Selection Silviculture Trials in North Island Native Forests:

Impacts on the Residual Forest and their Implications for Sustainable Forest Management

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ABSTRACT

Five management scale (24-45 ha) selection silviculture trials were established in central North Island podocarp forests between 1961 and 1979. In light of renewed interest in sustainable management, a variety of impacts on the residual forest over periods ranging from 3 to 22 years are reviewed. Despite the apparent suitability of podocarps for the group selection system, generally old canopy populations of rimu and matai with restricted age ranges and long rotations suggest that this is only attainable in the very long term. Tawa presents better prospects for selection management mimicking natural population processes.

Although harvest levels (9-55%) were well in excess of those approved under current legislation, the trials provide valuable insights into the likely ecological impacts of some current harvesting operations. Further documentation of longer term silvicultural and ecological outcomes will enable their full potential and relevance for current silvicultural practice to be realised.

INTRODUCTION

Selection silviculture, the management system involving the removal at intervals of single trees or small groups of trees selected from throughout a forest stand (Matthews 1991), was undertaken experimentally by the Forest Research Institute in North Island indigenous podocarp forests in five trials in the 1960s and 1970s. Recent legislation provides for selective timber harvest from freehold land under 'sustainable management' plans and permits approved by the Ministry of Forestry. This paper reviews the results of the trials in light of this legislation, using published and unpublished sources, to provide insights into the likely silvicultural and ecological impacts of current harvesting operations.

BACKGROUND

Although early Directors of Forestry (Allsop 1973) envisaged sustained-yield management, it was never practised in the North Island's indigenous forests on anything more than an experimental scale until 1975 when a revised indigenous forest policy was implemented (New Zealand Forest Service 1977) in response to growing public dissatisfaction with clearfelling and an increasing awareness of the heritage and wildlife values of native forest. A brief operational phase of partial logging — 'thinning from above' constituting a crude substitute for selection silviculture and accompanied in many cases by replanting (Beveridge et al. 1985) — followed but ended in 1984 with a government decision to halt logging in indigenous forests on the Crown estate in the North Island. However, continuing demand for high-quality timbers, particularly of native species not available from plantations, together with a growing recognition in some sectors of society that timber supply and the maintenance of ecological integrity in indigenous forests are not necessarily mutually exclusive, led to the amending in 1993 of the Forests Act 1949. The revised legislation allows a continuing harvest of significant volumes of indigenous timber on freehold land only under a 'sustainable forest management plan' — approved by the Ministry of Forestry — which sets annual or periodic timber harvest "at a rate matching the forest's productivity" (Ministry of Forestry 1997). Now, for the first time in New Zealand's history, substantial areas of indigenous forest are coming under sustainable management, defined as "maintaining the ability of forest.... to continue to provide a full range of products and amenities in perpetuity while retaining natural values" (Ministry of Forestry 1997). At September 1997, 82 plans and permits had been approved or were being processed, involving management of ~37 000 ha of freehold forest, with a further ~200 000 ha currently having management plans in advanced stages of development (Ministry of Forestry unpubl. data). Podocarp/tawa (*Beilschmiedia tawa*) associations comprise much of the North Island forest under or potentially under sustainable management. The silvicultural and ecological outcomes of the five existing trials in podocarp forests with varying amounts of tawa are therefore assuming new relevance for forest owners, managers, and researchers.

Although the theoretical objectives of the selection system are the improvement of the structure, merchantable quality, and thus commercial value of the forests in which it is employed (Matthews 1991), the main objective of the earliest trials was to find an ecologically more acceptable alternative to the uncontrolled logging — often followed by clearfelling — that was the norm when they began. Another long-term objective was to determine whether advance growth (existing regeneration) could be developed as a further timber crop (Forest Research Institute 1961) and thus find a practicable method of sustained-yield management for a common forest type (Forest Research Institute 1959). In the later trials, the aim was to remove some of the merchantable volume of the forest while maintaining a stable residual stand with other values essentially intact (e.g., Herbert and Beveridge 1977). The extractive and ecological focus was the podocarps, principally rimu (*Dacrydium cupressinum*) and to a lesser extent matai (*Prumnopitys taxifolia*), the mainstay of the country's timber industry from the decline of kauri (*Agathis australis*) as a commercial species early in the century until their eclipse by exotic conifers in 1959 (New Zealand Forest Service 1975). Some hardwoods, mostly tawa, were also removed.

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All trials were established on easy terrain in upland (450-650 m a.s.l.) forests on Pumice Soils (Hewitt 1992) on the Volcanic Plateau, the centre of distribution of rimu and matai in the North Island (Hinds and Reid 1957). Podocarp densities are generally higher in these forests than in many others in the North Island likely to come under sustainable management and their successional status has engendered considerable debate (e.g., Cameron 1954, McKelvey 1963). Three levels of podocarp density are usefully distinguished for management purposes (Beveridge 1983):

- Low-density: <20 merchantable podocarp trees/ha, merchantable volume <100 m^3/ha
- Medium-density: 20-50 merchantable podocarp trees/ha, merchantable volume 100-300 m^3/ha
- High-density: 50-90-(130) merchantable podocarp trees/ha, merchantable volume 300-600 m^3/ha

The forests occur largely on sites devastated by vulcanism *c.* 1900 years ago and are characterised by relatively old — mature to senescent — rimu and matai populations (loosely termed 'cohorts') with restricted age ranges and few younger trees. A conifer 'regeneration gap' (an absence of trees 10-30 cm dbh) is apparent in some places (e.g., Whirinaki) but not others (e.g., Tihoi, west Taupo). Recent studies (Ogden and Stewart 1995, Smale et al. 1997) have indicated that the regeneration model initially proposed for kauri — large, distinct cohorts regenerating after a major disturbance and succeeded over time by smaller, less distinct cohorts with broadleaved species becoming increasingly important — may apply to the large podocarps as well. With most trees aged between 500 and 700 years, matai is somewhat older on average than rimu (400-600 years), and miro (*Prumnopitys ferruginea*) younger (Katz 1980, Herbert 1980, Lusk and Ogden 1992, Smale et al. 1987). Storm-damaged crowns are common in rimu and matai. Extensive decay is common in the root systems of windthrown rimu and matai, much less so in miro and tawa (e.g., Hood et al. 1989), and is undoubtedly a major predisposing factor in their demise. In some forests, younger rimu trees are also present (e.g., down to 200 years at upper Tihoi: Herbert 1980), but not in others (e.g., Okurapoto, Whirinaki: Katz 1980). Major collapses of canopy podocarp populations — and thus changes in forest structure and composition — have occurred in places in the recent past and can be expected elsewhere in future; a new cohort is well advanced in some places (e.g., lower Tihoi: Herbert 1986) but not others (e.g., Horohoro: Smale et al. 1987).

In contrast, where prominent as a canopy species tawa occurs in all-aged continuously regenerating populations with a much younger average age than the podocarps (e.g., north Pureora: West 1995), and often appears to be ascendant elsewhere (e.g., Okurapoto, Whirinaki: Smale et al. 1985). Conifer↔hardwood regeneration cycles involving a variety of species other than tawa are evident at west Taupo (Beveridge 1973, Herbert 1986) and may be operating elsewhere.

