Seedling regeneration of celery-top pine *(Phyllocladus aspleniifolius)* after harvesting of rainforest in north-western Tasmania

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Abstract

Seedling regeneration of celery-top pine (Phyllocladus aspleniifolius) *was monitored following harvesting on three sites in north-western Tasmania. A different silvicultural system was trialled at each site: light selective harvesting with no burning, clearfelling followed by a high-intensity burn, and patchfelling followed by a low-intensity burn.*

Regeneration on all three sites reached rainforest regeneration stocking standards, with many plots containing seedlings of myrtle (Nothofagus cunninghamii) *and leatherwood* (Eucryphia lucida) *as well as celery-top pine. Celery-top pine regeneration was stimulated by both harvesting disturbance and burning, but was sparse or absent wherever the disturbance removed the organic soils and exposed the underlying gravels. Burning damaged or killed many of the retained trees, so wherever possible regeneration should be established with harvesting as the only disturbance.*

Early growth rates for celery-top pine were very slow, with average height growth of around 10 cm per year. The growth rings measured on stumps at two sites suggested that 300–400 years is required to produce a celery-top pine log of 50–60 cm diameter.

Introduction

Celery-top pine *(Phyllocladus aspleniifolius)* is an endemic Tasmanian conifer from the Podocarpaceae family. It is a common rainforest tree species on less-fertile sites, dominating thamnic rainforests (Jarman *et al.* 1984) at low altitude in western Tasmania, and also occurs as a sub-dominant tree in wet eucalypt forests (Barker 1992). Its scientific name is derived from the phylloclades or flattened branchlets that it bears instead of true leaves. The tree is long-lived (about 800 years) (Working Group for Rainforest Conservation 1987) and produces very durable timber. This has traditionally been used for boat-building, window frames and railway sleepers, but is now mainly used for furniture, interior lining and smaller craft items. Growth rings in celery-top pine are narrow, as growth is slow, but the rings are generally quite clear. Counting of growth rings of mature celery-top pine trees can estimate the length of time needed to grow celery-top pines of merchantable sawlog size (currently about 50 cm diameter at 1.3 m above ground).

Celery-top pine timber is mainly produced whilst harvesting eucalypt sawlogs from mixed eucalypt forest on less-fertile sites, or from the poorer margins of Special Timbers Zones (Rainforest) (Forestry Tasmania 2010) where the primary target species is often myrtle *(Nothofagus cunninghamii).* There have also been some small harvesting operations that have targeted celery-top pine for railway sleepers, and some salvage after wildfire. Approximately half of Tasmania's annual celery-top pine production comes from the far north-west of Tasmania. Statewide annual celery-top pine sawlog production fluctuates (Figure 1), varying in accord with the celery-top pine component of harvested stands. The average cut was 1530 m^3 per year over the period 1997-2008.

Celery-top pine has a small black seed, which is partially enclosed within a white aril (fleshy seed-stalk), and a fleshy red receptacle (Working Group for Rainforest Conservation 1987). Birds eat the receptacles and can disperse the seed over long distances (Kirkpatrick 1977, Hill and Read 1984). The seed is also stored in the soil (Read 1989). Delayed germination of the hard seed has been reported by both Hickey and Wilkinson (1999) and Read (1989). It is likely that some dormancy mechanism is necessary to survive bird dispersal (Read 1989) or that there is a requirement for an after-ripening period after seed is shed (Barker 1994, 1995). These characteristics potentially facilitate celery-top pine regeneration after mechanical disturbance and/or fire (Calais and Kirkpatrick 1983, Tyquin 2005, Tabor 2007).

Observations of relatively even-aged stands of celery-top pine (R. Mesibov, pers. comm.) suggested that celery-top pine can regenerate abundantly following major disturbance, for example wildfire, but the mechanisms for this are unclear. A series of logging and regeneration trials was established in Murchison Forest District during the 1980s, with the aim of identifying the requirements for celery-top pine seedling regeneration. The trials were located in areas contained within a mosaic of eucalypt coupes that were harvested and then regenerated using high-intensity burning over the same time period as the trials were established, and escapes from regeneration burns led to unintentional burns in several of the selectively logged trial coupes, providing additional variation between sites. This report summarises the findings from three different celery-top pine harvesting and regeneration trials. The three trials were located in two different coupes and the treatments applied at each site were different, without replication of any treatment. Comparisons between treatments therefore can be made only with due caution.

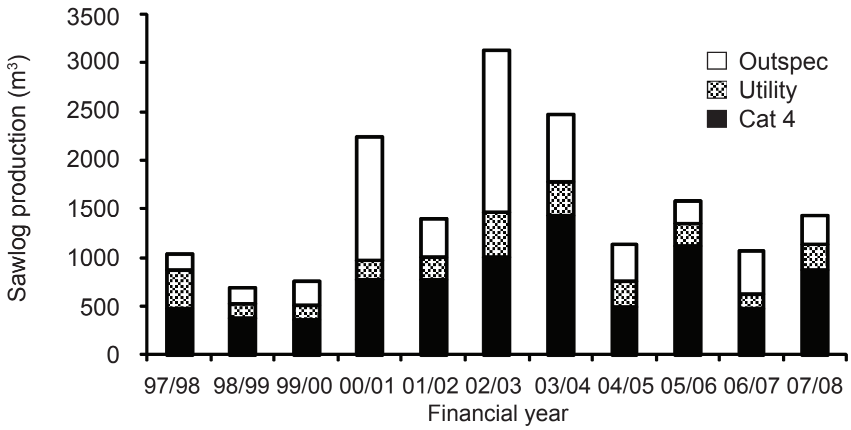

Figure 1. Statewide celery-top pine sawlog production from 1998 to 2008. Outspec, utility and Cat 4 refer to grades of sawlog.

Table 1. Harvesting and regeneration treatments for three rainforest sites

Site	Treatment	Area (ha)	Canopy retained	Harvest date	Site preparation	Burn date
Site 1	Selective harvesting, no burn	15	80%	Jul 1978	ground disturbance during harvest (50% of area)	nil
Site 2	Clearfell, high-intensity burn	17	0%	1981 (incomplete) + Nov 1984	hot burn (>50% of area)	Mar 1988
Site 3	Patchfell, low-intensity burn	7	5%	1981 (incomplete) + Sep 1986	low-intensity burn (58% of area)	Nov 1986

Methods

Site descriptions

The locations of the trial sites are shown in Figure 2. The three sites all lie within 5 km of each other, at 100 to 300 m above sea level. Harvesting and regeneration treatments, coupe areas and relevant dates are summarised in Table 1.

