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TREE SPECIES REGENERATION AFTER LOGGING IN TEMPERATE RAINFOREST, TASMANIA

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(with three tables and one text-figure)

ABSTRACT

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Selective mechanized logging for *Athrotaxis selaginoides* in temperate rainforest south of Rosebery in western Tasmania has resulted in a maze of logging tracks and associated destruction of part of the forest by firing. Mapping and analysis of regeneration of *A. selaginoides*, *Phyllocladus aspleniifolius*, *Eucryphia lucida* and *Nothofagus cunninghamii* at sites logged ten and twenty years previous to the study suggest that little successful tree establishment can be expected on areas where the topsoil has been removed by bulldozers, although the sides of the tracks where this material has been piled promise a restoration of the forest canopy. *A. selaginoides* and *P. aspleniifolius* establish in low densities after logging but appear to have low apparent rates of mortality in contrast to *E. lucida* and *N. cunninghamii* which establish in high densities, but have high apparent rates of mortality.

INTRODUCTION

Temperate rainforest, consisting of tall closed-forest, tall open-forest, closed-forest, open-forest and closed-scrub (Specht 1974) dominated by mostly microphyllous species in the genera *Nothofagus*, *Atherosperma*, *Phyllocladus*, *Athrotaxis*, *Eucryphia*, *Lagarostrobos* and *Anodopetalum* covers a substantial proportion of the area of Tasmania where precipitation exceeds 1250 mm per annum (Jackson 1968). These forests have been cut for timber at least since 1819, being most thoroughly exploited where *Lagarostrobos franklinii* or *Athrotaxis selaginoides* were common (Kirkpatrick 1977a). Although Howard (1973, 1974) has investigated the natural regeneration of *Nothofagus cunninghamii*, nothing is published on the responses of the temperate rainforest tree species of Tasmania to selective logging and associated disturbances. This study compares the regeneration found in undisturbed *Athrotaxis selaginoides-Nothofagus cunninghamii* closed-forests with that found ten and twenty years after logging and identifies the post-logging environments in which the various tree species most successfully regenerate.

THE STUDY AREA

The rainforests studied lie between Rosebery and Queenstown in western Tasmania (fig. 1). The climate is cool perhumid with no months receiving less than 120 mm precipitation and low winter mean monthly temperatures. The rainforests occur on argillaceous, yellow podzolic soils formed on the Mt Read Volcanics. These soils are acid in reaction throughout the profile and incorporate 20-40 percent organic matter in the surface horizon. The rainforest changes from a species-poor, structurally simple closed-forest at low altitudes on good sites to a species-rich and structurally complex closed-scrub on poor and/or high altitude sites (Kirkpatrick 1977b). There is continuous floristic and structural variation between these extremes.

Parts of the rainforests were logged for *Athrotaxis selaginoides* in the late nineteenth and early twentieth centuries using horse and bullock teams and tramways. More recent logging of *A. selaginoides* has employed bulldozers and trucks. The bulldozers have created a dendritic maze of snig tracks and logging roads and many fires have originated from these access lines. At least four major fires have destroyed rainforest in the study area (1896, 1928, 1963 and 1974/5) and smaller fires, many lit by bulldozer drivers and loggers, have been much more frequent. The logging of *A. selaginoides* in the area ceased in 1978, the resource having been exhausted.

METHODS

Areas logged 10 years previously (A, fig. 1), 20 years previously (B, fig. 1) and never logged (C, fig. 1) were located in 1976 in rainforest with the same species composition in the undisturbed parts of the vegetation. Thirty-three transects consisting of 10 one m^2 quadrats oriented orthogonally to snig tracks were laid out in the logged forests. Seven transects consisting of 10 two m^2 quadrats were laid out in the undisturbed forest. For each of the quadrats the location of all individuals of shrub and tree species was mapped and height-coded in the following classes: 0-0.1 m, 0.1-0.2 m, 0.2-0.4 m, 0.4-0.8 m, 0.8-1.6 m, 1.6+ m. Ring counts were made to correlate size classes with age by species. The extent of mosses and lichen, ferns, logs and stumps, bare ground and *Gahnia grandis* was also mapped for each quadrat. Note was made of whether the quadrat fell within the 'scraped' environment of the centre of the bulldozed logging tracks where soil had been removed, the 'pilings' environment of the side of the snig tracks where soil and dead wood has been pushed, or undisturbed soil. Aspect and slope were recorded and a sample of the top 70 mm of soil removed for later analysis for organic matter content using the rapid titration method of Walkley & Black as described in Piper (1956).