Earlier uncontrolled logging and ecological studies (e.g., Lusk and Ogden 1992) suggest that disturbance at different scales (involving creating canopy gaps of different average size) favours regeneration of different canopy species. It appears that podocarps favoured by increasing levels of canopy disturbance are, in order, miro, rimu, matai, and totara (*Podocarpus totara*) (Ogden and Stewart 1995); and amongst widespread hardwoods tawa, hinau (*Elaeocarpus dentatus*), kamahi (*Weinmannia racemosa*), and rewarewa (*Knightia excelsa*).

The first two trials were a parallel set established in 1961 in Pouakani (later part of Pureora) Forest and Whirinaki Forest in podocarp/tawa forest (Table 1), a medium-density type (M2 of McKelvey and Nicholls 1957) with plentiful tawa extensive on the Volcanic Plateau and apparently presenting few problems for selection silviculture. The type consists of frequent rimu and occasional matai and miro emergent over denser hardwood tiers with frequent tawa, occasional to frequent kamahi, and occasional hinau, maire (*Nestegis* spp.), and rewarewa. Advance growth of podocarps was common at Pureora but very rare at Whirinaki. One-third of merchantable volume was removed in each of two logged blocks (Smale et al. 1987) and a similar block left as a control.

Table 1: Selection silviculture trials in central North Island indigenous forests

Forest and management type	*Date of logging*	*Total area (ha)*	*Forest type*	*Percent. of merch. vol. removed*	*Logging pattern*
Pureora SF (medium density)	1961	45	podocarp/tawa (M2)	A: control B: 34% C: 30%	 B: group felling C: group felling
Whirinaki SF (medium density)	1961	24	podocarp/tawa (M2)	A: control B: 40% C: 35%	 B: group felling C: group felling
Tihoi SF (high density)	1975	44	dense mixed podocarp (L1)	A: control B: 30% C: 55%	 B: group felling C: group felling
Tihoi SF (low density)	1976	32	podocarp/[kamahi]/ shrub hardwoods (M1)	56%	
Whirinaki SF (high density)	1979	40	dense mixed podocarp/tawa (L2)	C: control S: 9% G: 14% I: 15%	 S: mortality-prone trees G: groups <12 trees I: individual trees

Selection silviculture was then extended to high-density mixed podocarp forest, initially believed to present particular difficulties for manipulation (Herbert and Beveridge 1977) and of relatively limited extent compared with the podocarp/tawa type initially chosen. This type (L1) consists of frequent rimu, matai, and miro over a sparse hardwood subcanopy. Arbitrary proportions of 30% and 55% of merchantable volume were removed from two logged blocks in 1975 at Tihoi, west Taupo (Herbert and Beveridge 1977).

In the fourth trial 56% of merchantable volume was removed from podocarp/[kamahi]/shrub hardwoods forest, a low-density type (M1) with little tawa which was widespread only at west Taupo (McKelvey 1963). At Tihoi the type consists of occasional rimu, matai, and miro over frequent pole-sized podocarps and shrub hardwoods and occasional hinau and black maire.

Early results from the high-density trial at Tihoi (Herbert 1980) suggested that reduced harvest levels were required for residual forest stability in dense podocarp forest. Consequently between 9 and 15% of merchantable volume was removed from three blocks of dense mixed podocarp/tawa forest at Whirinaki in 1979 in the last of the five trials (Smale et al. 1985). This type (L2) consists of frequent to abundant rimu and frequent matai and miro over frequent tawa and occasional other hardwoods. Here harvesting most closely approximated a silvicultural tool. Three different tree selection criteria were used, based on ecological (removing mortality-prone trees) or silvicultural criteria (removing groups of up to 12 trees; and individual tree selection).

In all trials the primary silvicultural objective of maintaining a stable residual forest imposed certain constraints on the logging methods used. Podocarps tend to occur in clumps so to minimise damage to residual trees, groups were selected for removal except in the 'mortality-prone' and 'individual tree selection' blocks of the high-density Whirinaki trial. Other standard features of the trials (Herbert 1991) were:

- Selection of groups for removal except in the 'mortality-prone' and 'individual tree selection' blocks of the high-density Whirinaki trial, to minimise damage to clumps of residual trees.
- 'Pre-marking', i.e., determining trees to be felled and direction of felling before harvesting began, to minimise damage

to forest (residual trees, existing advance growth).

- 'Pre-tracking', i.e., determining routes of machine movement before harvesting began, to minimise damage to both forest (residual trees, existing advance growth) and soils.
- Directional felling to ensure that trees fell in the desired direction, to minimise damage to residual trees; and
- Planting groups of large, nursery-raised podocarp seedlings on disturbed ground to supplement advance growth.

Cull trees (i.e., non-merchantable trees rejected for milling, in podocarps usually because of the presence of decay) were marked in later trials. Buffers of more-or-less intact forest were left around logged blocks as a protective measure and, with the exception of the low-density trial at Tihoi[4], an equivalent area of forest was left untreated as a control. Subsequent monitoring of these substantial tracts of unlogged forest, ranging in size from 8 to 15 ha, has provided valuable insights into the ecology of some widespread forest types in the region (Herbert 1980, Smale et al. 1985, Smale et al. 1987, Herbert 1991).

IMPACTS OF SELECTION SILVICULTURE ON THE RESIDUAL FOREST OVER 3-22 YEARS

Results from 3-22 years after harvesting are summarised and discussed in terms of impacts on (1) residual tree condition, (2) ground condition, (3) forest stability, (4) productivity, (5) structure, (6) regeneration of major canopy species, (7) canopy recovery after logging, and (8) incursion of weeds. The following is drawn largely from Beveridge and Herbert (1978), Herbert (1980), Herbert and Beveridge (1977), Pardy (1984), Smale et al. (1985), and Smale et al. (1987), supplemented by information obtained during recent (1997) inspections of the trials.

(1) Impacts on residual tree condition

Damage caused directly by harvesting to residual trees can involve:

- **crowns:** branch and foliage loss caused by falling trees,
- **boles:** debarking from falling trees or their dragged boles, or
- **rootplates:**
  - **undercutting:** severance of major lateral roots, and
  - **compaction:** damage to shallow lateral and superficial fibrous roots, both caused by machine movement
  - **slash accumulation:** from crowns of felled trees.

Medium -density podocarp/tawa forest at Pureora, 36 years after removal of one-third of merchantable volume. View from major extraction track.

Of these, crown damage, bole damage, and slash accumulation on rootplates are probably the least serious from an ecological viewpoint, occurring naturally during storms and their attendant treefalls. Undercutting and compaction are more serious, and are thought to lead respectively to short-term and long-term ill-health and instability.

