ESTABLISHING A MONITORING PROGRAM FOR TASMANIA'S MONTANE CONIFERS

by Nicholas B. Fitzgerald and Jennie Whinam

(with five text-figures, four plates, one appendix and one table)

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Tasmania's relictual cool temperate conifer flora is at risk from projected climate change during this century. Montane and rainforest conifer species exhibit several characteristics which indicate likely vulnerability to environmental change. They are adapted to cool and wet conditions and are highly sensitive to drought and fire. Increased moisture stress and fire are therefore expected to drive declines and local extinctions in these species with ecosystem-changing consequences. A long-term monitoring program has been established to examine trends in condition and recruitment for four Tasmanian endemic conifer species. Permanent monitoring sites have been established at 13 locations in Tasmania's highlands. The target species include two long-lived, slow-growing rainforest tree species – Pencil Pine (*Athrotaxis cupressoides*) and King Billy Pine (*A. selaginoides*) – and two shrubby conifers typically associated with high elevation coniferous heath vegetation – Dwarf Pine (*Diselma archeri*) and Drooping Pine (*Pherosphaera hookeriana*). Conifer condition was assessed visually using four condition classes. Presence of juvenile plants was recorded as were cones (strobili) on mature plants. Conifers were mostly in good condition, with Drooping Pine the only species to frequently exhibit poorer condition. Condition varied significantly between sites for Pencil Pine but not for King Billy Pine. No recruitment of Pencil Pine was evident at the majority of its sites (23 of 34), whereas seedlings and juveniles were present at most King Billy Pine sites (20 of 24). Recruitment appeared to be more or less continuous for the shrubby conifer species.
Key Words: conifers, monitoring, climate change, Tasmania, *Athrotaxis cupressoides, Athrotaxis selaginoides, Diselma archeri, Microcachrys tetragona, Pherosphaera hookeriana, Pherosphaera lawrenci.*

INTRODUCTION

Tasmania has 10 native species of conifers (Division Pinophyta) of which eight are relictual species of rainforest and montane habitats (Hill 1998, Hill & Orchard 1999). Within Australia, Tasmania's cool temperate conifer flora has high levels of diversity and endemism (Enright & Hill 1995) and Tasmania is one of five global hotspots of conifer diversity (Contreras-Medina *et al.* 2001). The 50% endemism rate at the generic level is among the highest rates of endemism in conifer floras worldwide (Contreras-Medina & Vega 2002). Rainforest and alpine vegetation communities dominated by conifers are internationally significant due to their primitive flora and Gondwanan affinities (Balmer *et al.* 2004) and presently cover less than 1% of Tasmania's land area.

A dramatic decline in the extent, diversity and dominance of Australian conifers during the Tertiary coincides with increasing aridity in this period, with many of the relictual species now restricted to Western Tasmania, which is a refugium for conifers (Jordan 1995, Carpenter *et al.* 2011).

Most Tasmanian conifers exhibit physiological drought intolerance (Brodribb & Hill 1998) and are extremely fire sensitive (Gibson *et al.* 1995, Kirkpatrick *et al.* 2010). Vulnerability to climate change is determined by a complex range of factors broadly comprising adaptive capacity, resilience and exposure (Williams *et al.* 2008). Montane conifer species possess many of the characteristics associated with vulnerability to climate change (Williams *et al.* 2008): (i) poor physiological tolerances to high temperature and low moisture availability; (ii) life history traits including longevity, slow growth rates and poor dispersal; (iii) present limited geographic range; and (iv) predicted exposure to climate change (based on downscaled general circulation models for Tasmania; Grose *et al.* 2010). Therefore, local extinctions and consequent range contractions are likely to occur in these species. Uncertainties such as ecological and evolutionary adaptive responses and potential feedbacks and interactions make it difficult to predict how fast and widespread these impacts will be.

There have been many episodes of rapid climate change – most recently during the Quaternary glacial cycles – with relatively few extinctions, suggesting that species have been able to persist, evolve or migrate more successfully than is predicted by current models (Botkin *et al.* 2007). However, the additive effects of pressures such as increased fire, herbivory, low levels of recruitment and physiological stress may increase the likelihood of extinctions.

Dieback symptoms such as chlorosis, foliage thinning and death have been observed in several conifer species at widespread locations in Tasmania's highlands. These symptoms may be pathological (e.g., Whinam *et al.* 2001, Yuan *et al.* 2000) or environmental. Changes in vegetation condition can be related to a variety of causes and manifest at different scales ranging from individuals, to populations, to the overall extent of the community. Observation and monitoring at different scales is therefore a strategic approach to detect and quantify change, which can inform adaptive management strategies such as protection of refugia, *ex situ* conservation and assisted migration.

Four Tasmanian endemic conifer species have been selected for long-term monitoring. These species are expected to be sensitive to environmental change and consequently are likely to be useful indicator species. They exhibit different life histories, are keystone species in several vegetation communities of conservation significance and are also iconic elements of the Tasmanian environment. Most populations of these conifers occur in reserves, particularly the Tasmanian Wilderness World Heritage Area where they contribute to the globally significant flora and vegetation values (fig. 1).

King Billy Pine (*Athrotaxis selaginoides* D. Don) and Pencil Pine (*A. cupressoides* D. Don) are slow-growing rainforest trees with a lifespan of around 1300 years (Cullen & Kirkpatrick 1988a, b, Gibson *et al.* 1995). King Billy Pine is a canopy dominant or emergent tree in mid-elevation climax rainforests (typically 360–1100 m), and also occurs in krumholz (dwarf) form in alpine scrub. Pencil Pine is a highland species, mostly occupying an altitudinal range of 990–1370 m, where it is dominant in subalpine rainforest and woodland and also occurs in alpine vegetation (Kirkpatrick 1996). Both species exhibit mast seed production with seed dispersal by wind typically limited to around 100 m, although Pencil Pine relies mostly on asexual reproduction with root suckers observed more than 50 m from a parent plant (Cullen & Kirkpatrick 1988a, b, Kirkpatrick *et al.* 2010).

Dwarf Pine (*Diselma archeri* Hook.f.) is a dense shrub typically 0.5–1.5 m tall in alpine heathland, but occasionally taller in subalpine forest. There is a small atypical population of this species at Lake Johnston in the West Coast Range where it occurs as a tree reaching heights of over 10 m with diameter at breast height (DBH) up to 45.5 cm (Fitzgerald 2011). Drooping Pine (*Pherosphaera hookeriana* W. Archer syn. *Microstrobos niphophilus* J.Garden & L.A.S.Johnson) is similar in appearance, habitat and dioecious habit; however, the two species are in different families. Drooping Pine has a more limited distribution (fig. 1) and our observations suggest that it always co-occurs with Dwarf Pine. Both species are dominants of coniferous heathland, which may also include Creeping Pine (*Microcachrys tetragona* Hook.), Mountain Plum Pine (*Podocarpus lawrencei* Hook.f.) and shrubby forms of the two *Athrotaxis* species. Coniferous heathland occurs at high elevations, typically 1070–1490 m.