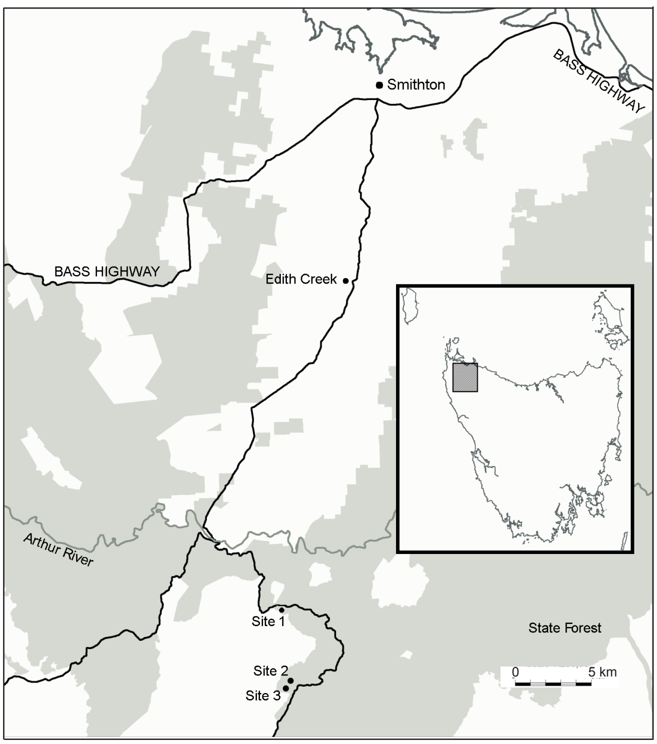

Figure 2. Location of trial sites. Grey shading, State forest.

Site 1 experienced selective harvesting and no burning. It covers 15 ha of State forest adjoining Sumac Road, 500 m east of the Julius River Bridge (GDA: 335100 E, 5442250 N). The forest was mature thamnic rainforest dominated by myrtle up to 25 m tall. It was well stocked with celery-top pines mostly greater than 30 cm diameter at breast height (dbh, breast height being 1.3 m), with a dense understorey of horizontal *(Anodopetalum biglandulosum).* There were no celery-top pine saplings (up to 5 cm dbh) or poles (trees of 5–30 cm dbh). The topography is relatively flat, with a gradual fall to the south-west to a tributary of the Julius River. The parent material is pre-Cambrian dolomite. Soils are black to brown peat, averaging 0.5 m in depth and overlying dolomite gravel.

Site 2 experienced clearfell and high-intensity burning. It is part of Sumac Compartment 7E, in an area between Dempster Plain and Sumac Rivulet (GDA: 335700 E, 5437300 N). The trial area was in a 17 ha patch of thamnic rainforest situated within a larger area of wet eucalypt forest. The wet eucalypt forest comprised *Eucalyptus obliqua* and *E. nitida* over myrtle, sassafras *(Atherosperma moschatum),* leatherwood and manferns *(Dicksonia antarctica).* The rainforest was dominated by myrtle (up to 25 m tall) and celery-top pines with a sub-dominant leatherwood layer and a scattering of blackwood *(Acacia melanoxylon).* The shrub layer was predominantly native plum *(Cenarrhenes nitida)*, native laurel *(Anopterus glandulosus)* and horizontal. The trial area is on a north-west facing slope. Organic soils (peats) overlay pre-Cambrian dolomite gravel and silt.

Site 3 experienced patchfelling and low-intensity burning. It was a 7 ha patch of thamnic rainforest, also within Sumac Compartment 7E (GDA: 335400 E, 5436800 N). The trial site was dominated by myrtle, leatherwood and celery-top pine, with *Leptospermum* spp., horizontal and native plum. The forest surrounding the trial area was patchy *E. obliqua* and *E. nitida* forest with areas of buttongrass moorland. The trial area was flat. Organic soils overlay pre-Cambrian dolomite gravels.

Harvesting and burning treatments

Site 1 was selectively harvested for special species sawlogs during the winter of 1978. Single trees or small groups of trees were removed. The trial area was excluded from further harvesting when the surrounding mixed forest was subsequently cut-over for eucalypt sawlog and pulpwood. Undisturbed areas were mainly horizontal thickets or patches of myrtle and leatherwood without celery-top pine. Harvesting of the celery-top pine was incomplete, with eleven live celery-top pine trees per hectare remaining after logging, amongst retained leatherwood and myrtle stems. An area was fenced with wire netting in July 1980 to assess the impacts of browsing on the regeneration of rainforest species, but presumably some seedlings were lost to browsing in the period between harvesting and fencing. No regeneration burning was undertaken. Site disturbance was estimated using temporary regeneration transects.

Site 2 was selectively logged in 1981, producing some celery-top pine and blackwood sawlogs. The surrounding eucalypt areas were harvested for sawlog during the winters of 1983 and 1984, producing predominantly *E. nitida*, and then logged for pulpwood in 1984. In late 1984, the site was harvested again, with both celery-top pine and blackwood sawlog and pulpwood being taken. Only scattered rainforest trees remained on the site. The result was very close to a clearfell. The area was lightly scarified after harvesting.

No regeneration burning was planned for Site 2. However, the trial area was burnt in March 1988, when the adjoining eucalypt coupe was burnt in a high-intensity regeneration burn. A site visit in early 1989 reported that "the burn was estimated to have affected more than 50% of the trial area with about 15 cm of peat remaining on most burnt areas" (John Kelly, pers. comm.). An unknown depth of peat had been burnt away by the fire. Windthrow of the retained rainforest trees followed and, by the 14-year measurement, very few pre-harvest trees remained alive on the trial area.