Crown damage and rootplate undercutting occurred at similarly low levels in the later trials where it was assessed, regardless of logging intensity (Table 2). Although the incidence of bole damage was greatly lessened in the lightly-logged trial in dense podocarp forest, rootplate compaction was much less reduced and

[4] *Six blocks, about 15% of the area of the low-density trial at Tihoi were left unlogged for several reasons, providing a quasi-control comparison.*

Table 2: Impact of selection silviculture on residual canopy trees (podocarps and tawa) in central North Island podocarp forests
(data not available from the medium-density trials at Pureora and Whirinaki)

Forest and management type	*Date of logging*	*Forest type*	*Percent. of merch. vol. removed*	*Trees with crown damage (%)*	*Trees with bole damage (%)*	*Trees with rootplates undercut (%)*	*Trees with rootplates compacted (%)*	*Trees with slash accumulation rootplates (%)*
Tihoi SF (high density)	1975	dense podocarp	A: control B: 30% C: 55%	A: - B: - C: -	A: - B: 9 C: 17	A: - B: 9 C: 7	A: - B: 16 C: 18	A: - B: 24 C: 21
Tihoi SF (low density)	1976	podocarp/[kamahi] /shrub hardwoods	A[5]: control B: 56%	- 5	- -	- 8	- 6	6
Whirinaki SF (high density)	1979	dense podocarp/tawa	C: control S: 9% G:14% I: 15%	C: - S: 5 G:3 I: 9	C: - S: 4 G:4 I: 6	C: - S: 7 G: 6 I: 5	C: - S: 16 G:12 I: 11	C: - S: 34 G:21 I: 20

[5] *Six unlogged blocks provided a quasi-control.*

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slash accumulation not at all. The similarity of all three kinds of rootplate damage, regardless of logging intensity, reflects the fact that ground removal of even a small amount of timber necessitates a minimum amount of machine movement.

Relationships between degree of damage to individual residual trees and their subsequent survival remain to be examined. Nevertheless, the general similarity of levels of residual tree damage in both high-density trials suggests that the much higher early mortality in the heavily logged trial at Tihoi than in the lightly logged Whirinaki one was due directly to impaired wind-firmness of the residual stand rather than indirectly to ill-health resulting from logging damage.

(2) Impacts on ground condition

Ground disturbance by machinery involves a range of impacts of varying severity and naturalness, from merely crushing understorey vegetation (e.g., around felled trees and along minor extraction routes), to disturbance of litter and topsoil horizons and the fibrous feeding roots therein, to complete removal of soil and channelling and compaction of the underlying substrate (e.g., scraped compacted ground along major extraction routes).

The total amount of ground tracked by machinery was remarkably similar regardless of logging intensity (Table 3), reflecting again the necessity of a certain amount of machine movement for ground extraction of even a small amount of timber. For example, in the most heavily logged blocks (55% volume removals, Tihoi low-density and high-density trials), the amount of ground disturbed by tractor was 25% compared with 21% in the least heavily logged (9%, Whirinaki high-density trial). Proportions of ground covered by slash reflected logging intensity much more closely: up to 34% at Tihoi compared with as little as 13% at Whirinaki.

Ground disturbance incurred during harvesting bears some resemblance to that occurring naturally during treefalls, but there are also important differences. Crushing of understorey vegetation, for example, occurs under treefalls of every kind. Soil displacement, however, occurs only in the pits under the rootplates of uprooted trees and without the compaction incurred by heavy machine movement, and severance of lateral roots of residual trees not at all. Conversely, natural tree death by uprooting is a significant means of soil rejuvenation (Norton 1995), important in relatively wet regions such as the central North Island where acidic leaching leads in the long term to net losses of plant nutrients (Gibbs 1983). Soil rejuvenation also occurs during harvesting with churning of soil horizons on more heavily disturbed sites.

(3) Impacts on residual forest stability

In all but one trial, mortality rates of residual merchantable trees within the monitoring periods following harvesting were similar to or lower than those in unlogged forest, averaging 0.9%/year in podocarps (Table 4). Selection silviculture impaired residual forest stability only in the first trial in dense podocarp forest (Tihoi), where removal of even 30% of merchantable volume led to greatly increased mortality in residual merchantable trees; in the 20 months after logging twice as many trees died in the 30% logged block as in the control, and four times as many in the 55% block. Cull trees were disproportionately important in tree mortality in both logged and control blocks in the later three trials where they were monitored.

Of the common modes of natural death of forest trees, tree felling is most similar to windsnap. Uprooting was as common as windsnap in the low-density Tihoi trial and the high-density one at Whirinaki, and standing death as common as windsnap in the medium-density trial at Pureora. Standing death accounted for twice as much mortality as uprooting and windsnap together at Tihoi. Modes of death remain to be compared between logged and unlogged forest.

Different modes of tree death have differing ecological impacts, for example, on soil development and pattern and on regeneration patterns. In standing death the whole tree disintegrates slowly *in situ*; gap formation is bypassed altogether, allowing advance growth to develop undisturbed. Although windsnap often follows, the absence of crown and reduced amount of bole remaining mean that gaps formed are minimal compared with those created immediately by windsnap and uprooting. Windsnap leaves stumps and root systems to disintegrate *in situ*, as does harvesting. Uprooting creates 'pit and mound' microtopography: shallow basins where the soil profile has been removed altogether and parent material exposed, which become litter traps; and mounds comprised of upturned root systems and attached soil

Table 3: Impact of selection silviculture on ground condition in central North Island indigenous forests
(data not available from the medium-density trials at Pureora and Whirinaki)

Forest and management type	*Date of logging*	*Forest type*	*Percent. of merch. vol. removed*	*Ground disturbed by machine movement (%)*	*Ground undisturbed by machine movement (%)*	*Heavy slash accumulation (%)*	*Ground undisturbed by slash (%)*
Tihoi SF (high density)	1975	dense podocarp	A: control B: 30% C: 55%	A: - B: 27 C: 26	A: - B: 73 C: 74	A: - B: 25 C: 34	A: - B: 68 C: 53
Tihoi SF (low density)	1976	podocarp/[kamahi] /shrub hardwoods	A[3]: control B: 56%	- 15	- 85	- 9	- 87
Whirinaki SF (high density)	1979	dense podocarp/tawa	C: control S: 9% G:14% I: 15%	C: 2[4] S: 21 G: 19 I: 14	C: 98 S: 79 G: 81 I: 86	C: 1 S: 20 G: 14 I: 13	C: 98 S: 61 G: 75 I: 77

[1] *Six unlogged blocks provided a quasi-control.*
[2] *Tracking from earlier limited extraction of totara.*

which eventually decay. In contrast to logging, all natural modes of tree death leave boles to decay on the forest floor.

(4) Impacts on productivity

Another salient feature of the trials was the almost universal occurrence of net volume decrement in both logged and unlogged forest (Table 4). Impacts on productivity reflected those on residual forest stability; selection silviculture lowered productivity only in the first trial in dense podocarp forest where net decrement of 1.5-1.7 m^3/ha/annum in residual merchantable trees in logged blocks contrasted with a small net increment in the unlogged control. Internal decay, however, is likely to have reduced that increment substantially.

Basal area increment averaged 0.4m^2/ha/year in logged patches in the medium-density trial at Pureora, similar to that in patches of adjacent unlogged forest without canopy tree deaths. Increased diameter growth in tawa saplings and poles previously suppressed by overtopping podocarps followed harvesting there (Ogden and West 1981) in response to increased illumination and reduced inter-specific competition (Smale and Kimberley 1986). However, age-related declines in diameter growth in rimu and matai at Pureora and Tihoi suggest that most residual trees of these species are probably too old to respond to any reduction in competition from logging.