Observed climate change in Tasmania includes a rise in mean annual temperature of 0.1°C per decade since the 1950s and changed rainfall seasonality (Grose *et al.* 2010) with regional variation in magnitude and direction of change. Ecological impacts in the Tasmanian highlands are already apparent; notably severe dieback of Cider Gum (*Eucalyptus gunnii* ssp. *divaricata* McAulay & Brett) on the eastern Central Plateau which appears to be largely driven by drought associated with a long-term decline in rainfall (Calder & Kirkpatrick 2008).

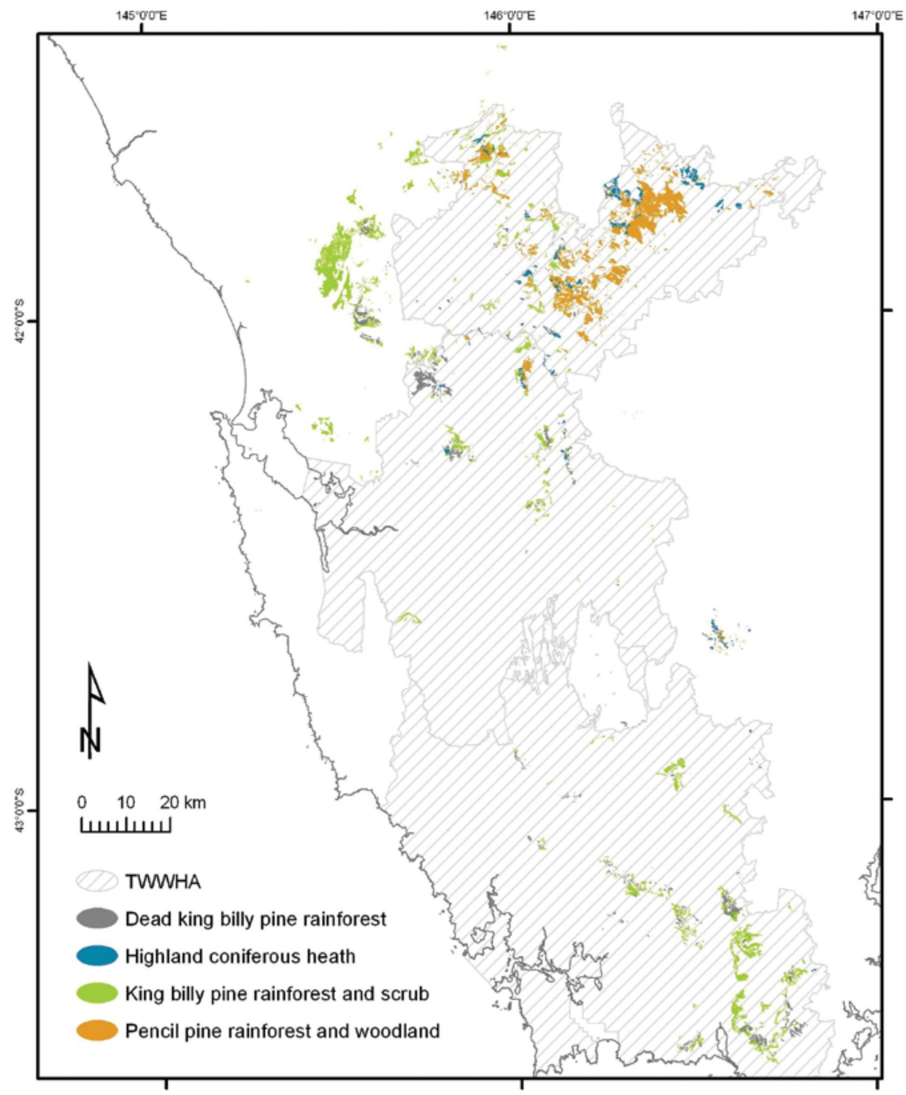

FIG. 1 — Distribution of vegetation communities dominated by the four conifer species targeted for monitoring. Shaded area is the Tasmanian Wilderness World Heritage Area. Vegetation mapping from TASVEG 2.0.

Recent climatic projections for Tasmania indicate little change for central and western Tasmania until after 2040, when there is likely to be a reduction in annual rainfall for the Central Plateau (core range of Pencil Pine) and a marked decrease in summer rainfall in the central west which coincides with the core range of King Billy Pine (Grose *et al.* 2010). Based on six global climate model simulations downscaled for Tasmania, the Central Highlands and western Tasmania are expected to experience increases (from the baseline period 1978–2007) in average and maximum temperatures of approximately 1–2°C during 2040–2069, increasing to 2.5–3°C after 2070; this magnitude of change is expected to be year-round on the Central Plateau, while the West Coast is likely to see more warming in summer than other seasons (Grose *et al.* 2010).

Ecophysiological studies show that King Billy Pine is adapted to cool temperatures (Read & Busby 1990) and is poorly adapted to water stress (Brodribb & Hill 1998, Jordan *et al.* 2004). Read & Busby (1990) suggest that low summer rainfall is the primary limitation for King Billy Pine based on bioclimatic modelling, while their physiological research indicates high summer temperatures are directly limiting, at least at lower elevations where rainfall is adequate. The difficulty of interpreting the climatic niche is compounded by the substantial influence of fire and slow dispersal ability on the realised niche and the possibility that present distributions of vegetation with conifers may reflect past climatic events (Read & Busby 1990).

Pencil Pine, King Billy Pine and Drooping Pine are capable of asexual reproduction by layering or suckering (Cullen & Kirkpatrick 1988a, Gibson *et al.* 1995, TSS 2009). The relative importance of seedling versus vegetative reproduction appears to vary between species and sites.

Cunningham *et al.* (2007) suggest using the term "condition" to describe the appearance of a tree, while "health" refers to actual physiological and pathological factors. This paper describes the method employed for monitoring the condition and recruitment of Tasmania's montane conifer species and provides a baseline for assessing change in the future. The monitoring method presented here is a relatively simple and efficient system for documenting long-term trends in recruitment and condition of flora species and can be applied to other species in Tasmania and elsewhere.

METHODS

Thirteen localities were selected for conifer monitoring, covering much of the geographic extent of the four target conifer species (fig. 2). All sites are recorded on the Parks & Wildlife Service Information Management System (PWSIMS).