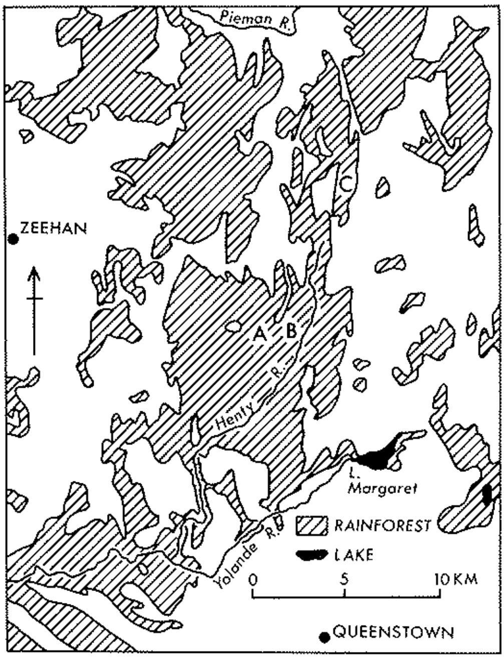

FIG. 1 - The extent of rainforest in the study region, locations mentioned in the text, and locations of groups of transects.

The density of all tree and shrub species in each height class for each quadrat was counted from the maps, and the cover of the various ground cover types was placed into the following classes for each quadrat: 1-10%, 11-25%, 26-50%, 51-75%, 76-100%. The mean density for each species and each size class of each species was calculated for each environment and ground cover type for all quadrats, 10-year logged quadrats and 20-year logged quadrats. For these analyses a ground cover type was assumed to be present in a quadrat if it covered 26% or more of its area. The mean percentage cover of the five ground cover types was calculated for each logging and environment type. The differences observed are real in as much as the selected transect sites belong to the same vegetation type. Thus, these differences are not appropriate for statistical testing.

RESULTS

Regeneration of Ground Cover

The 10-year, 20-year and undisturbed sites differ markedly in the percentage cover of each of moss, ferns, *Gahnia grandis*, logs and bare ground (table 1). Moss cover, slightly greater on the scraped than the pilings environment, approximately doubles on the logged areas from 10 to 20 years, but forms dramatically less of the ground cover in the undisturbed forest. Fern cover increases through time on the scraped environment, but decreases on the pilings environment. In the undisturbed forest ferns, mainly *Blechnum wattsii*, account for 10% of the ground cover. *Gahnia grandis* tussocks account for almost 10% of the

TABLE 1

PERCENTAGE COVER OF GROUND COVER TYPES IN LOGGED AND UNDISTURBED FOREST

Forest Environment	Moss	Ferns	Logs	*Gahnia*	Bare Ground
Scraped:					
10 years	32.6	2.9	1.6	8.5	54.4
20 years	60.8	4.1	2.8	18.1	13.2
Pilings:					
10 years	23.7	10.5	21.0	13.4	31.4
20 years	54.4	6.3	14.7	16.7	7.9
Undisturbed	11.0	10.4	8.1	0.9	49.9

cover in the 10-year scraped environment, slightly more on the 10-year pilings and at 20 years more than doubles on the scraped areas and increases slightly on the pilings. *Gahnia* has negligible cover in the undisturbed forest. Bare or litter covered ground is greater on the scraped areas than on the pilings and decreases dramatically from the 10-year to 20-year sites. In the undisturbed forest litter covers almost half of the ground. Log cover is extremely low in the scraped areas and much higher on the pilings than in the undisturbed forest.

The scraped environment is subject to the accumulation of water in hollows on the gentler slopes and accelerated gully and sheet erosion on the steeper slopes. The organic content of the soil is minimal, determinations ranging from 0.001% to 5.09% in the top 70 mm with a mean of 2.85% (n = 6). The pilings environment is far more heterogeneous with logs, topsoil from the scraped areas and logging debris creating a variety of micro-habitats. Drainage is usually free. The determinations of organic matter content of the pilings topsoil varied from 1.3% to 40.4% with a mean of 16.2% (n = 24). In the undisturbed forest the organic matter contents measured varied between 20.2 and 40.8% with a mean of 33.1% (n = 4).