(5) Impacts on structure and composition

The removal of between 30 and 56% of merchantable volume, mostly larger podocarps, has altered the structure of the residual forest by removing a substantial proportion of the component which contributes most to its structural integrity and disproportionately to biodiversity (Norton 1995). Mature to senescent trees in podocarp/beech (*Nothofagus* spp.) and beech forests elsewhere are disproportionately important as habitat for many bird species (O'Donnell and Dilks 1994) and mistletoes (Owen and Norton 199?). In the earlier high-density trial at Tihoi, increased mortality after harvesting exacerbated this loss. Only in the mortality-prone and individual tree selection blocks of the high-density trial at Whirinaki where just 9-15% of merchantable volume was removed has there been minimal loss of structural integrity.

Twenty years after logging in the medium-density trial at Pureora, mean foliage density between 11 and 7 m was significantly lower than in unlogged forest, but below 1 m was significantly higher in logged than unlogged forest. A similar decrease in upper foliage density between 15 and 24 m occurred at Whirinaki, but was higher only at 7 m — probably from crown expansion of existing subcanopy trees — and there was no difference in the lowest tiers (J.R. Leathwick unpubl. data). Despite these differences, overall foliage density profiles were essentially similar in logged and unlogged forest.

Logging in the Whirinaki high-density trial reduced the overall mean diameter of canopy trees only slightly where selection was based on silvicultural criteria (i.e., removing individual trees or groups of trees) and increased it slightly where ecological criteria (i.e., removing mortality-prone trees) were employed (Table 5, p 26). The relative abundance of canopy species was almost unchanged (Table 6, p 26). In three of the five trials, matai suffered proportionally greater mortality than rimu, reflecting its greater average age and poorer average condition. Nearly two decades later, blocks where individual or mortality-prone trees were harvested at Whirinaki present a 'near-natural' (Benecke 1996) appearance.

In the medium-density trial at Pureora, tree ferns, wineberry (*Aristotelia serrata*), and bush lawyer (*Rubus cissoides*) were significantly more common in logged blocks 20 years later than in

Table 4: Impact of selection silviculture on residual stability and productivity in central North Island indigenous forests

Forest and management type	*Date of logging*	*Monitoring period (yrs)*	*Forest type*	*Percent. of merch. vol. removed*	*Residual forest stability (% of residual merch. trees lost/yr)*	*Residual productivity: periodic merch. vol. increment (m^3/ha/yr)*
Pureora SF (medium density)	1961	21	podocarp/tawa	A: control B: 34% C: 30%	A: 0.4 B: 0.3 C: 0.4	A: -0.7 B: -0.2 C: -0.2
Whirinaki SF (medium density)	1961	22	podocarp/tawa	A: control B: 40% C: 35%	A: 1.2 B: 1.2 C: 0.9	- - -
Tihoi SF (high density)	1975	3	dense podocarp	A: control B: 30% C: 55%	A: 0.6* B: 1.2* C: 2.4*	A: 0.2 B: -1.5 C: -1.7
Tihoi SF (low density)	1976	6	podocarp/[kamahi] /shrub hardwoods	A[1]: control B: 56%	A: 0.2 B: 0.3	- -
Whirinaki SF[2] (high density)	1979	3	dense podocarp/tawa	C: control S: 9% G:14% I: 15%	A: 0.8 S: 0.3 G: 0.8 I: 0.8	A: -4.0 S: -1.0 G: -4.8 I: -5.4

* *Over the first 20 months after logging.*
[1] *Six unlogged blocks provided a quasi-control.*
[2] *Mortality includes the effects of Cyclone Bernie (April 1982).*

Table 5: Impact of selective harvest on mean diameter (cm) of canopy trees (>30 cm dbh) in high-density podocarp forest at Whirinaki, central North Island
Arrows indicate direction of change from unlogged to logged state.

	Rimu	Matai	Miro	Kahikatea + Totara	Tawa	Other hardwoods	Overall
Group selection (G)							
Before logging	95	80	48	102	41	48	71
Logged	92	79	50	101	44	55	77
Direction of change	↑	↑	↓	↑	↓	↓	↓
Individual selection (I)							
Before logging	94	78	46	94	41	39	72
Logged	95	73	51	128	36	35	83
Direction of change	↓	↑	↓	↓	↑	↑	↓
Mortality-prone trees (S)							
Before logging	97	84	49	78	41	51	73
Logged	77	83	45	73	44	58	66
Direction of change	↑	↑	↑	↑	↓	↓	↑

Table 6: Relative density (%) of canopy trees (>30 cm dbh) before and after selective harvesting in high-density podocarp forest at Whirinaki, central North Island
(derived from Smale et al. 1987). Arrows indicate direction of change from unlogged to logged state.

	Rimu	Matai	Miro	Kahikatea + Totara	Tawa	Other hardwoods
Group selection (G)						
Before logging	41	15	26	1	16	1
After logging	39	15	27	1	17	1
Direction of change	↓	=	↓	=	↓	=
Individual selection (I)						
Before logging	32	26	13	6	21	2
After logging	30	26	14	6	23	2
Direction of change	↓	=	↓	=	↓	=
Mortality-prone trees (S)						
Before logging	41	18	17	1	21	2
After logging	40	18	18	2	20	2
Direction of change	↓	=	↓	↓	↓	=

adjacent forest. Wineberry and a ground fern, *Blechnum fluviatile*, were significantly more common in logged blocks at Whirinaki and mahoe (*Melicytus ramiflorus*) less common (J.R. Leathwick unpubl. data).

(6) Impacts on regeneration of major canopy species

Major differences in the amount of advance growth of podocarps present before harvesting existed between localities, regardless of forest type. Podocarp regeneration over 15 cm high was common at west Taupo but very rare at Whirinaki. Red deer (*Cervus elaphus*) and possums (*Trichosurus vulpecula*) have been present for about twice as long at Whirinaki as west Taupo, and heavy browsing by deer and possums of seedlings planted in 1961 outside exclosures at Whirinaki but not at Pureora suggest that browsing animals have played a significant role at Whirinaki. Advance growth of tawa was common wherever the species was important in the canopy.

In the medium-density trial at Pureora, levels of advance growth <3m tall 12 and 23 years after harvesting were similar to those existing beforehand (~1500-4000 podocarps/ha, ~4000-11 000 tawa/ha). Only tawa remained significantly (~50%, p <0.01) reduced in one block. The fact that two-thirds of the logged blocks remained undisturbed indicates that at least this proportion of smaller stems was probably bypassed during logging and that losses incurred by it had largely been recouped in the decade or so following, podocarps from seed and tawa from both seed and vegetative regrowth of damaged and neighbouring stems. In the low-density trial at Tihoi, harvesting destroyed about a quarter of existing advance growth (~300 podocarps/ha 1-30 cm dbh).

Comparisons between pre- and post-logging advance growth are not available for the remaining trials. Twelve years after harvesting in the Whirinaki medium-density trial, however, the density of podocarp regeneration was similar everywhere (~100-250/ha) but tawa significantly lower (35-39%, p<0.01) in both logged blocks than in the unlogged control (~200-350/ha). The density of podocarp regeneration increased markedly over the following decade even in unlogged forest, indicating that factors other than logging (e.g., decreased browsing intensity) were responsible. Over the same period tawa densities increased in logged blocks to similar levels to that in the control, suggesting recovery from losses caused by logging.