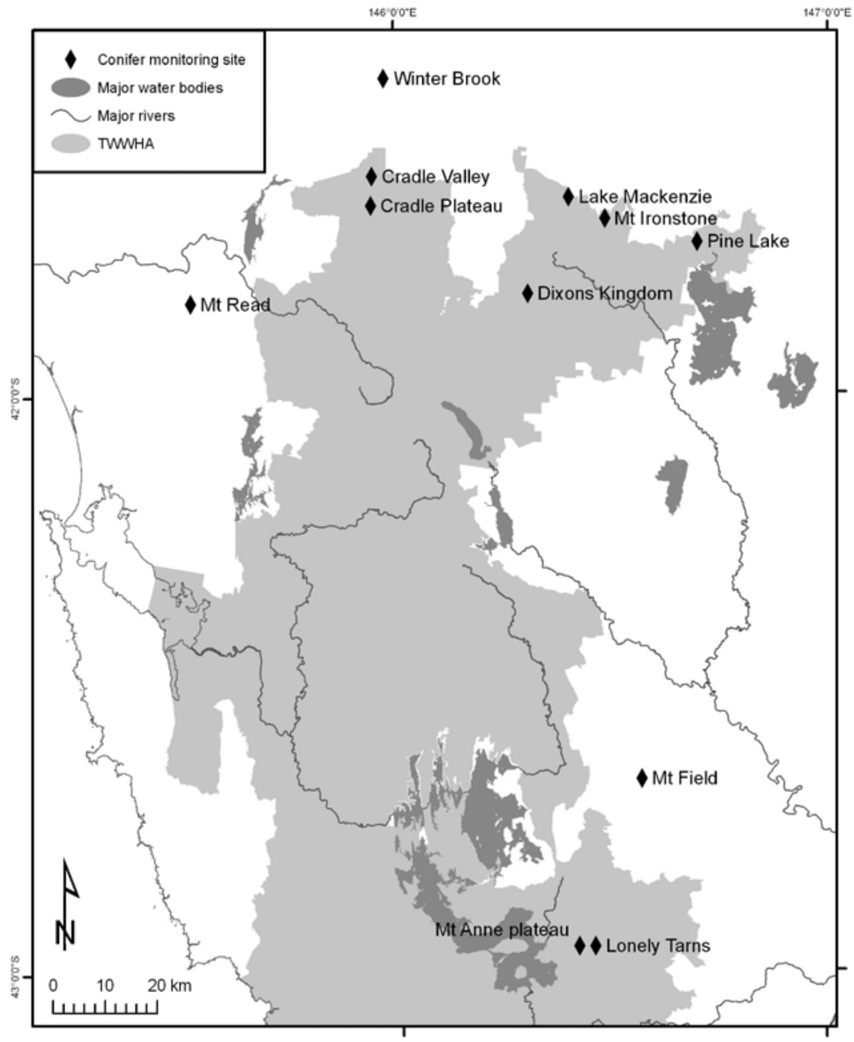

FIG. 2 — Location of montane conifer monitoring sites in Tasmania.

Site description

For each plot the slope, aspect, geology, landform, fire history, vegetation community and ground cover were recorded (see appendix 1). Floristic description involved recording dominant vascular plant species and cover scores by stratum and lifeform categories.

Athrotaxis forest monitoring

Monitoring for *Athrotaxis* forest and woodland uses a modified point-centred quarter method (PCQM) where each "plot" consists of 12 *Athrotaxis* "individuals'"and sampling is based on a permanently marked centre-point. The nearest three *Athrotaxis* trees over 2 m tall are recorded within each of four quadrants delineated by the cardinal compass points. PCQM is widely used for forest inventory surveys as it is more efficient than plot-based sampling and although it is designed for single-trunked upright trees it can be adapted to situations where trees have multiple or leaning trunks (Dahdouh-Guebas & Koedam 2006, Mitchell 2007). Using this method there is theoretically no distance limit for inclusion of trees from the centre-point; however, in practice with small discrete stands of *Athrotaxis* there may be a quarter in which there are fewer than three trees. In this case a correction factor can be applied to the PCQM data to adjust for vacant quarters, or for fewer than 12 individuals (Mitchell 2007). The formula used to estimate density assumes a random distribution of trees which is rarely the case in nature (Mitchell 2007). Pencil Pine appears to have a distinctly clumped distribution in most cases, particularly in woodland communities. Consequently the results must be considered estimates of stand density rather than definitive measures.

Multi-trunked trees where the trunks clearly arise from a common base are recorded as an individual, as are distinct clusters of stems. Root suckers or trunks distant from the cluster (more than c. 1.5 m) are treated separately, even if it appears that they may be connected. Suckering in Pencil Pines results in clonal stands (Cullen & Kirkpatrick 1998b), so it is not feasible or desirable for a field monitoring program to define individuals on a genetic basis.

For each of the 12 "individuals" at a site the following details were recorded: distance and direction from marker post; DBH at 1.3 m (for rare instances where many small stems occur in addition to one or more of larger diameter measure all stems that are more than ¼ the diameter of the largest stem); chlorosis or death of apical foliage (recent/old/absent); cones (absent, present on <50% of branches, present on >50% of branches); age (current season or older) and predominant sex of cones; and an overall condition score ranging from 1 (dead) to 4 (no dieback symptoms). Reference photographs of conifers representing the different condition scores are used as a guideline for assigning the four condition classes (see pls 1–4). The simple four-class condition score was chosen to provide repeatability and reduce observer bias compared to a larger number of classes.

While other researchers have used several indices of tree condition (e.g., crown extent, crown density, crown vigour, leaf condition) for trees with well-defined architecture and dieback processes (e.g., Cunningham *et al.* 2007, Souter *et al.* 2010a, b), this has proved impractical for *Athrotaxis* species due to considerable variability in tree form, which is likely to be related to age and site characteristics.

Recruitment was noted for all conifer species present with the following categories: none, seedling, asexual, seedling and asexual, indeterminate. In addition to the 12 trees per plot any smaller *Athrotaxis* individuals (under 2 m tall) are recorded with location relative to the centre point and a height estimate.

Classification and ordination of plots were performed on the mean health score of trees using PATN (Belbin 1993). Classification used the Agglomerative Hierarchical Fusion, with Gower Metric Association Measure and Flexible UPGMA and SSH ordination method.

Highland coniferous heathland monitoring

For coniferous shrubbery (and *Athrotaxis* vegetation under 2 m tall) sampling is based on 10 x 10 m quadrats oriented to magnetic north and marked with permanent aluminium corner stakes. For each conifer species in a quadrat the following details were recorded: percentage cover (Braun-Blanquet scale); average and maximum height; cones (absent, present on <50% of branches, present on >50% of branches); age and predominant sex of cones; and an overall condition score ranging from 1 (dead) to 4 (no dieback symptoms). Recruitment was noted for all conifer species present with the following categories: none, seedling, asexual, seedling & asexual, indeterminate.

Apart from the four target species, the same observations were also recorded for other conifer species when present at a site.