Site 3 was also selectively logged in 1981, producing some celery-top pine and blackwood sawlog. As at Site 2, the surrounding eucalypt areas were harvested for sawlog during the winters of 1983 and 1984, producing predominantly *E. nitida,* then logged for pulpwood in 1984. In late 1986, Site 3 was harvested again to more stringent specifications. This resulted in a patchfell with some scattered unmerchantable rainforest trees remaining. A dense patch of horizontal remained unlogged. The area produced celery-top pine sawlog, small amounts of blackwood and myrtle sawlog, and some celery-top pine and myrtle pulpwood. A low-intensity burn was conducted under mild conditions in spring 1986. The extent of the burn was estimated using temporary regeneration transects.

Regeneration and seedbed monitoring

Natural regeneration was monitored with both permanent plots (Sites 1 and 2, although at Site 2 these were lost in the subsequent burn and limited data are available) and temporary regeneration surveys (Sites 1, 2 and 3). Seedling data on some plots may include advanced-growth seedlings present before the harvesting took place. A plot is defined as "stocked" if it contained at least one seedling.

Thirteen circular 4 m^2 permanent plots were subjectively located at Site 1 across the range of available seedbeds and light conditions. Five of these were within the netting fence. The plots were assessed two, four and six years after harvesting. Seedlings of rainforest tree species (myrtle, blackwood, leatherwood, celery-top pine and sassafras) were counted and the height of the tallest seedling of each species was measured.

Regeneration surveys were also carried out on striplines 100 m apart with 4 m^2 circular plots at 20 m intervals. These were measured one, six and 22 years after harvesting at Site 1, 14 years after the escaped regeneration burn at Site 2, and one, five and 16 years after burning at Site 3. These temporary transects were randomly located each time, and therefore sampled slightly different areas at each measurement, but usually comprised 3–5 striplines of 10–15 plots, depending on coupe size and shape. On each plot, the presence or absence of any rainforest tree species seedlings, the number of celery-top pine seedlings, and the height of the tallest celery-top pine seedling were recorded. Seedbed disturbance was scored with plots classified as being either completely undisturbed, or having predominantly canopy disturbance with only minor ground disturbance, or ground disturbance with scraped peat (these plots may have had additional canopy disturbance), or peat removal; when it was more difficult to determine plot history, they were classified as either disturbed or undisturbed.

The results of stocking versus disturbance were analysed using Fishers exact test for count data to establish whether differences were significant.

Species diversity and forest structure

During the final regeneration survey at each site, a basal area sweep was carried out at each plot point with a factor 2 optical wedge, and the basal area of live celery-top pine trees recorded. The understorey species present on each plot were also recorded. A species was not counted as "common" unless it appeared on at least 15% of plots.

Photographs were also taken at the final measurement, and observations on the general forest structure were made. Aerial photographs taken at intervals during the measurement period were also examined to monitor changes in the forest structure across the three sites over time.

Celery-top pine ring counts

Annual growth rings on mature celery-top pine stumps at Sites 1 and 2 were counted to estimate how long the trees had taken to reach their pre-harvest diameter. Growth rings in *Phyllocladus* are clear, but annual rings can often be absent (Allen *et al.* 2001; Cook *et al.* 1995) so counts need to be interpreted with caution. Ring counts were regressed against stem diameters to examine the relationship between age and diameter.

At Site 1, rings were counted on 11 sound celery-top pine stumps located within an area of approximately 1 ha within and around the fenced area, which was located at the end of the main track. Stem sections (discs) were cut from the top of each stump, planed and the rings counted in the office using a hand-held magnifying lens. Stem diameter was measured at the top of the stump (0.3–0.8 m above the ground).

At Site 2, rings were counted on 12 sound celery-top pines within a 0.1 ha circular plot located within the harvested area. Diameters of these trees were measured at 1.3 m (breast height), before harvesting took place. Sections were taken from the top of the stumps (0.2-0.4 m above the ground) and rings counted under a low-power microscope. Where two good counts were taken on different radii, the mean of the counts was used.

Two adjustments were made to allow comparison of data from Site-1 trees measured at stump height (0.3-0.8 m) with data from Site-2 trees measured at breast height (1.3 m). First, a figure of 10 years was subtracted from the age of Site-1 stump counts made at 0.3 m (pro-rata for other stump heights), on an assumption of seedling height growth of 10 cm per year. Second, 10 mm was subtracted from Site-1 stump diameters, on an assumption of a diameter increase of 1 mm per year. However, due to the age of the trees and their very slow growth, this standardisation made very little difference (data not shown) so the original measurements and counts are shown.

Celery-top pine seedfall

Celery-top pine seedfall was measured from 1981 to 1987 using one 1 m^2 circular seed trap, 1.3 m high, subjectively located beneath standing celery-top pines at Site 1.

Results

Species diversity and forest structure

The three sites were very different in structure and species diversity at the final measurement (Figure 3). Figures 4-6 show typical site views plus details of the regeneration at each site.

Site 1 (selective harvesting, no burn) at 22 years still resembled rainforest, being dominated by myrtle and leatherwood ranging from 15 to 25 m in height (Figure 4). Harvesting was barely visible in the aerial photographs taken in 1989 (about 10 years after harvesting), and only the major extraction track and landing contained patches of bare gravel. Several rainforest understorey species (such as *Trochocarpa gunnii* and *Cenarrhenes nitida*) persisted only at Site 1.

At Site 2, the clearfell and high-intensity burn resulted in a very open canopy, with very few rainforest species surviving the escaped regeneration burn. Gravel tracks and landings were still easy to identify. A live celery-top pine basal area of 0.2 m^2 was recorded at the final measurement, but these trees were mainly on the boundaries of the harvested area (data not shown). Bracken *(Pteridium esculentum)* was the most common species on plots at Site 2 (Figure 5). Several sclerophyllous species typical of disturbed sites in this region were found only at Site 2

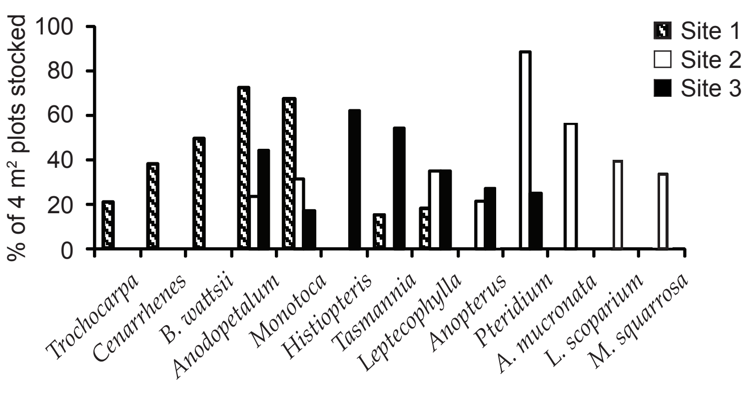

Figure 3. Common understorey species by site at final measurement. B., Blechnum; A., Acacia; L., Leptospermum; M., Melaleuca.