Nine years after harvesting in the high-density trial at Tihoi, the density of podocarp regeneration (~2000-3000/ha) was significantly lower (26%, p<0.01) in the 30% logged block than in the control (Veale 1986). High densities (~14 000/ha) of ephemeral podocarp seedlings (virtually all <15 cm high) occur in unlogged high-density forest at Whirinaki, showing that effective seed production, dispersal, and germination are all occurring there. Densities of podocarp and tawa regeneration were significantly lower (24-42%, p<0.01) in logged blocks than in the control immediately after logging.

Despite the absence of pre-logging data limiting interpretation of many of these results, it is clear that selection silviculture using ground extraction inevitably reduces advance growth of major canopy species, and that recovery to pre-harvest levels can take at least 10-20 years. Tawa seedlings evidently re-establish more slowly on logging-disturbed ground than podocarps, a reflection of the species' establishment requirement for substrates with some humus and overhead shelter.

In all trials, miro was greatly over-represented as juveniles in both unlogged and logged forest compared with its importance as a canopy species, a common phenomenon (Hinds and Reid 1957); it comprised from 20% to nearly 60% of all podocarps <5cm dbh. Rimu was generally the next most common species (20% to nearly 40%), followed by matai and kahikatea (*Dacrycarpus dacrydioides*). Correlations between site characteristics and the density of podocarp regeneration indicated that the presence nearby of mature seed trees, sparse to moderately dense canopy and understorey tiers, and light ground disturbance favoured replacement (Veale 1986).

Removal of tree boles means that gaps produced by harvesting differ fundamentally from those created naturally by standing death, uprooting, and even windsnap, leading potentially to different regeneration patterns (Norton 1995). All modes of natural treefall leave tree boles to decay on the forest floor; in central North Island podocarp forests these are 'safe sites' for the regeneration of kamahi (Wardle 1966) and some podocarps as well. However, the head logs left after logging can provide safe sites for podocarp regeneration, as in the medium-density trial at Pureora.

(7) Forest recovery after harvesting

Ground harvesting completely destroys forest structure in some places (e.g., at skid sites), partly in others (e.g., where advance growth has survived felling of a previously overtopping tree), and leaves it intact in others (as in residual patches of undisturbed forest). Complete loss initiates new primary or secondary successions, depending on the degree to which the underlying substrate is disturbed or not. Partial loss shifts the forest forward around the forest growth (i.e., canopy replacement) cycle to gap or building phases, depending on its severity. Managed forest is likely to be floristically more diverse than before, containing limited areas of primary successional vegetation where forest structure has been lost entirely and the underlying substrate disturbed.

Harvesting in the medium-density trials, the heavily logged high-density trial, and the group-selection block of the high-density trial has resulted in a smaller proportion of mature forest and a correspondingly larger proportion of younger — gap, later building — phases. In the lightly logged high-density trial, however, many major extraction tracks are sufficiently narrow and carefully placed as to have retained the canopy above them and in the blocks where mortality-prone trees or individual trees were harvested, some gaps were small enough to have been closed simply by lateral expansion of the surrounding 50-60 m high canopy. Therefore the maximum extent of logging gaps in the latter trial is probably less than the proportion of ground used as major extraction routes plus that covered by heavy slash (16-24%). Estimates of proportions of different-aged patches in unlogged forest are few. However, one hectare of forest at Mamaku similar to that in the medium-density trials at Pureora and Whirinaki contained only 10% of its area in gaps (Smale et al. 1997), suggesting that some outcomes of the most lightly logged trials may be within the range of conditions commonly encountered in unlogged forest. They can be exceeded naturally by localised catastrophic damage from occasional climatic (e.g., Shaw 1983) or rare geological events.

Forest recovery after harvesting has been documented quantitatively only in the medium-density trial at Pureora. Where forest structure had been lost altogether, successional sequences depended on the type of ground disturbance incurred. Putaputaweta (*Carpodetus serratus*), grasses (especially *Cortaderia fulvida*), sedges (*Uncinia* and *Carex* spp.), and ground ferns initially colonised scraped compacted sites. Twenty four years later, they supported thickets of putaputaweta and small-leaved coprosmas (*Coprosma rotundifolia* and *C.* 'taylorae') over dense ferns. Rimu seedlings are sufficiently common on some such sites — some 5 000/ha along major extraction tracks 16 years after logging — to foreshadow dense podocarp stands there. Wineberry and tree fuchsia (*Fuchsia excorticata*) colonised sites with churned soil containing humus, most wineberry collapsing under the weight of lianes and succumbing to its natural lifespan after 15-20 years and tree fuchsia to possum browsing. Rimu, tawa, and to a lesser extent matai seedlings are now frequent on these sites.

Sites covered by slash were originally colonised by wineberry, tree fuchsia, pate (*Schefflera digitata*), tree ferns (mostly *Dicksonia squarrosa*) and a little later, fivefinger (*Pseudopanax arboreus*), kamahi, and ground ferns. Twenty-four years on, they were dominated by tree fern groves or dense ground ferns, most wineberry having died and fuchsia and much kamahi and fivefinger having succumbed to possums. Kamahi is an important species in podocarp regeneration cycles in these forests (Beveridge 1973) and its demise by possums may have significant long-term consequences for forest structure and composition. Thirty-six years later, rimu and tawa seedlings are frequent on these sites.

Current observation suggests that similar successions are occurring in the other trials, but with some differences. Tihoi has a shorter history of possum occupation than Pureora; much fuchsia survives and remains, along with putaputaweta and senescing wineberry, an important component of successions on logging-disturbed ground there. Deer largely eliminated palatable shrub hardwoods in the Whirinaki trials, inducing dense swards of grasses, sedges, and ground ferns. Senescing wineberry — which lives longer at Whirinaki than at west Taupo — and putaputaweta dominate logging-disturbed ground in the medium-density trial there. As well as rimu, small matai seedlings are common on scraped, compacted and on churned ground.

In the case of partial loss of forest structure, nearly a century is needed, on average, for logged patches with surviving tawa advance growth to recover 80% of their previous basal area (Smale et al. 1987); a longer time would obviously be needed in places where forest structure had been lost altogether and a shorter time by the forest as a whole. Similar estimates have been made for warm-temperate rain forest in mainland Australia (Horne and Gwalter 1987). Where well-developed tawa advance growth survived harvesting, the removal of podocarps merely telescoped the canopy replacement process. Similar responses can occur where podocarp advance growth has survived harvesting. Rimu and miro developing around kamahi stumps in unlogged forest grew much faster on average with full overhead light than under a canopy (Smale and Kimberley 1986), and thickets of miro saplings have responded to the removal of previously overtopping tawa.