RESULTS

Recruitment was evident at 11 out of 34 sites for Pencil Pine, with most, or possibly all, juveniles being root suckers. Recruitment was most frequent at Mount Field, followed by Pine Lake, with very little or no recruitment observed at the other study sites. Recruitment was more frequent for *A. selaginoides* with juveniles present at 20 out of 24 sites. All King Billy Pine recruitment appeared to be from seed except at Mount Read where there were apparent root suckers, although further investigation would be required to determine their origin. Some sites had large numbers of small seedlings (less than c. 3 cm tall) but larger seedlings were infrequent.

Condition scores for Pencil Pine show a significant difference between sites (Kruskal-Wallis test, $p < 0.001$) with Mount Field and Mount Ironstone having a median condition score of 3 while the other sites have a median of 4 (table 1). There is no significant difference between sites for *A. selaginoides* with all sites having a median score of 4 (Kruskal-Wallis test, P-Value = 0.067).

Pine Lake (fig. 3) is the only location where condition scores appear to be related to tree size, as measured by DBH (Kruskall-Wallis test, $p = 0.012$), while Lake Mackenzie and Mount Ironstone display a significant relationship at the 10% confidence level. These sites are all located on the northern part of the Central Plateau and are dominated by Pencil Pine, although the nearby Mickeys Creek site does not show a similar relationship.

Recruitment of the shrubby conifer species was evident at most sites, although it was not feasible to distinguish seedlings from root suckers. Instances where no recruitment was observed were usually associated with very low coverage of that particular species in the plot (e.g., only one mature plant present). Continuous vegetative reproduction appears to be commonplace in Drooping Pine and Dwarf Pine. Variation in timing of surveys precludes useful comparison of cone production between sites since the strobili (cones)

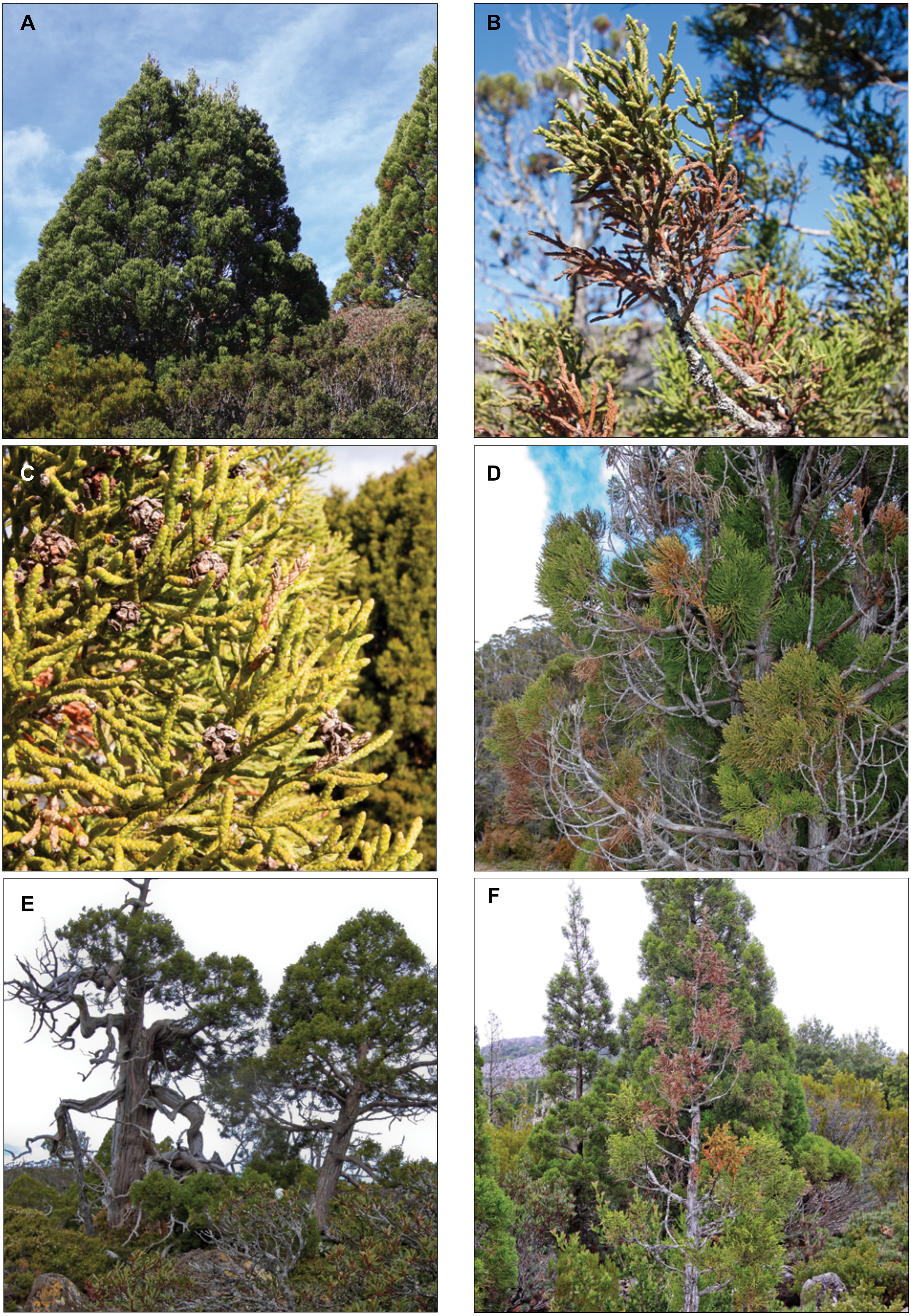

PLATE 1

Examples of Pencil Pine, Arthrotaxis cupressoides*, condition classes: (A), (B) = 4; (C), (D) = 3; (E), (F) = 2.*

PLATE 2

Examples of King Billy Pine, Athrotaxis selaginoides*, condition classes: (A), (B) = 4; (C), (D) = 3; (E), (F) = 2.*

PLATE 3
Examples of Dwarf Pine, Diselma archeri, *condition classes: (A), (B) = 4; (C), (D) = 3; (E), (F) = 2.*