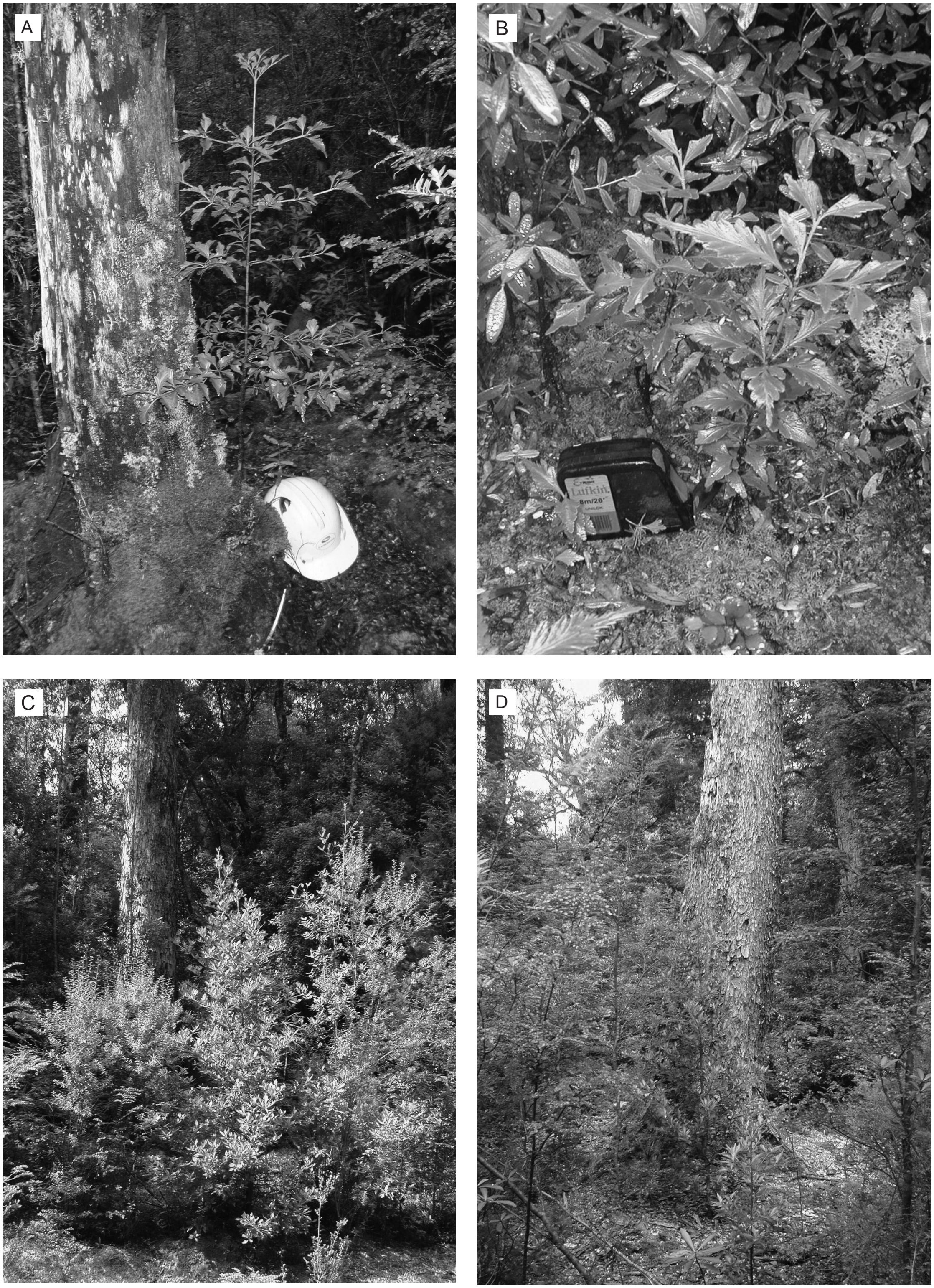

Figure 4. Site 1, 22 years after selective harvest. A, Celery-top pine seedling within rainforest. B, Young celery-top pine and leatherwood regeneration. C, Rainforest regeneration along a track. D, Rainforest regeneration within selectively harvested rainforest.

Figure 5. Site 2, 14 years after clearfell and high-intensity burn. A, Young celery-top pine seedlings with bracken and Leptospermum *sp. B, General view of vegetation, comprised mainly of sclerophyllous species and bracken.*