Podocarp seedlings — mostly rimu, kahikatea, and totara — planted in groups on selected microsites in logged gaps with minimal subsequent releasing have performed well in all trials; overall survivals were ~80% over 15-20 years, and mean annual height increments average 15 cm. Large seedlings have performed better than smaller ones but potted stock has shown no advantage over bare-rooted and mulching has not proved beneficial (Steward and Pardy 1990). In the high-density trial at Whirinaki, most podocarp seedlings planted in the substantial gaps cleared of slash in the group selection block have survived and are up to 5 m tall after 18 years. Gaps were cleared of slash, allowing seedlings to escape smothering by tree ferns. In the individual tree and mortality-prone selection blocks, however, most seedlings have long since succumbed to competition fro m the tree fern understorey. Rimu is regarded as the key species for planting because it has the widest site tolerance, can survive long periods of suppression, is the least palatable to introduced mammals, and has the best overall performance of the large podocarps (Beveridge et al. 1985). In contrast, tawa planted elsewhere in the region has shown poor survival but reasonable growth rates (Knowles and Beveridge 1982).

Assuming average growth rates, estimated times for major canopy species to reach moderate diameters (60 cm dbh) from large seedling size are ~240 years for rimu and tawa but longer — well over 300 years — for slower-growing matai and miro (Herbert 1980, Hinds and Reid 1957, Smale et al. 1985, Smale and Kimberley 1986, Smale et al. 1986, Smale et al. 1987, Smale et al. 1997). Despite the conifer↔hardwood regeneration cycles operating in some of these forests, observations of natural regeneration and experimental data (e.g., Steward and Pardy 1990) indicate that the sites most readily available for planting — gaps created by felled podocarps — are suitable for podocarp seedlings.

(8) Incursion of weeds

Incursion of invasive weeds has not occurred to any significant extent within selectively managed forest itself. Exceptions are sites where logging machinery has removed soil altogether and compacted the underlying substrate (e.g., skid sites) or compacted it in low-lying places, impeding drainage. Some severely scraped, compacted sites have been invaded by heather (*Erica lusitanica*) and buddleia (*Buddleia davidii*), and waterlogged ones by grey willow (*Salix cinerea*) and adventive herbs such as rushes (*Juncus* spp.). Weedy legumes with long-lived seeds such as gorse (*0*) and broom (*Cytisus scoparius*) are frequently dispersed with road metal along major roads. The long-term persistence of some of these species in forest environments, however, is doubtful.

IMPLICATIONS FOR FUTURE SUSTAINABLE

MANAGEMENT

The selection system is generally considered suitable for continuously regenerating shade-tolerant species (Matthews 1991) adapted to a small-scale disturbance regime, i.e., regenerating in the understorey of high forest or in small gaps. Such species characteristically have 'reverse J' (≈ negative exponential) diameter distributions which are typical of an ideal selection forest and which harvesting is supposed to maintain (Matthews 1991). Of the major canopy species in the trials, only tawa consistently has 'reverse J' diameter distributions. Miro often shows this pattern, but nowhere in the central North Island do rimu or matai even begin to approach it. The effects of harvesting on diameter distributions of major species are a crucial issue in selection silviculture but have yet to be examined in the trials.

Selection silviculture aims at mimicking natural replacement patterns, so the size of felling coupes is critical in the use of harvesting as a silvicultural tool (Benecke 1996). Natural openings in tawa-dominant forest at Rotoehu and Mamaku average 0.014 ha in extent (Smale and Kimberley 1983, Smale et al.1997), i.e., with a diameter of ~12 m, much less than predominant canopy height. Significantly, this is the critical maximum gap size for tawa at Hurakia, west Taupo (P.R. Nieuwland unpubl. data). Tawa maintains sizeable banks of advance growth: long-lived, slow-growing, shade-tolerant 'striplings' which can develop slowly to maturity under intact canopies although growth is greatly enhanced by higher light levels (Smale and Kimberley 1986, West 1995). Rimu is more light-demanding and its persistent shade-tolerant seedlings (Smale and Kimberley 1986) need at least disintegrating hardwood overstories (Herbert 1986) or small gaps to develop further. More light-demanding species such as rimu and matai may be better suited to the 'group selection' system advocated for the New Zealand beeches by Wardle (1984), entailing the removal of larger groups of trees — creating larger gaps — than the true selection system (Matthews 1991). Quantitative data on relative growth rates of podocarps planted in gaps of widely different sizes in the Whirinaki high-density trial are needed to confirm this. Thus tawa, the major hardwood in these trials, appears well suited to the selection system but the major conifer, rimu, more suited to the group selection system. Maintaining both conifers and hardwoods in the same tract of forest will apparently necessitate artificial disturbance (i.e., creating canopy gaps) at a range of scales.

Group selection silviculture of podocarps in the foreseeable future should involve pre-empting natural mortality of ageing canopy populations by harvesting declining trees — in small groups where possible, leaving scattered groups of seed trees (i.e., sound trees with healthy crowns), and supplementing advance growth by planting large nursery-raised seedlings in logged gaps. The usual aim of improving the quality of the 'crop' scarcely applies to the mature to senescent cohorts of rimu and matai in many forests. The proportion of wood volume that can be harvested at any one time from a given area of forest without impairing residual stability and productivity depends on the forest or 'management' type; that is, the lower the density of merchantable trees, the larger the proportion of standing volume that can safely be removed. The widespread occurrence — at least in upland forests on the Volcanic Plateau — of relatively old canopy populations of rimu and matai with net volume decrement, restricted age ranges, and few small trees — together with their long rotations — suggest that proper selection silviculture will only be attained in these forests in the very long term.

Some associated hardwood species may be more amenable to selection silviculture in the shorter term, tawa — with all-aged continuously regenerating populations on favourable sites — in particular presenting good silvicultural prospects. Selection silviculture should involve harvesting sound individual trees which are suppressed by others or are suppressing others, and felling defective trees which are suppressing others.

Felling cycles are an important issue in forests managed by the selection system (Matthews 1991). With most rimu and matai trees nearing the end of their normal lifespan (~600 years: Norton et al. 1988, Enright and Ogden 1995), mortality rates — currently approaching 1% per annum in virgin forest — are likely to increase and existing cohorts largely to disappear within the next century or so. Further harvests from existing cohorts of these species will therefore be possible only for a limited period and their frequency will be restricted by the need to allow recovery from previous logging. Aerial salvage of dead trees or using existing extraction tracks would seem appropriate in managed forests. Where advance growth is not already well-developed, there will then be a substantial delay — even if planting is undertaken immediately after harvesting — before further harvesting can occur. With enough of the previous podocarp cohort left to allow significant harvests of timber and another already well advanced, the forest in the low-density trial at Tihoi represents something of an ideal at which selection silviculture might aim. Long-term changes in forest structure and composition and declining timber yields have been predicted with selective harvesting repeated at 30 to 40 year intervals in Australian rain forests (Horne and Hickey 1991); similar studies of the impact of repeated harvests are needed here.

CONCLUSIONS

The objective of these trials, i.e., removing a proportion of the merchantable volume of the forest while maintaining a stable residual stand with other values essentially intact, falls short of the theoretical aim of the selection system: improving the quality and value of the forest. Extracting a certain proportion of the existing volume does not in itself ensure that diameter distributions of major species are regulated in the desired manner (Roach 1974). Only the last Whirinaki trial approaches the selection system in its use of harvesting as a silvicultural tool. The selection system is often regarded as the most natural one, but in fact few natural forests appear to resemble it and careful human intervention is needed to maintain it (Matthews 1991). The ecological characteristics apparent in the main podocarps — adaptation to low-frequency, large-scale disturbances and consequent decline in their absence — suggest that, notwithstanding the results reviewed here, manipulation of forests such as those in the trials by a group selection system will inevitably lead to long-term changes in structure and composition different from those that would have occurred without it (see Norton 1995). However, they may well remain within the range of outcomes occurring naturally in these forests. As a species with a shorter lifespan better adapted to higher-frequency, small-scale disturbances, tawa presents better prospects for selection silviculture mimicking natural population processes.

