the skirt of excess mesh was rolled up. In the top photo, note the *sphagnum* growing through the mesh to the

right of the tree guard. We were concerned that this would make the tree guards difficult to remove over time, and hence rolled the skirts on all tree guards left in the field.

Recommendations for next re-survey

The methods we describe above should be adapted for future re-surveys. Specifics will depend on:

i) the data being collected,
ii) the number of failed interventions to be removed, and
iii) the extent that infrastructure being left in place requires maintenance or replacement.

We make the following broad recommendations.

Duration and personnel

Even the simplest re-survey of the remaining 619 interventions could be expected to take at least four solid field days, with a team of 2-4 people working together. When planning a re-survey, a brief (1-2 day) site visit should be undertaken to check the state of the interventions, run through re-survey methods and estimate the time, personnel and materials required. A bushwalker with reasonable fitness can visit all five sites in a day.

Equipment

The field team should be equipped with appropriate clothing and safety equipment for working several kilometres from a vehicle in a remote alpine environment.

The following equipment may be used for data collection:

- A method of locating interventions. If someone with detailed knowledge of the trial cannot be present, a tablet or phone in a waterproof case with a map and the intervention points loaded would be ideal.
- Waterproof digital camera.
- Measuring tape (if heights are to be recorded).
- Clipboards, waterproof data sheets and pencils.
- Printed list of the intervention type associated with each tag number.
- Something to visibly mark interventions as they are re-surveyed. In 2021 we folded the ends of each tag.

The following equipment may be used for removal and maintenance of existing infrastructure:

- Work gloves and safety glasses for each participant
- Wire cutters for removing tie wire
- Tin snips, in case stainless mesh needs to be cut.
- Multiple pairs of pliers.
- Spare stainless tie wire.
- Duct tape for securing bundles of poles.
- Large, tough bags or containers for any jute pins removed
- Smaller bags or containers for any tie wire, tech screws, Perspex markers and tags removed.
- Depending how gear is to be retrieved from the field, either: a) helicopter bag to be loaded, or; b) large, sturdy backpacks to walk gear out.

If Pencil Pines survive to outgrow the tee-pee tree guards it will be necessary to replace or re-configure them. It may be possible to do this using leftover equipment from failed plantings. Alternatively, new materials may need to be helicoptered or carried in.

Additional data collection

The next re-survey should be used as an opportunity to validate the topographic classification scheme used in the analysis for the final report from UTAS. The macrotopographic classes used (dry, moderate, wet and *sphagnum*) were developed based on field observations, but interventions were assigned to these classes from high-resolution orthophotos, after field work was completed. Microtopographic classes (run-on, run-off) were adapted from written descriptions which field observers recorded for each intervention point, however these were ambiguous for 20% of interventions.

As each intervention point is re-visited it should be assigned both a macrotopographic and microtopographic class in the field. To avoid bias, observers should not be aware of the class already assigned in the existing data set. These new field-based data can be compared with the existing classifications using confusion matrices.

Macrotopography

Field observers should familiarise themselves with the macrotopographic classes described in the UTAS final report. These are “dry”, “moderate”, “wet” and “*sphagnum”*. The report will contain descriptions of each of these classes, as well as some representative photos. Each intervention point should be classified by field observers into one of these classes as it is re-visited.

Microtopography

This should be assessed at the 0.5m scale, independently of macrotopography. Each intervention point should be classified as either “run-on” or “run-off”, imagining how water poured over the intervention point would behave if the ground surface (not including standing vegetation) were impervious. Hummocks, mounds or slopes should be classified as “run-off”. Hollows, depressions and flats should be considered “run-on”.