Regeneration of Forest Trees

Nothofagus cunninghamii, *Eucryphia lucida*, *Phyllocladus aspleniifolius* and *Athrotaxis selaginoides* were the only tree species in the study area sufficiently frequent to include in the analyses. In the undisturbed forest *A. selaginoides*, *N. cunninghamii* and *E. lucida* are approximately equally abundant in the tree and sapling layers and *P. aspleniifolius* is frequent but considerably less common. Recruitment is continuous for all four species in the undisturbed forest (table 2).

Nothofagus exhibits dense regeneration on both the scraped and piling environments ten years after logging. Twenty years after logging the density on the scraped environment decreases from 6.4 individuals per m^2 to 0.5 and on the pilings environment from 7.5 to 2.0. In both cases there is no major shift in the size class distribution (table 2), which suggests that mortality is high and recruitment continuous. *Nothofagus* regenerates most densely in moss and on bare ground in the logged areas, but it is only where moss cover is present that the proportion of tall seedlings is higher in the 20-year than in the 10-year quadrats (table 3).

Eucryphia regeneration is less dense than that of *Nothofagus* on both the 10-year scraped and piling environments, but more dense on both environments on the 20-year site (table 2). Although there is a marked increase in seedling density through time on the scraped environment the seedlings were generally smaller on the 20-year site (table 2) suggesting an extremely high rate of both recruitment and mortality. In contrast, there is a decrease in density but an increase in height on the pilings environment (table 2). *Eucryphia* maintains relatively high densities through time on quadrats with all types of ground cover, but it is only on quadrats with substantial areas of ferns, bare ground or

TABLE 2

SPECIES REGENERATION:
Height class distribution and mean density by environment.

Forest Environment	Tree Species*	Height Classes (m) 0-0.1	0.1-0.2	0.2-0.4	0.4-1.6	>1.6	Mean density (m^2)
Scraped:							
10 years	N	81.5	13.5	4.2	0.8	-	6.4
	E	35.3	37.3	24.8	2.7	-	2.5
	P	60.0	20.0	20.0	-	-	0.1
	A	-	-	-	-	-	0.0
20 years	N	80.0	20.0	-	-	-	0.5
	E	69.6	21.7	8.7	-	-	6.1
	P	-	-	-	-	-	-
	A	100.0	-	-	-	-	0.2
Pilings:							
10 years	N	50.2	32.5	14.0	3.3	-	7.5
	E	42.3	27.8	19.4	8.3	2.4	5.4
	P	31.0	37.2	27.9	3.1	0.7	0.8
	A	90.0	10.0	-	-	-	0.3
20 years	N	71.2	12.3	12.3	4.2	-	2.0
	E	54.0	16.0	18.0	9.0	3.0	2.5
	P	24.0	28.0	40.0	8.0	-	0.7
	A	9.2	27.6	32.2	27.6	4.6	0.8
Undisturbed	N	11.0	4.0	7.0	18.0	61.0	0.5
	E	24.0	20.0	7.0	9.0	39.0	0.9
	P	35.0	12.0	15.0	8.0	31.0	0.2
	A	1.0	3.0	0.0	12.0	84.0	0.5

* N = *Nothofagus cunninghamii*, E = *Eucryphia lucida*, P = *Phyllocladus aspleniifolius*, A = *Athrotaxis selaginoides*.

logs that there is a marked increase in the proportion of the upper height classes (table 3).

Phyllocladus is virtually absent from the scraped environment and maintains its density and increases its proportion of the upper height classes on the pilings environment (table 2). On the 20-year site it is only found in quadrats with substantial cover of moss and/or logs, although it is present on all ground cover types on the 10-year site (table 3).

Athrotaxis was the only species to have a higher density on the 20-year than on the 10-year site. The increase of density is concentrated on the pilings environment (table 2) where bare ground and/or moss cover are strongly associated with seedling establishment (table 3). The increase in density and size of the seedlings suggests that establishment is low but continuous and that mortality is low.