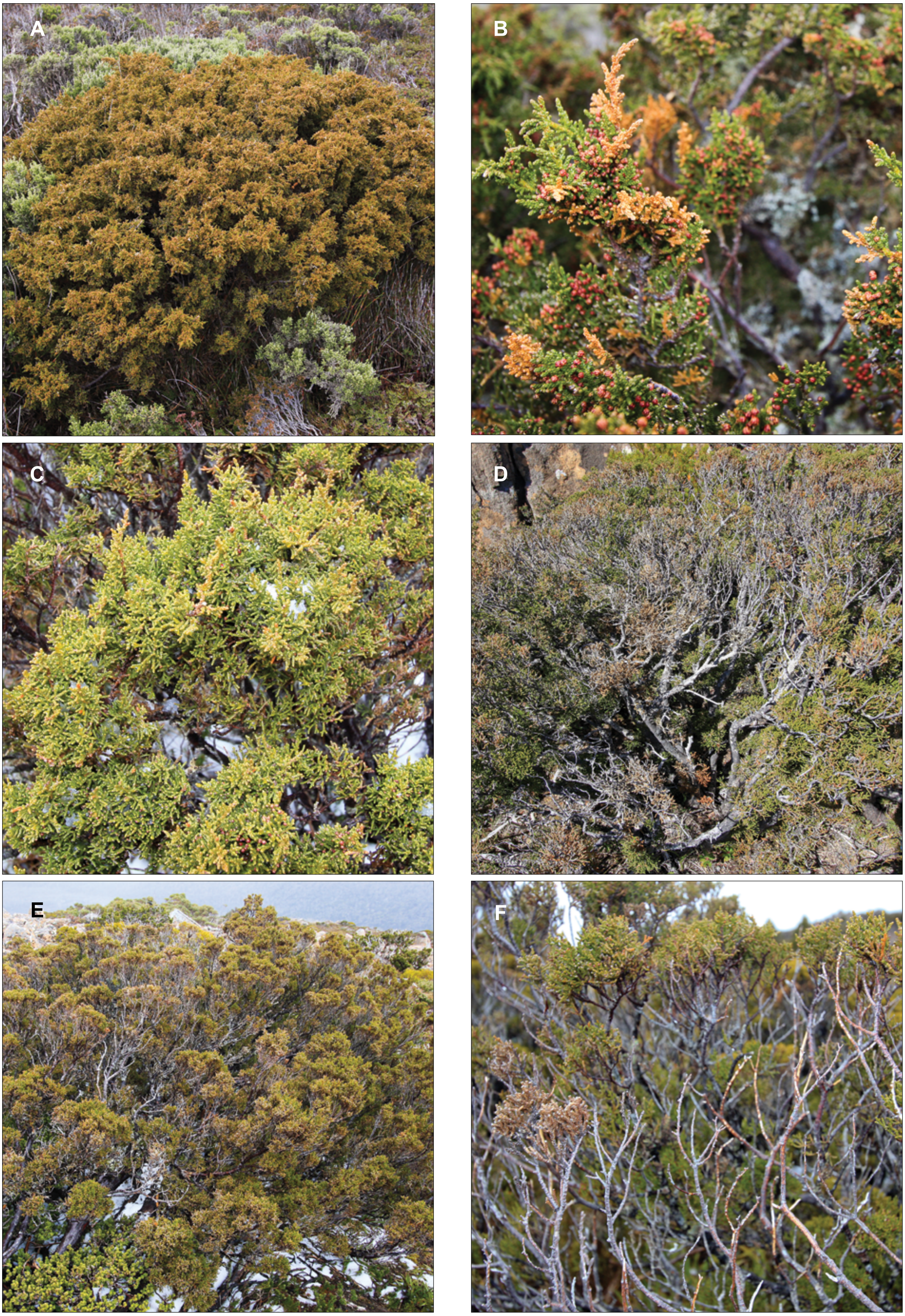

PLATE 4

Examples of Drooping Pine, Pherosphaera hookeriana, *condition classes: (A), (B) = 4; (C), (D) = 3; (E), (F) = 2.*

TABLE 1
Frequency of tree condition scores by species and site.

Species	Location	Condition[1] Score				Total
		1	2	3	4	
Arthrotaxis cupressoides	Cradle Valley			1	21	22
	Dixons Kingdom		3	24	93	120
	Lake Mackenzie			16	32	48
	Mickeys Creek		3	14	19	36
	Mount Field		3	35	22	60
	Mount Ironstone			23	13	36
	Pine Lake		4	31	37	72
	Total		13	144	237	382
A. selaginoides	Cradle Valley		1	9	26	36
	Mount Read			27	53	80
	North East Ridge	1	1	7	50	59
	Winter Brook		1	9	46	56
	Total	1	3	52	175	231
A. Xlaxifolia	Cradle Valley				2	2
	Mount Read			2		2
	Total			2	2	4
Diselma archeri	Mount Read				14	14
	Total				14	14
Total		1	16	198	428	643

[1] Condition class ranges from 1 (dead) to 4 (good condition).

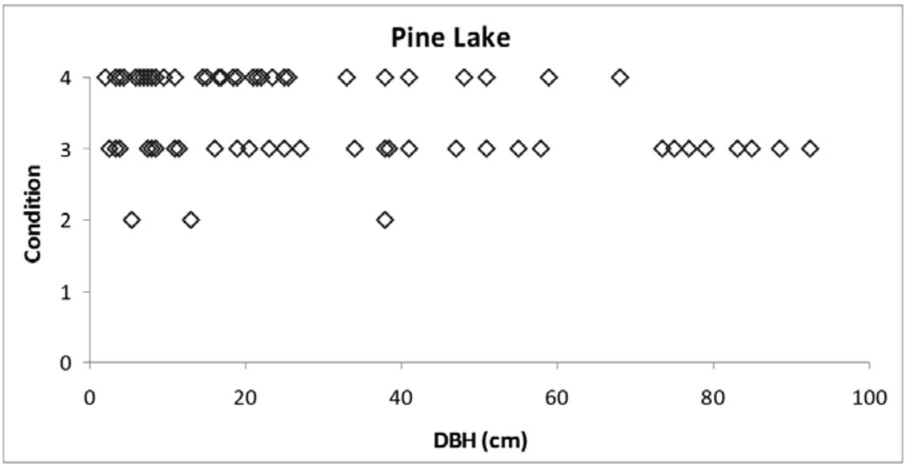

FIG. 3 — Condition scores for Pencil Pine individuals at Pine Lake related to trunk diameter.

are not retained on the plant for more than a few weeks, unlike in *Athrotaxis*.

Dwarf Pine generally exhibited good condition, with 26 out of 30 quadrats having an average condition of 4 (fig. 4). Drooping Pine quadrats were evenly split between those averaging 3 and 4. Ordination analysis (Belbin 1993) indicates that aspect and slope are the most significant variables discriminating the two groups, with good condition (Group 2, score = 4) associated with steeper slopes and more southwesterly aspects (fig. 5).

DISCUSSION

Size class distributions of conifer trees at the study sites indicate continuous or episodic regeneration for Pencil Pine with more episodic recruitment for King Billy Pine (Fitzgerald 2011), which supports recruitment patterns previously reported for these species (Cullen & Kirkpatrick 1988b, Cullen 1991).