Metadata

Site information

The below table outlines the location of each site and contains information on both the original number of interventions established, and how many remain in the field. A re-survey may turn up some minor errors in these numbers, as there were a handful of errors in reconciling the various data collection steps

Site	Easting	Northing	**Number remaining after Dec 2021 re-survey** **Number established 2019-2020**									
			Total (all types)	Infrastructure Type					Intervention Type			
				Open	Stn	Plast	Galv	Tailor	TPpair	TPsingle	Sown	Nat
Burnt North	449747	5387553	116 256	24 126	71 109	8 8	10 10	3 3	106 190	0 0	4 60	6 6
Unburnt North	450474	5386869	108 262	24 132	66 109	8 10	7 8	3 3	98 196	0 0	4 60	6 6
Pine Bog	447957	5384296	157 387	11 194	127 173	10 10	9 10	0 0	107 227	48 97	0 60	2 3
Eagle Valley	448493	5384116	112 272	8 134	91 124	8 9	5 5	0 0	102 200	0 0	4 60	6 12
Unburnt South	448298	5383253	126 262	32 132	73 108	9 9	8 9	4 4	119 194	0 0	0 60	7 8
TOTAL (all sites)			619 1439	99 716	428 623	43 46	39 44	10 10	532 1007	48 97	12 300	27 35

Re-survey data sheet

This data sheet can be adapted for the next re-survey.

TagNo			
Photo			
Macrotop	Dry Mod Wet Sphag	Dry Mod Wet Sphag	Dry Mod Wet Sphag
Microtop	Run-on Run-off	Run-on Run-off	Run-on Run-off
Inf type	Open STN GLV PL Tailored	Open STN GLV PL Tailored	Open STN GLV PL Tailored
Inf intact?	Y N	Y N	Y N
Removed?	Y N	Y N	Y N
Type	TPpair TPsingle Sowing Natural	TPpair TPsingle Sowing Natural	TPpair TPsingle Sowing Natural
cutting	Pres/abs Alive/dead intact/broken Health/dam % living: Size:	Pres/abs Alive/dead intact/broken Health/dam % living Size:	Pres/abs Alive/dead intact/broken Health/dam % living Size:
seedling	Pres/abs Alive/dead intact/broken Health/dam % living Size:	Pres/abs Alive/dead intact/broken Health/dam % living Size:	Pres/abs Alive/dead intact/broken Health/dam % living Size:

Communication and Data Records

The findings from this project will be communicated directly to staff from the Parks and Wildlife Service and other interested parties through a series of meetings and workshops such as the Bushfire Research Group.

The results of the 2021 re-survey will be communicated as part of Ben French's PhD, including various presentations and a thesis chapter. This chapter will also be submitted as a final report to the Natural and Cultural Heritage Division of NRE.

Findings from the trial will published in an appropriate scientific journal in the future: possibly following a re-survey.

A decision support tool, based on this study, is being developed to help guide future Pencil Pine restoration efforts.

All data and metadata files, including descriptions of methods, have been uploaded to a repository housed by the University of Tasmania's OneDrive storage facility. These will also be provided to the Natural and Cultural Heritage Division of NRE.

References

Bliss, A., 2017. Relicts at risk: Impacts of 2016 Tasmanian fires on *Athrotaxis cupressoides*. In, School of Biological Sciences University of Tasmania, Hobart.

Bliss, A., Prior, L.D., Bowman, D., 2021. Lack of reliable post-fire recovery mechanisms makes the iconic Tasmanian conifer *Athrotaxis cupressoides* susceptible to population decline. Australian Journal of Botany 69, 162-173.

Bowman, D.M.J.S., Bliss, A., Bowman, C.J.W., Prior, L.D., 2019. Fire caused demographic attrition of the Tasmanian palaeoendemic conifer *Athrotaxis cupressoides*. Austral Ecology 44, 1322-1339.

Harding, M., Turner, D., Williamson, G., Nichols, S., Bowman, D., 2022. Post-fire impact assessment of Tasmanian *Sphagnum* bogs. Unmanned aerial system mapping trials and method development. Bushfire and Natural Hazards CRC, Melbourne.

Marris, E. Tasmanian bushfires threaten iconic ancient forests. *Nature* **530,** 137–138 (2016). https://doi.org/10.1038/nature.2016.19308

Mathiesen, K. (2016) World heritage forests burn as global tragedy unfolds in Tasmania, *The Guardian*, 27 January. Available at: https://www.theguardian.com/environment/2016/jan/27/world-heritage-forests-burn-as-global-tragedy-unfolds-in-tasmania#:~:text=World%20heritage%20forests%20are%20burning,across%20the%20supercontinent%20of%20Gondwana. (Accessed: 16 June 2022)