Because of relatively steep and inaccessible terrain, much current and proposed future management in North Island forests entails aerial (helicopter) harvesting (Ministry of Forestry, pers. comm.), likely to involve less impact on the residual forest (ground condition, residual trees, and advance growth) than the ground extraction used in the trials. On the other hand, because trees were marked and extraction routes chosen by research staff, the trials represent optima which have not been achieved in operational logging in the past and are unlikely to be achieved in future. Despite their limitations, they have provided valuable insights not only into the likely impacts of some current management practices but also into the ecology of some widespread forest types in the region.

A good understanding of the ecology of natural forests is an essential prerequisite for successful (i.e., 'near-natural') manipulation of them. Some outcomes of selection silviculture, at least in some forest types, can be within the range of conditions normally encountered in unlogged forest. Other un-natural ecological impacts, such as the removal of potential 'safe' regeneration sites for some canopy species and a reduction in soil rejuvenation by uprooting, may not be avoidable but require documentation.

Much work remains to be done on the ecological impacts of sustainable management on native forests and long-established management trials with fully comparable unlogged controls can help show how closely — or otherwise — selection silviculture mimics the natural dynamics of these forests.

Although many of the implications of these trials are accommodated in the management prescriptions in current legislation, there is a pressing need for further documentation of the longer-term silvicultural and ecological outcomes of some of them to assist silvicultural practice that aims to achieve ecological sustainability. The scale of proposed sustainable management of native forests suggests that current funding levels are not sufficient to fund the research base needed to underpin it.

Most future management of lowland forests on freehold land in the North Island will be in low- or medium-density podocarp forests, particularly tawa-dominated ones, so the early Pureora and Whirinaki trials are particularly relevant in this context. The last trial, in high-density podocarp forest at Whirinaki, is also highly relevant because both its harvest levels and its ecological aims are closest to those of present practice. These trials should be maintained not only for further documentation but also as demonstration areas of 'near-natural' management of indigenous forest.

A case can also be made, however, for the establishment of further trials using aerial extraction methods on steeper terrain and examining a more comprehensive range of impacts (e.g., nutrient cycling, soil health, reproductive health of residual canopy trees) than has been undertaken so far. If carried out on several freehold properties in conjunction with owners/managers, they would have the important advantages of replication (unattainable in existing trials because of cost constraints), reality (measuring the impacts of contemporary harvesting practices), and relevance (ready application of results by forest owners and managers).

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REFERENCES

Allsop, F. 1973: The first fifty years of New Zealand's Forest Service. New Zealand Forest Service Information Series No. 59. Government Printer, Wellington.

Benecke, U. 1996: Ecological silviculture: the application of age-old methods. New Zealand Forestry, August 1996: 27-33.

Beveridge, A.E. 1973: Regeneration of podocarps in a central North Island forest. New Zealand Journal of Forestry 18: 23-35.

Beveridge, A.E. 1983: Regeneration of podocarps and maintenance of productivity. In: Thompson, K.; A.P.H. Hodder; A.S. Edmonds (eds.): Symposium on 'Lowland forests in New Zealand'. University of Waikato, Hamilton, New Zealand.

Beveridge, A.E.; J.W. Herbert. 1978: Selective logging trials and their implications for management of the West Taupo forests. Proceedings of the New Zealand Forest Service seminar on 'Management proposals for State Forests of the Rangitoto and Hauhungaroa Ranges'. New Zealand Forest Service, Wellington.

Beveridge, A.E.; D.O. Bergin; G.F. Pardy. 1985: Planting podocarps in disturbed indigenous forests of the central North island. New Zealand Journal of Forestry 30: 144-158.

Cameron, R.J. 1954: Mosaic or cyclical regeneration in North Island podocarp forests. New Zealand Journal of Forestry 7: 55-67.

Enright, N.J.; Ogden, J. 1995: The southern conifers — a synthesis. In: Enright, N. J.; R.S. Hill (eds.) Ecology of the southern conifers. Melbourne University Press, Melbourne. 341p.

Forest Research Institute 1959: Report of the Forest Research Institute for the period 1 January to 31 December 1959. New Zealand Forest Service, Wellington.

Forest Research Institute 1961: Report of the Forest Research Institute for the period 1 January to 31 December 1961. New Zealand Forest Service, Wellington.

Gibbs, H.S. 1983: Development and plant relationships of lowland forest soils. In: Thompson, K.; A.P.H. Hodder; A.S. Edmonds (eds.): Symposium on 'Lowland forests in New Zealand'. University of Waikato, Hamilton, New Zealand.

Herbert, J.W. 1980: Structure and growth of dense podocarp forest at Tihoi and the impact of selective logging. New Zealand Journal of Forestry 25: 44-57.

Herbert, J. W. 1986: Cyclic regeneration of podocarps at Tihoi. In: Veale, B. J.; J.G. Innes (eds.) Ecological research in the central North Island Volcanic Plateau region. Proceedings of a New Zealand Forest Service Forest Research Institute workshop, Pureora.

Herbert, J.W. 1991: North Island podocarp and podocarp-hardwood forests Pp 18-27 in: Stewart, G.H. (comp.) Review of the ecology and silviculture of indigenous forests for the production of timber. Forest Research Institute, Ministry of Forestry contract report FWE 91/66.

Herbert, J.W.; Beveridge, A.E. 1977: A selective logging trial in dense podocarp forest. New Zealand Journal of Forestry 22: 81-100.

Hewitt, A. E. 1992: New Zealand soil classification. Manaaki Whenua Land care Research, Lincoln, New Zealand. 133 p.

Hinds, H. V.; J. S. Reid. 1957: Forest trees and timbers of New Zealand. New Zealand Forest Service Bulletin No. 12. Government Printer, Wellington.

Hood, I.A.; C.J. Sandberg; M.O. Kimberley. 1989: A decay study of windthrown indigenous trees. New Zealand Journal of Botany 27: 281-298.

Horne, R.R.; J. Hickey. 1991: Review: Ecological sensitivity of Australian rainforests to selective logging. Australian Journal of Ecology 16: 119-129.

Horne, R.; J. Gwalter. 1987: The recovery of rainforest overstorey following logging. 2. Warm-temperate rainforest. Forest Ecology and Management 22: 267-281.

Katz, A. 1980: Structure and growth of dense podocarp forest in Whirinaki. Forest Research Institute, New Zealand Forest Service, Indigenous Forest Management report no. 25.

Knowles, F.B.; A.E. Beveridge. 1982: Biological flora of New Zealand. 9. Beilschmiedia tawa (A. Cunn.) Benth. et Hook. f. ex Kirk (Lauraceae) Tawa. New Zealand Journal of Botany 20: 37-54.