Long-term recruitment failure (dating back at least until the first half of the nineteenth century) of Pencil Pine on the Central Plateau in open grassy montane rainforest has in the past been attributed to high levels of grazing pressure from wallabies (*Macropus rufogriseus (*Desmarest, 1817)) and rabbits (*Oryctolagus cuniculus* Linnaeus, 1758), possibly due to the removal of top order predators (Cullen & Kirkpatrick 1988a). However, recruitment observed during our study at Pine Lake but not at similar habitat at Mickeys Creek suggests that other factors may also play a role.

Natural processes such as intraspecific competition and aging can influence tree condition so caution is required when interpreting tree condition and dieback. For example, at Pine Lake none of the largest individuals were classified in the highest condition class, probably due to natural senescence. Similarly the poorest condition individuals occur in the smaller size classes and apparently reflect natural thinning.

Seasonal and interannual variations in condition and phenology are natural phenomena and therefore robust long-term datasets are needed to identify real trends. A further complication is the difficulty of meaningful assessment of tree condition in exposed environments, where trees are deformed and defoliated by weather conditions, but may be healthy despite having features such as dead branches (or trunks), reduced crown size or bark stripped by ice storms.

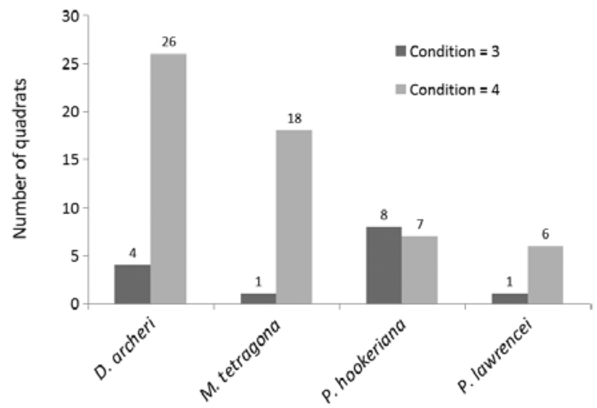

FIG. 4 — Number of quadrats by average condition class for shrubby conifer species, Diselma archeri, Microcachrys tetragona. Pherosphaera hookeriana, *and* P. lawrenci. *Condition class ranges from 1 (dead) to 4 (good condition.*

Extreme events such as drought and heatwaves (White *et al.* 2010) and consequent increases in fire severity and frequency (Williams *et al.* 2009) are likely to have more impact on conifers than shifts in mean temperature and rainfall. Rainforest and alpine vegetation is at risk of increased frequency and intensity of fire events if recent trends of increased incidence of dry lightning and drier soil conditions in western Tasmania continue (DPIPWE 2010). Predicting the locations of likely future climatic and fire refugia for montane conifers would help inform the conservation management of these species, especially in terms of fire protection priorities.

In all four conifer species, both plants and seeds are readily killed by fire. The four conifers have poor seed dispersal which limits the possibility of successful recolonisation (Kirkpatrick & Dickinson 1984). Although King Billy Pine can recolonise or regenerate after fire in some circumstances, it is more commonly eliminated by fire (Cullen 1987). Palynological profiles provide strong evidence for local extinctions of conifer species due to fire and in some cases reoccupation has not occurred after thousands of years (Cullen & Kirkpatrick 1988a, Kirkpatrick & Dickinson 1984).

Warmer temperatures are expected to increase the altitude of the treeline (Richardson & Friedland 2009), theoretically resulting in subalpine forest migrating upslope. Given the longevity and slow growth of *Athrotaxis*, migration of *Athrotaxis* forest would be slow but the already established shrubby *Athrotaxis* at higher altitudes would provide a basis for forest development at sites previously marginal for tree species, dependent on factors such as wind and snow in addition to temperature (Green 2009). Observed mortality of Snow Peppermint (*Eucalyptus coccifera* Hook.f.) co-occurring with Pencil Pine is likely due to severe frosts (Cullen & Kirkpatrick 1988b), so a reduction in the severity of frost might be expected to facilitate eucalypt invasion of Pencil Pine woodland.

Changes in phenology are expected in response to environmental change, either through physiological responses to environmental cues or as a response to stress. Phenological

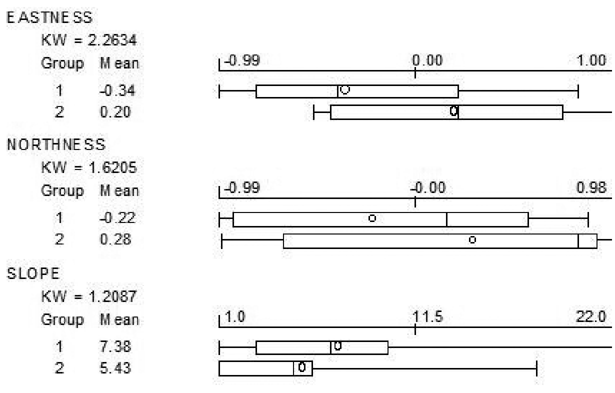

FIG. 5 — Box-plots of the three most significant variables (KW = Kruskall-Wallis statistic) discriminating between two groups of plots based on condition scores for Drooping Pine. Group 1 is plots with an average condition class of 3 (representing somewhat poor condition) while Group 4 plots have an average condition class of 4 (good condition). Box represents quartiles, whiskers are the range, vertical line is median, diamond is mean. An eastness value of 1 = due east while -1 = due west, similarly northness value of 1 = due north and -1 = due south.

changes can be variable and difficult to predict within a species, so long-term and geographically broad datasets are needed to determine trends (Primack *et al.* 2009). The phenology of *Athrotaxis* warrants further study and it would be informative to undertake annual monitoring of cone production along with germination trials.

Drooping Pine produces limited quantities of viable seed with a deep physiological dormancy which may result in a semi-persistent soil seed bank (Wood 2011, James Wood, pers. comm.). This is supported by field observations which suggest that seedlings are very rare and reproduction is largely vegetative in this species (TSS 2009).

This survey determines the current condition status across the range of four conifer species, providing a baseline for monitoring of spatial and temporal trends. Additionally, dendrochronology undertaken on *Athrotaxis* species at various locations provides centuries-scale data on growth rates and responses to environmental change by these species (e.g., Allen *et al.* 2011). Long-term changes in the health of conifers at the stand level are likely to occur over decadal scales. If climate change is a driver of health decline, the conifers may not show significant effects until a climatic threshold is reached.

In the future, time series data will be analysed for long-term spatial and temporal trends in conifer condition. The range of monitoring sites provides replication and allows analysis of spatial patterns in condition, particularly if combined with remote sensing techniques. The geographic variation between sites (e.g., altitude) also provides a surrogate for climate and will be useful in examining the potential influence of climatic factors on conifer health.

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APPENDIX 1
Site details for conifer monitoring plots.