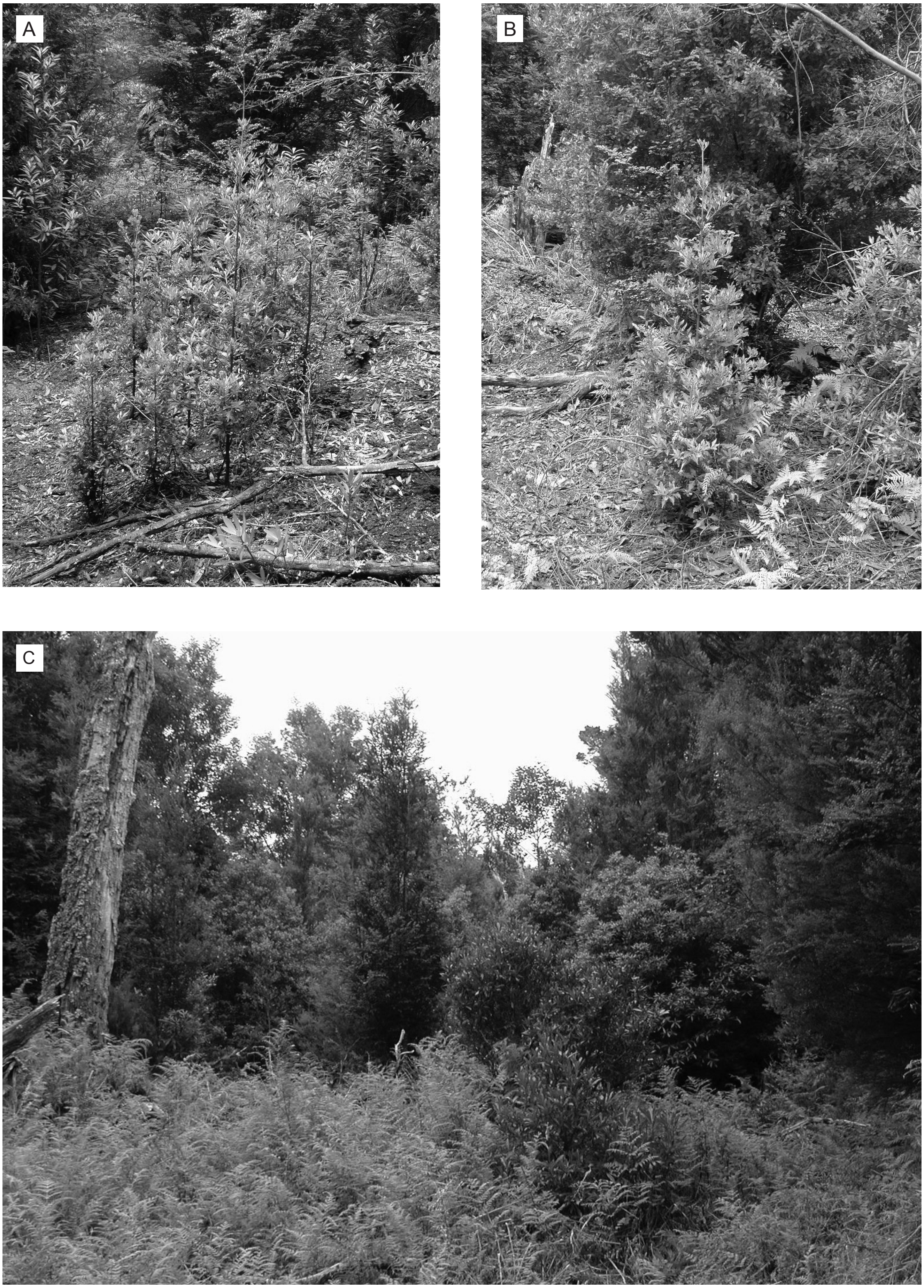

Figure 6. Site 3, 16 years after patchfell and low-intensity burn. A, Group of celery-top pine seedlings. B, Young celery-top pine seedling in an opening. C, Rainforest regeneration emerging through wet fern (Histiopteris incisa).

(e.g. *Acacia mucronata, Leptospermum scoparium* and *Melaleuca squarrosa*).

Site 3 (patchfell, low-intensity burn) still retained myrtle and leatherwood trees, particularly in unburnt patches. The canopy was open, with rainforest regeneration growing in full sunlight (Figure 6), and some disturbed areas covered only with moss. The regeneration contained a high proportion of species known to colonise disturbed rainforest, such as *Tasmannia lanceolata* (Read and Hill, 1983) and *Histiopteris incisa* (Neyland and Brown 1994), and also some species more typical of sclerophyllous vegetation (*Monotoca glauca* and *Leptecophylla juniperina*). Regeneration had also occurred on the snig tracks, with little of the underlying gravel visible. Both Site 1 and Site 3 retained an average basal area of 0.6 m^2/ha live celery-top pine at final measurement (data not shown).

Natural regeneration

Healthy celery-top pine seedlings were found across all sites at their final measurement. Between 45 and 70% of 4 m^2 plots were stocked (Figure 7). Many of these plots were also stocked with myrtle and leatherwood seedlings. All treatments achieved more than the minimum rainforest regeneration standard of 65% of 4 m^2 plots stocked with at least one rainforest tree species (Forestry Tasmania 2003). Very few sassafras seedlings were found in any of the treatment areas and their counts have been omitted from the results.

At Site 1 (selective harvesting, no burn), at 1 year, the most abundant regeneration of celery-top pine was established on peaty seedbeds that had been disturbed (Figure 8). Although categorising seedbed became more difficult with time, the number of plots stocked continued to be higher on disturbed seedbeds than on undisturbed seedbeds. The celery-top pine seedling stocking on the regeneration transect at the year 6 measurement at Site 1 was significantly greater ($p < 0.001$) on disturbed seedbed (31 of 38 plots stocked) than on undisturbed seedbed (2 of 23 plots stocked).

At Site 3 (patchfell, low-intensity burn), the majority of the area was either burnt and/or disturbed, with a very small sample of unburnt or undisturbed plots. Although there was lower stocking of other rainforest seedlings on the burnt seedbed (data not shown), the celery-top pine seedling stocking on the regeneration transect at the final measurement

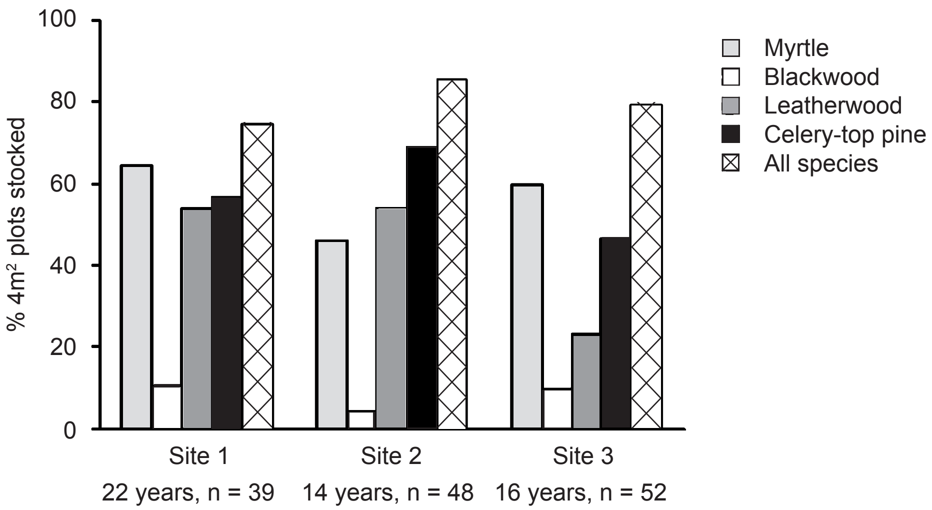

Figure 7. Stocking at final measurement. A plot is scored as stocked if it contains more than one seedling (> 4 cm tall) of the indicated species. n, number of plots.