DISCUSSION

Twenty years after logging the areas scraped to subsoil by bulldozers show little promise of a restoration of the forest canopy. Although *Eucryphia* is present in substantial density on such sites there is no evidence of successful establishment beyond the small seedling stage. *Nothofagus*, at much lower densities, presents a similar picture, and *Phyllocladus* and *Athrotaxis* are virtually absent. The explanation for this lack of success of seedling regeneration probably lies largely in the nature of the substratum. The almost total lack of organic content in the soil must hinder nutrient adsorption, reduce moisture absorption and reduce the development of pedality. Poor aeration and

TABLE 3

SPECIES REGENERATION:
height class distribution and mean density in groundcover types.

Ground Cover	Logging Period	Tree Species*	Height Classes (m) 0-0.1	0.1-0.2	0.2-0.4	>0.4	Mean density (m^2)
Moss	10 years	N	65.4	21.0	9.6	4.0	10.8
		E	38.3	31.7	22.7	7.4	5.6
		P	42.9	38.1	19.0	-	0.6
		A	100.0	-	-	-	0.3
	20 years	N	71.7	10.0	10.0	8.3	1.6
		E	58.5	30.7	12.5	3.5	4.0
		P	20.0	40.0	40.0	-	0.3
		A	20.0	30.0	20.0	30.0	0.4
Ferns	10 years	N	21.5	42.9	35.8	-	4.6
		E	16.3	46.5	32.5	4.8	4.8
		P	100.0	-	-	-	0.2
		A	-	-	-	-	0.0
	20 years	N	-	-	-	-	0.0
		E	35.3	11.7	35.3	17.7	1.0
		P	-	-	-	-	0.0
		A	50.0	-	50.0	-	0.3
Logs	10 years	N	48.4	22.6	22.6	6.4	3.8
		E	25.0	55.0	15.0	5.0	2.4
		P	28.4	39.8	27.3	4.2	0.7
		A	80.0	20.0	-	-	0.4
	20 years	N	-	100.0	-	-	0.8
		E	66.6	-	20.0	13.4	2.2
		P	23.8	28.6	38.2	9.2	1.2
		A	-	33.0	33.0	33.0	0.5
Gahnia grandis	10 years	N	42.9	42.9	14.3	-	1.7
		E	11.5	30.8	46.2	11.5	2.9
		P	20.0	20.0	60.0	-	0.3
		A	-	-	-	-	0.0
	20 years	N	100.0	-	-	-	0.6
		E	42.9	-	57.1	-	0.7
		P	-	-	-	-	0.0
		A	-	-	-	-	0.0
Bare ground	10 years	N	48.6	38.4	11.9	1.2	3.8
		E	41.3	27.5	21.2	10.0	4.5
		P	36.8	36.8	26.4	-	0.7
		A	75.0	25.0	-	-	0.2
	20 years	N	68.4	15.8	15.8	-	1.6
		E	54.3	13.5	15.3	16.9	2.1
		P	-	-	-	-	0.0
		A	12.5	12.5	37.5	37.8	0.4

*N = *Nothofagus cunninghamii*, E = *Eucryphia lucida*, P = *Phyllocladus aspleniifolius*, A = *Athrotaxis selaginoides*.

drainage result from the lack of organic matter, compaction during the logging process and the high clay content of the subsoil. The lack of even a partial canopy cover increases microclimatic fluctuations. These conditions may ameliorate in the long term with a drift of litter from the adjacent forest and pilings and the observed expansion of the cover of moss and *Gahnia grandis*. However, substantial local cover of *Gahnia* appears to preclude the establishment of all tree species. *Gahnia* survives under the low light conditions of rainforest unburnt for centuries and readily forms a closed-tussock sedgeland where rainforest has been burnt or otherwise disturbed. Where this vegetation type has become established through fire or other disturbance there is no subsequent tree invasion, *Eucryphia* only being present with *Gahnia* when other ground cover types covered a substantial area of a quadrat. As the scraped areas constitute 10-30% of the forest from which timber has been extracted the long term productivity of the forest must be seriously reduced.