LOCATION	SITE	EASTING	NORTHING	ELEV^{N}	PLOT TYPE	SLOPE	ASPECT	TASVEG	GEOLOGY	POSITION	LAND-FORM	FIRE HISTORY
Cradle Plateau	CMCH01	412115	5385705	1233	10 x 10 m	7	300	HCH	Quartzite/Schist	Mid Slope	Other	None
Cradle Plateau	CMCH02	412127	5385733	1232	10 x 10 m	5	270	HCH	Quartzite/Schist	Lower Slope	Other	None
Cradle Plateau	CMCH03	412387	5385767	1239	10 x 10 m	7	34	HCH	Quartzite/Schist	Mid Slope	Other	None
Cradle Plateau	CMCH04	412159	5386260	1278	10 x 10 m	4	100	HCH	Quartzite/Schist	Upper Slope	Other	None
Cradle Plateau	CMCH05	412053	5386363	1280	10 x 10 m	2	10	HCH	Quartzite/Schist	Ridge	Other	None
Cradle Plateau	CMCH06	412166	5386590	1249	10 x 10 m	10	30	HCH	Glacial till	Mid Slope	Other	None
Cradle Valley	CVKB01	413157	5390467	990	PCQ	15	160	RKP	Quartzite/Schist	Mid Slope	Other	None
Cradle Valley	CVKB02	413164	5390562	1014	PCQ	15	150	RPW	Quartzite/Schist	Mid Slope	Other	None
Cradle Valley	CVKB03	411935	5389954	945	PCQ	10	165	RKP	Quartzite/Schist	Mid Slope	Other	None
Cradle Valley	CVKB04	411891	5389988	956	PCQ	8	160	RKP	Quartzite/Schist	Mid Slope	Other	None
Cradle Valley	CVPP01	412290	5391381	846	PCQ	28	190	RPP	Glacial till, Quartzite/Schist	Lower Slope	Other	None
Walls of Jerusalem	DKPP01	442547	5369072	1279	PCQ	18	130	RPP	Dolerite	Mid Slope	Other	None
Walls of Jerusalem	DKPP02	442490	5368992	1266	PCQ	10	150	RPP	Dolerite	Mid Slope	Other	None
Walls of Jerusalem	DKPP03	442374	5368914	1260	PCQ	4	120	RPP	Dolerite	Mid Slope	Other	None
Walls of Jerusalem	DKPP04	442345	5368649	1239	PCQ	7	130	RPP	Dolerite	Mid Slope	Other	None
Walls of Jerusalem	DKPP05	442828	5369050	1289	PCQ	15	220	RPW	Dolerite	Mid Slope	Talus slope	None
Walls of Jerusalem	DKPP06	442349	5368052	1177	PCQ	3	170	RPP	Dolerite	Lower Slope	Bog	None
Walls of Jerusalem	DKPP07	442158	5367901	1160	PCQ	12	210	RPP	Dolerite	Lower Slope	Other	None
Walls of Jerusalem	DKPP08	442321	5368157	1195	PCQ	5	160	RPP	Dolerite	Mid Slope	Other	None
Walls of Jerusalem	DKPP09	442301	5369227	1326	PCQ	12	170	RPP	Dolerite	Upper Slope	Other	None
Walls of Jerusalem	DKPP10	442085	5369183	1305	PCQ	5	140	RPP	Dolerite	Mid Slope	Other	None
Lake Mackenzie	LMPP01	449207	5386940	1142	PCQ	3	200	RPW	Dolerite	Lower Slope	Talus slope	None
Lake Mackenzie	LMPP02	449755	5387619	1147	PCQ	3	170	RPW	Dolerite	Mid Slope	Blockstream	Stags, scars
Lake Mackenzie	LMPP03	450197	5387561	1184	PCQ	10	190	RPP	Dolerite	Mid Slope	Other	None

APPENDIX 1 cont.

LOCATION	SITE	EASTING	NORTHING	ELEV^{N}	PLOT TYPE	SLOPE	ASPECT	TASVEG	GEOLOGY	POSITION	LAND-FORM	FIRE HISTORY
Lake Mackenzie	LMPP04	450079	5387112	1132	PCQ	5	190	RPP	Dolerite	Lower slope	Talus Slope	Stags, Scars
Mount Anne	MACH01	452577	5243555	1230	10 x 10 m	18	40	HCH	Dolerite	Mid slope	Other	None
Mount Anne	MACH02	452493	5243564	1264	10 x 10 m	15	45	HCH	Dolerite	Upper slope	Other	None
Mount Anne	MACH03	452465	5243496	1282	10 x 10 m	10	30	HCH	Dolerite	Upper slope	Other	None
Mount Anne	MACH04	452420	5243465	1291	10 x 10 m	14	20	HCH	Dolerite	Ridge	Other	None
Mount Anne	MACH05	452637	5243858	1258	10 x 10 m	4	150	HCH	Dolerite	Ridge	Other	None
Mount Anne	MACH06	452708	5243792	1238	10 x 10 m	22	120	HCH	Dolerite	Upper slope	Other	None
Mount Anne	MACH07	452713	5243654	1207	10 x 10 m	2	140	HCH	Dolerite	Gully	Other	None
Mount Anne	MACH08	453262	5244467	1181	10 x 10 m	30	20	HCH	Dolerite	Mid slope	Talus Slope	None
Mount Anne	MACH09	453544	5244483	1095	10 x 10 m	5	20	HCH	Dolerite	Mid slope	Other	None
Mount Anne	MACH10	453628	5244507	1070	10 x 10 m	8	0	HCH	Dolerite	Mid slope	Other	None
Mount Anne	MACH11	455512	5243396	929	10 x 10 m	6	100	HCH	Glacial till	Gully	Other	None
Mount Anne	MACH12	455542	5243492	925	10 x 10 m	6	30	HCH/ MRR	Dolerite, glacial till, quartzite/schist	Upper slope	Other	None
Mount Anne	MACH13	455411	5243561	916	10 x 10 m	1	270	HCH	Glacial till	Flat	Bog	None
Mount Anne	MACH14	455273	5243393	930	10 x 10 m	8	180	HCH/ HHW	Glacial till	Lower slope	Other	None
Mount Anne	MACH15	455177	5243426	928	10 x 10 m	7	280	HCH	Glacial till	Upper slope	Other	None
Mount Anne	MAKB01	453963	5247185	780	PCQ	13	310	RKP	Limestone	Mid slope	Other	None
Mount Anne	MAKB02	454036	5247054	826	PCQ	25	310	RKP	Limestone	Mid slope	Other	None
Mount Anne	MAKB03	454094	5246895	892	PCQ	20	330	RKP	Limestone	Mid slope	Other	None
Mount Anne	MAKB04	454110	5246792	937	PCQ	25	355	RKP	Limestone	Upper slope	Other	None
Mount Anne	MAKB05	454329	5246470	1089	PCQ	5	160	RKS	Limestone	Ridge	Other	None
Mickeys Creek	MCPP01	473880	5377055	1226	PCQ	3	180	RPP	Dolerite	Mid slope	Talus Slope	Stags, scars
Mickeys Creek	MCPP02	474087	5376925	1210	PCQ	1		RPW/ RPP/ HHE	Dolerite	Flat	Bog	Stags, scars
Mickeys Creek	MCPP03	474990	5376917	1215	PCQ	5	200	RPW	Dolerite	Lower slope	Blockstream	Stags, scars
Mount Field	MFCH01	464485	5275568	1208	10 x 10 m	10	30	RPW	Dolerite	Lower slope	Talus Slope	None

APPENDIX 1 cont.