(age 14 years) was greater at this site on burnt or disturbed seedbed (23 of 46 plots stocked) compared to unburnt or undisturbed seedbed (1 of 6 plots stocked), although this result was not statistically significant.

The changes in seedling stocking over time for Sites 1 and 3 are shown in Figure 9 (the permanent plots at Site 2 were lost in the escaped regeneration burn). In both trials, the stocking of celery-top pine and myrtle from the regeneration surveys at final measurement was similar to that at age 5–6 years. The stocking of blackwood declined from age 1 to age 5 at Site 3. The density of celery-top pine seedlings increased

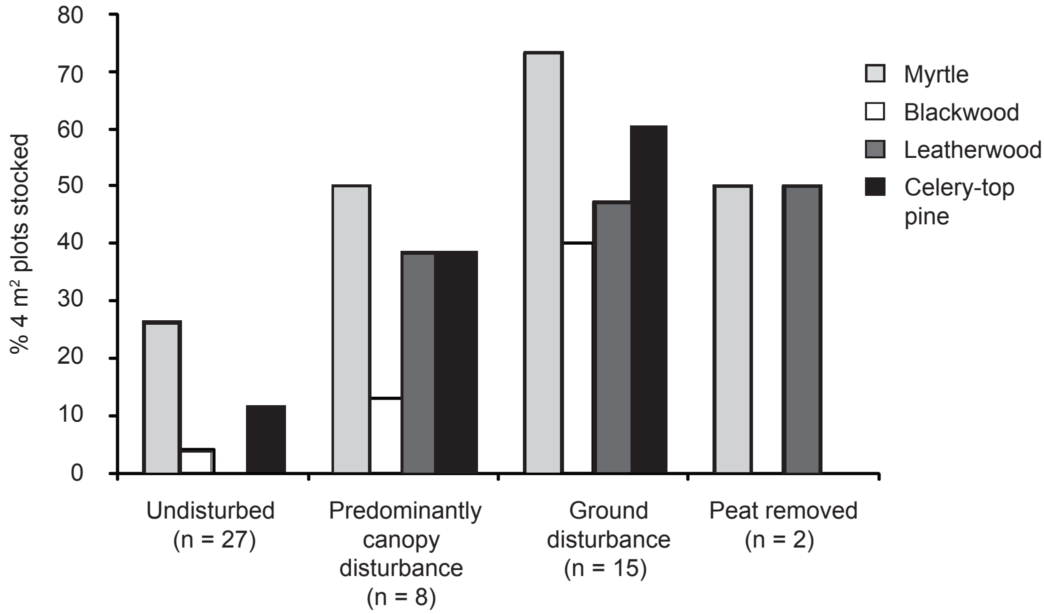

Figure 8. Stocking, Site 1, year 1, by seedbed.

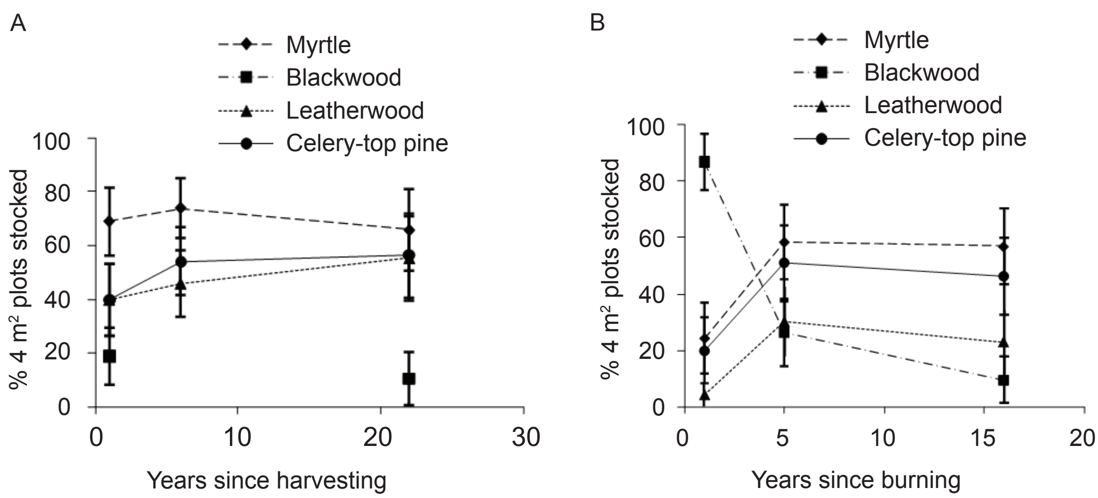

Figure 9. Stocking over time, all seedbeds. A, Site 1. B, Site 3. Bars show 95% confidence limits.

Table 2. Mean height (standard error) and periodic annual height increment (PAI) of tallest celery-top pine seedlings for each treatment. Data from temporary regeneration transects.

Treatment	Year since treatment	No. plots	Height (cm) (SE)	PAI (cm/year)
Site 1	1	52	3	-
	6	61	35 (4.6)	6.4
	22	39	162 (28.0)	7.9
Site 2	14	48	60 (12.5)	4.3
Site 3	1	45	3	-
	5	53	12 (1.7)	2.2
	16	52	179 (25.3)	15.2

over time at all sites (Figure 10), due to progressive recruitment.

The mean height of the tallest celery-top pine seedling increased with measurement age (Table 2), with periodic annual increments of 2.2-15.2 cm/year. Seedling heights for myrtle, leatherwood and celery-top pine seedlings from the unfenced permanent plots at Site 1 also increased over time (Figure 11), with mean annual height increments for the species of 14, 11 and 10 cm/year respectively.