Lusk, C.; Ogden, J. 1992: Age structure and dynamics of a podocarp-broadleaf forest in Tongariro National Park, New Zealand. Journal of Ecology 80: 379-393.

Matthews, J.D. 1991: Silvicultural systems. Clarendon Press, Oxford. 284 pp.

McKelvey, P.J. 1963: The synecology of the West Taupo indigenous forest. New Zealand Forest Service Bulletin No. 14.

McKelvey, P.J. 1973: The pattern of the Urewera forest. Forest Research Institute, New Zealand Forest Service, Technical Paper No. 59.

McKelvey, P.J.; J.L. Nicholls. 1957: A provisional classification of North Island indigenous forests. New Zealand Journal of Forestry 7: 84-101.

Ministry of Forestry 1997: Indigenous forestry: Sustainable management. A guide to plans and permits. Ministry of Forestry, Christchurch.

New Zealand Forest Service 1975: Statistics of the Forests and Forest Industries of New Zealand. New Zealand Forest Service Information Series No. 33. Government Printer, Wellington.

New Zealand Forest Service 1977: Management policy for New Zealand's indigenous State Forests. New Zealand Forest Service, Wellington.

Norton, D.A. 1995: Ecological realism and the sustainable management of indigenous forests for timber production. Pp. 70-77 in: Norton,

D.A.; Allen, J.C. (eds.): Professional forestry — evolving issues in forest management. School of Forestry, University of Canterbury, Christchurch.
Norton, D.A.; J.W. Herbert; A.E. Beveridge. 1988: The ecology of Dacrydium cupressinum: a review. New Zealand Journal of Botany 26: 37-62.
O'Donnell, C.F.J.; P.J. Dilks. 1994: Foods and foraging of forest birds in temperate rainforest, south Westland, New Zealand. New Zealand Journal of Ecology 18: 8-107.
Ogden, J.; C.J. West. 1981: Annual rings in Beilschmiedia tawa (Lauraceae). New Zealand Journal of Botany 19: 397-400.
Ogden, J.; G.H. Stewart. 1995: Community dynamics of the New Zealand conifers. In: Enright, N. J.; R.S. Hill (eds.) Ecology of the southern conifers. Melbourne University Press, Melbourne. 341p.
Owen, H.J.; D.A. Norton. 1995: The diet of introduced brushtailed possums Trichosurus vulpecula in a low-diversity New Zealand Nothofagus forest and possible implications for conservation management. Biological Conservation 71:339-345.
Pardy, G.F. 1984: The early impact of selective logging in low-density podocarp forest, Tihoi. Forest Research Institute, New Zealand Forest Service, Production Forestry Division Project Record No. 647 (unpubl.)
Roach, B.A. 1974: What is selection cutting and how do you make it work? What is group selection and where can it be used? Applied Forestry Research Institute, State University of New York, Syracuse, N.Y. Miscellaneous Report No.5.
Shaw, W.B. 1983: Tropical cyclones: determinants of pattern and structure in New Zealand's indigenous forests. Pacific Science 37: 405-414.
Smale, M.C.; M.O. Kimberley. 1983: Regeneration patterns in Beilschmiedia tawa-dominant forest at Rotoehu. New Zealand Journal of Forestry Science 13: 58-71.
Smale, M.C.; D.O. Bergin; G.F. Pardy; G.A. Steward. 1985: Selective logging of dense podocarp forest at Whirinaki: early effects. New Zealand Journal of Forestry Science 15: 36-58.
Smale, M.C.; J.L. Bathgate; R. Guest. 1986: Current prospects for tawa. New Zealand forestry 31: 13-18.
Smale, M.C.; M.O. Kimberley. 1986: Growth of naturally regenerated Beilschmiedia tawa and podocarps in unlogged and selectively logged podocarp/tawa forest, Pureora. New Zealand Journal of Forestry Science 16: 131-141.
Smale, M.C.; A.E. Beveridge; G.F. Pardy; G.A. Steward. 1987: Selective logging in podocarp/tawa forest at Pureora and Whirinaki. New Zealand Journal of Forestry Science 17: 29-50.
Smale, M.C.; B.R. Burns; P.N. Smale; P.T. Whaley. 1997: Dynamics of upland podocarp/broadleaved forest on Mamaku Plateau, central North Island, New Zealand. Journal of the Royal Society of New Zealand 27: 513-522.
Steward, G.A.; G.F. Pardy. 1990: Performance of rimu planted in logged gaps after salvage logging, Pureora Forest Park. Forest Research Institute, New Zealand Forest Service, Forest and Wildlands Ecosystems Division Project Record No. 2563 (unpubl.)
Veale, B.J. 1986: Natural regeneration in selectively-logged management trials in podocarp forests of the central North Island. Forest Research Institute, New Zealand Forest Service, Production Forestry Division Project Record No. 1170 (unpubl.)
Wardle, J.A. 1984: The New Zealand beeches. Ecology, utilisation and management. New Zealand Forest Service, Wellington. 447 pp.
Wardle, P. 1966: Biological flora of New Zealand. Weinmannia racemosa (Cunoniaceae) Kamahi. New Zealand Journal of Botany .
West, C. J. 1995: Sustainability of Beilschmiedia tawa-dominated forest in New Zealand: population predictions based on transition matrix model analysis. Australian Journal of Botany 45: 51-71.

BOOK REVIEW

Trees, Timber and Tranquillity

This new book by Lindsay Poole FRSNZ, which covers interesting aspects of the author's distinguished career in botany and forestry, is available through the Royal Society.

From birth at Whatatu in 1908 and youthful bird-nesting in Tuparoa Bay to visiting the 100-year-old redwood grove in Whaka Forest during the 1997 forestry centennial celebrations, much of Lindsay Poole's life has been involved with trees.

A traineeship with the Forest Service was followed by the theoretical study of forestry and science at the Forestry School at Auckland University College. Then followed practical activities with the Forest Service, such as quartermastering unemployment camps, shooting deer and a spell in Head Office, during the depression, and a year in the Botany Division of DSIR. With the war came scientific liaison work in London, and then a spell in the Forestry and Timber Control of the British Military Government in Germany. There he became involved directly in the strictly controlled forestry administration and operations. Wood was absolutely essential for war. The forests has not long gone through one world war, had survived and looked as though they could supply another. In spite of overcutting, the long-term needs and sustained yields of the forest were paramount.

On his return to New Zealand he was appointed Assistant Director and in 1949 Director of the Botany Division, and this led unexpectedly to being appointed Assistant Director of the Forest Service, and later Director-General.

By 1950 the Service was becoming broadly based and particularly active in establishing plantation forests and preparing the way for the sale of substantial quantities of wood from planting that was started at the beginning of the century by Lands Department. While disposal of the wood was achieved readily enough, disposal in a safe forest way proved to be impossible. This had adverse repercussions in all wood sales through to the 1980s and eventually led to the demise of the Forest Service.

"Trees, timber and tranquillity" (published by C. Rex Monigatti Publishing, ISBN 0-473-04789-6) is in hardback, 148 pages, with colour and black & white photos. It can be purchased for $35 from the Royal Society through SIR Publishing; email sales@rsnz.govt.nz.

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