The topsoil and logging debris of the pilings environment have proved suitable for the establishment and survival of individuals of all four species, and stocking is such that a restoration of the rainforest canopy seems virtually certain in the absence of fire. The data suggest that the four species differ in their patterns of establishment and mortality on the pilings. *Athrotaxis* lies at one extreme with a low but apparently continuous pattern of establishment and an apparently low mortality rate. The other gymnosperm, *Phyllocladus*, exhibits a less pronounced version of the same patterns. *Eucryphia* and *Nothofagus*, the two angiosperm species, have apparently high and continuous establishment rates and extremely high apparent mortality rates.

The growth rates of the four species, all of which are utilizable for their timber, are extremely low. The most valuable species, *Athrotaxis*, has been shown by ring counts to take 300 years to reach diameters at breast height of 0.3-0.4 m in a stand at 750 m on Mt Read (Ogden 1978a). Ring counts of seedlings on the pilings indicate that *Eucryphia* and *Nothofagus* seedlings 0.4-0.8 m tall fall into the range of 6-9 rings. *Phyllocladus* seedlings vary from 7-11 rings for the same height class and *Athrotaxis* seedlings vary from 8-12 rings. The faster growing species are probably both shorter-lived than the slower-growing gymnosperms. The maximum recorded age of *Nothofagus* is 450-500 years (Gilbert 1959), although Jackson (1968) suggests that its normal lifespan is approximately 350 years. The maximum recorded age for *Phyllocladus* is 780 (?-900) years and for *Athrotaxis* is 900 (-1300) years (Ogden 1978b). No data are available for *Eucryphia*. The period taken for growth to a size utilisable for timber probably varies in order from shortest to longest from *Eucryphia* through *Nothofagus* and *Phyllocladus* to *Athrotaxis*, and there is little doubt that the growth rate of *Athrotaxis* is an order of magnitude slower than that of the two angiosperm species on most sites below 800 m.

The fire ecology of the four species is correlated with their relative longevities and growth rates. *Athrotaxis* is killed by all fires except those of the lowest intensity and flame height. Seed is held in cones on the tree only during late summer and early autumn (Ogden 1978a) and heavy seeding occurs only once in every five or six years (Orme, pers. comm.). The seeds are viable for only three to four months (Orme, pers. comm.). Thus, regeneration after fire can and does occur, but is more the exception than the rule. Where isolated trees are spared by fire most seedlings occur within a radius of 30 m from the parent tree, making recolonization an extremely slow process. Large areas of *Athrotaxis* forest have been completely destroyed by fire in western Tasmania since white settlement (Kirkpatrick 1977a).

Phyllocladus is as fire sensitive as *Athrotaxis*. However, the seed is surrounded by a white fleshy aril and may be dispersed by birds. Isolated trees and seedlings of *Phyllocladus* are often found remote from the nearest possible parent and the species is found widely in forests that have originated after wildfire. Thus, although almost invariably being killed by fire and having seeds of equally short viability period and tenure on the tree, *Phyllocladus* more rapidly recolonizes suitable sites than *Athrotaxis*.

Both *Eucryphia* and *Nothofagus* are capable of vegetative recovery from firing, although mortality is usually high. Both species shed seed in late summer-early autumn, the light winged seeds of *Eucryphia* being better adapted to dispersal than those of *Nothofagus*.

Given the high fire susceptibility of the dominant species of the *Athrotaxis*-*Nothofagus* closed-forest, their slow growth rates to merchantable size, and the increased chances of ignition and spread of fire provided by the opening up of the canopy and the extension of inflammable vegetation types such as *Gahnia grandis* tussock sedgeland after logging, great care will need to be taken to ensure that the forests in the study area will be capable of producing another crop. However, if human sources of ignition can be excluded, a difficult task given the easy accessibility now provided by a maze of logging and mining exploration roads, lightning fires are sufficiently infrequent to allow the survival of most of the remaining forest in the area.

The logging methods used in the last twenty years seem inappropriate in a context of sustained yield. On the more fertile basalt soils of the rainforests in northwestern Tasmania similar methods may result in adequate regeneration on logging tracks, but even there would seem undesirable in their encouragement of accelerated erosion. The restriction of bulldozers to tracks constructed from felled cull saplings and small trees as in similar forests in Argentina would seem to present the most desirable alternative to the present methods, as the logs would both prevent the loss of the organic-rich topsoil and would provide a suitable substratum for seedling establishment.

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