Celery-top pine ring counts

There was a clear relationship between stump diameter and age for the stem sections from Sites 1 and 2 (Figure 12). With the exception of two outliers, the trees at Site 1 are mostly around 370 years old, which suggests that the stand is relatively even-aged and originated around the year 1600. The stand at Site 2 appears to be uneven-aged, although the number of trees about 200 years old suggests a disturbance at about that time, and again at about 350 years ago. The establishment of trees within this stand occurred periodically between 1550 and 1900.

The relationship between age and stem diameter allowed estimation of the rotation lengths required to achieve particular stem diameters (Table 3). These were comparable with estimates of Tyquin (2005) for two sites in the south of the State (Table 3). An approximate rotation length of 300–400

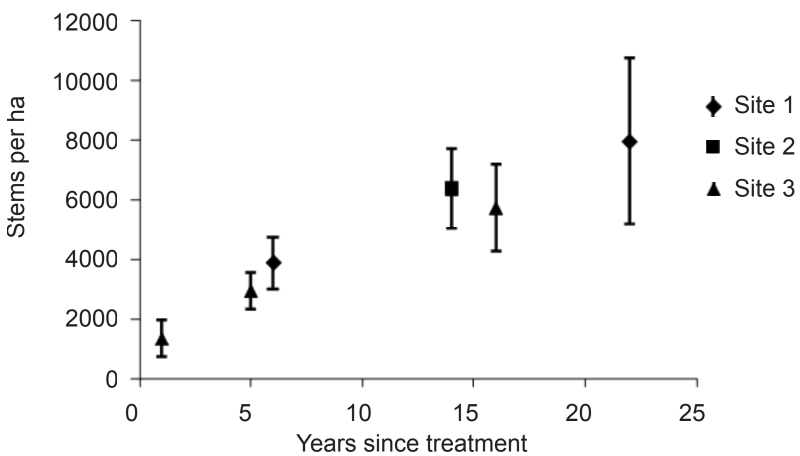

Figure 10. Celery-top pine seedling density over time by site. Bars show standard error. Data from temporary regeneration surveys

Table 3. Rotation lengths required for given celery-top pine diameters

Diameter (cm) @ 0.4 m high	Estimated years required	
	Site 1 model	Tyquin (2005) model
30	270	142
40	310	216
50	350	305
60	380	409
70	420	-
80	450	-

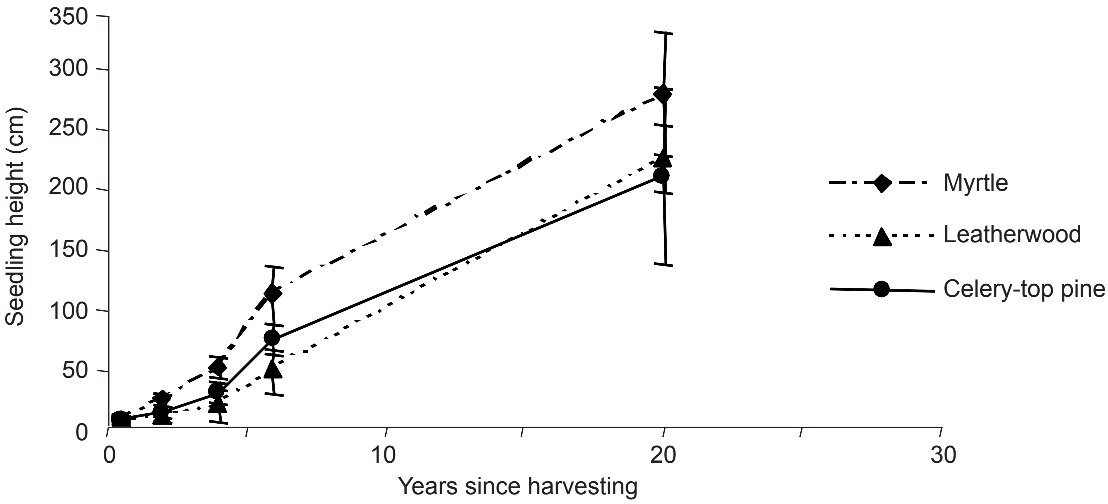

Figure 11. Seedling height over time, Site 1. Bars show standard error.

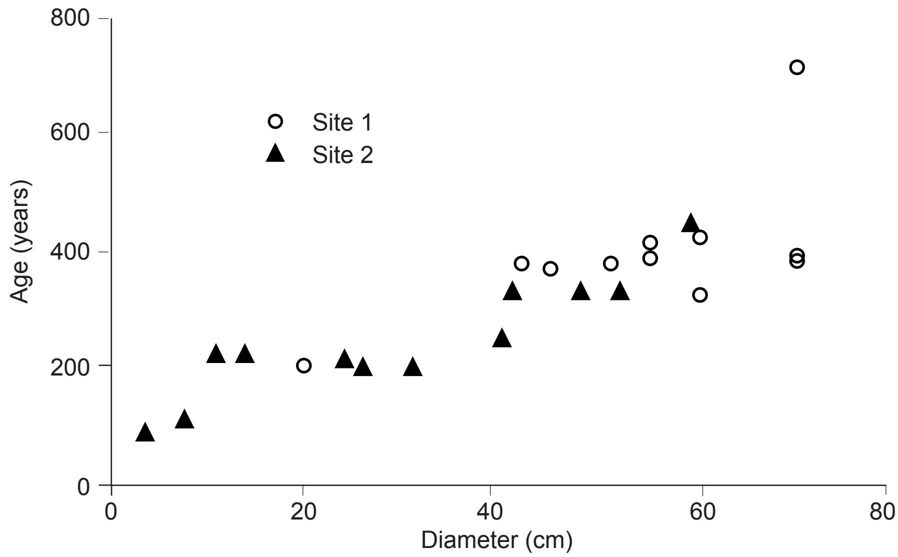

Figure 12. Celery-top pine diameter at 0.4 m, and age, Sites 1 and 2. Linear regression between ring-count age and diameter across the two sites was Age = 81.23 + 5.25 Diameter (r^2 = 0.72). Diameter measured at 0.4 m.

years is required to produce a celery-top pine log of 50-60 cm dbh.