LOCATION	SITE	EASTING	NORTHING	ELEV^N	PLOT TYPE	SLOPE	ASPECT	TASVEG	GEOLOGY	POSITION	LAND-FORM	FIRE HISTORY
Mount Field	MFCH02	464907	5275048	1220	10 x 10 m	22	290	HCH	Dolerite	Mid slope	Talus slope	None
Mount Field	MFCH03	463972	5276825	1149	10 x 10 m	18	120	RPW	Dolerite	Lower slope	Talus slope	None
Mount Field	MFCH04	465834	5274021	1274	10 x 10 m	2	160	HCH	Dolerite	Flat	Other	None
Mount Field	MFCH05	465846	5273951	1274	10 x 10 m	1	160	HCH	Dolerite	Flat	Other	None
Mount Field	MFCH06	465965	5273327	1273	10 x 10 m	3	330	HCH	Dolerite	Upper slope	Other	None
Mount Field	MFCH07	465843	5273334	1251	10 x 10 m	6	190	HCH	Dolerite	Upper slope	Blockstream	None
Mount Field	MFCH08	465567	5274030	1290	10 x 10 m	5	320	HCH	Dolerite	Ridge	Other	None
Mount Field	MFCH09	465661	5274579	1242	10 x 10 m	1	40	HCH	Dolerite	Upper slope	Other	None
Mount Field	MFCH10	465801	5274601	1223	10 x 10 m	1	100	HCH	Dolerite	Mid slope	Other	None
Mount Field	MFPP01	464485	5275568	1208	PCQ	10	30	RPW	Dolerite	Lower slope	Talus slope	None
Mount Field	MFPP02	464384	5275691	1185	PCQ	15	280	RPW	Dolerite	Mid slope	Other	None
Mount Field	MFPP03	463972	5276825	1149	PCQ	18	120	RPW	Dolerite	Lower slope	Other	None
Mount Field	MFPP04	464119	5276795	1141	PCQ	15	250	RPW	Dolerite	Lower slope	Other	None
Mount Field	MFPP05	463992	5276074	1162	PCQ	12	30	RPF	Dolerite	Lower slope	Other	None
Mount Ironstone	MIPP01	457036	5383255	1239	PCQ	6		RPW	Dolerite	Mid slope	Blockstream	None
Mount Ironstone	MIPP02	457195	5383363	1229	PCQ	4	330	RPW	Dolerite	Mid slope	Blockstream	None
Mount Ironstone	MIPP03	457122	5383414	1223	PCQ	6	330	RPW	Dolerite	Mid slope	Blockstream	None
Mount Read	MRCH01	378708	5366156	1074	10 x 10 m	5		RKF	Mt Read volcanics	Upper slope	Other	None
Mount Read	MRCH02	378569	5366138	1070	10 x 10 m	8	100	HCH	Mt Read volcanics	Ridge	Other	None
Mount Read	MRKB01	378643	5365299	892	PCQ	4	220	RKF	Mt Read volcanics, quartzite	Upper slope	Other	None
Mount Read	MRKB02	377534	5366684	976	PCQ	8	280	RKP	Mt Read volcanics	Mid slope	Other	None
Mount Read	MRKB03	378624	5365577	910	PCQ	2	170	RKF	Mt Read volcanics	Gully	Other	None
Mount Read	MRKB04	378961	5366286	1099	PCQ	7	180	RKF	Mt Read volcanics	Upper slope	Other	None
Mount Read	MRKB05	377523	5366648	968	PCQ	13	230	RKP	Mt Read volcanics	Mid slope	Other	None
Mount Read	MRKB06	377709	5367451	963	PCQ	35	70	RKP	Mt Read volcanics	Ridge	Other	*Athrotaxis* stags

APPENDIX 1 cont.

LOCATION	SITE	EASTING	NORTHING	ELEV^{N}	PLOT TYPE	SLOPE	ASPECT	TASVEG	GEOLOGY	POSITION	LAND-FORM	FIRE HISTORY
Mount Read	MRKB07	377590	5367316	947	PCQ	18	270	RKP	Mt Read volcanics	Upper slope	Other	*Athrotaxis* stags
Mount Read	MRKB08	377672	5367335	967	PCQ	35	290	RKP	Mt Read volcanics	Mid Slope	Other	*Athrotaxis* stags
Nive River	NRCH01	447397	5349114	910	50 x 2 m	0	298	SRI	Dolerite	Flat	Other	None
Pine Lake	PLPP01	475472	5378439	1195	PCQ	2	10	RPW	Dolerite	Lower slope	Blockstream	None
Pine Lake	PLPP02	475749	5378308	1185	PCQ	2	110	RPW	Dolerite	Flat	Blockstream	Stags, scars
Pine Lake	PLPP03	475029	5379090	1196	PCQ	3	95	RPP	Dolerite	Flat	Blockstream	None
Pine Lake	PLPP04	474947	5378989	1198	PCQ	4	110	RPW	Dolerite	Flat	Blockstream	Stags, Scars
Pine Lake	PLPP05	474817	5378880	1203	PCQ	8	80	RPP	Dolerite	Mid Slope	Blockstream	None
Pine Lake	PLPP06	475044	5378764	1195	PCQ	2	50	RPW	Dolerite	Flat	Bog	None
Winterbrook	WBKB01	414091	5410168	839	PCQ	18	40	RKP	Conglomerate	Mid Slope	Other	None
Winterbrook	WBKB02	414241	5410204	807	PCQ	15	70	RKP	Conglomerate	Mid Slope	Other	None
Winterbrook	WBKB03	414565	5410251	743	PCQ	30	310	RKP	Conglomerate	Mid Slope	Other	None
Winterbrook	WBKB04	414769	5410445	707	PCQ	8	320	RKP	Conglomerate	Mid Slope	Other	None
Winterbrook	WBKB05	414813	5410467	705	PCQ	7	350	RKP	Conglomerate	Mid Slope	Other	None
Winterbrook	WBKB06	416157	5411600	621	PCQ	0	0	RML	Conglomerate	Flat	Other	None