Celery-top pine seedfall

Celery-top pine seed caught in the Site 1 seed-trap fluctuated from almost nil in some years to moderate falls of less than 4 g per m^2 per year (equivalent to 100–1000 seeds per m^2 beneath the standing trees); the reasons for this variation are unknown. The exception was 1982, a celery-top pine mast seed year, when five times this amount fell. Hickey and Wilkinson (1999) reported that 1982 was also a mast seed year for myrtle in north-west Tasmania. Most celery-top pine seedfall occurred from January to June.

Discussion

The varying levels of harvesting and burning intensity across the three sites resulted in very different forests structurally, floristically and aesthetically at the final measurement. Lack of site and treatment replication means that the results cannot be generalised, but they are still considered indicative of the likely response of celery-top pine at similar sites within the broader geographical region, where most of the celery-top pine in northwest Tasmania is harvested.

Site 1 still had the appearance of a rainforest 22 years after selective harvesting, with the harvesting disturbance only obvious from the presence of stumps, and ribbons of rainforest regeneration showing where snig tracks had been. The data showed that burning is not necessary for celery-top pine regeneration. Continued recruitment of the other rainforest species is also likely to be more successful where the area is not burnt and a seed source is maintained.

The hot burn at Site 2 resulted in a sea of bracken, with some taller sclerophyllous shrubs. However, hidden beneath the bracken, and emerging through it, was a healthy stocking of rainforest species. Although this clearfelled area has regenerated successfully to date, there is a risk with hot burns that the peat layer may be removed, along with the ground-stored seed resource. The conversion of rainforest into sclerophyllous vegetation also puts it at increased risk from wildfire in the future (Barker 1991).

After patchfelling and a low-intensity burn at Site 3, some patches of the original forest were retained, which contributed to both structure and diversity. Otherwise, the canopy was open and the site had the appearance of a disturbance forest in an early successional stage. This site appeared to retain most of the peat layer, which increased the possibility of continued regeneration in the future.

Regeneration was successful in all treatments, with an adequate stocking of established rainforest species at each site within 14 to 22 years after treatment. All treatments had at least 45% of 4 m^2 plots stocked with celery-top pine, and greater than 65% of 4 m^2 plots stocked with rainforest seedlings of any species. Although the percentage of plots stocked over time did not increase, the density (stems per ha) of celery-top pine seedlings did increase over time. Recruitment of celery-top pine seedlings thus continued throughout the measurement period, even where a celery-top pine seed source was not apparently available. Even with possible bird dispersal of celery-top pine seed, this suggests that celery-top pine regeneration can result from delayed germination of ground-stored seed. This is consistent with Tyquin (2005) who found that the highest frequency of celery-top pine saplings occurred 20–30 years after wildfire disturbance, and with Tabor *et al.* (2007) who found that the abundance of rainforest regeneration (including celery-top pine) increased with coupe age to at least age 15 years after a clearfell, burn and sow treatment.

Celery-top pine germination appeared to be stimulated by the harvesting disturbance and burning, with many patches of dense regeneration occurring on disturbed seedbeds at all three sites. Low densities of celery-top pine seedlings were spread across the remaining, less heavily disturbed areas. However, both harvesting disturbance and burning have the potential to damage the thin peaty soils at these sites and expose the infertile gravels below. Celery-top pine seed did not regenerate in locations at which the peat layer had been removed and the underlying gravel exposed. This is probably a consequence of any seed stored in the peat layer having been removed.

Tolerance to both light and shade conditions is evident in celery-top pine (Tyquin 2005), with a better growth rate under intermediate light conditions (Read 1985; Barker 1992). In these trial areas, good early height growth was seen at Site 1, where it is likely that the retained rainforest structure provided shade and shelter for the celery-top pine germinants. The highest growth rates obtained after year five were on Site 3, where more light was available. Height growth at Site 2 was slow, probably as the site was colonised with bracken, producing intense competition for water, nutrients or light. The high-intensity burn across this area is also likely to have destroyed any advanced-growth seedlings. The periodic annual height increment for celery-top pine measured from both permanent plots and regeneration surveys was 2-15 cm/year. This is comparable with the periodic annual height increment of 10 cm/year for celery-top pine found by Hickey and Wilkinson (1999). Growth rates for the other rainforest species are well below those recorded by Hickey and Wilkinson (1999) for rainforest seedlings under a partial canopy on fertile sites.

The tallest seedlings of all species on Site 1 consistently occurred outside the fenced area (data not shown). This, combined with roughly equivalent seedling densities on plots inside and outside of the fence (data not shown), indicates that browsing mammals did not have a big impact on the main rainforest tree species at that site. However, the drop over time in blackwood stocking at all sites may be attributable to mammal browsing.

Ring counts of celery-top pine stumps show that celery-top pine continues to grow slowly throughout its life. Maximum diameter growth rates of 2 mm/year may be reached during the second century of growth. A celery-top pine of sawlog size (50–60 cm diameter) is likely to take 350–400 years to grow. Tyquin (2005) suggests a range of 100 years should be placed around expected values.

It is likely that the quantity of celery-top pine harvested in the future will remain small and variable, as it is not intended to target celery-top pine forests for harvesting. However, it is important to have a regeneration prescription in place for these forests when they are harvested. Where harvesting of celery-top pine is undertaken, small group or single-tree harvesting is recommended, which should be done with minimum damage to retained stems. Advanced-growth stems should be retained. This will maintain a forest structure, provide shelter for regeneration and minimise death of myrtle from myrtle wilt (Packham 1991; Elliott *et al.* 2005). Some ground disturbance is required for celery-top pine regeneration, but this should be provided by harvesting disturbance only, and without destroying any peat layer. Fire is not required to produce adequate celery-top pine regeneration, and changes the structure of the rainforest dramatically. A cool burn may be strategically implemented in some areas to reduce the fire hazard and prevent the spread of wildfire, however the aesthetics of rainforest after harvesting are important to its public acceptance and the use of fire should be minimised.

Acknowledgements

These trials were established with the assistance of John Hickey, John Kelly and Bob Mesibov. Remeasurement of the trials was assisted by Neil McCormick and Leigh Edwards.

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