Cattle grazing and the regeneration of totara (*Podocarpus totara* var. *waihoensis*) on river terraces, south Westland, New Zealand

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Abstract: Totara-matai forests are an under-represented forest type in Westland, relative to their original extent, and require protection and enhancement where possible. This study examined the regeneration of totara on gorse-covered river terraces of the Whataroa and Waiho Rivers, on a site grazed by cattle at Whataroa, and ungrazed sites at both locations. Totara is regenerating prolifically at all sites. Tall-seedling densities were significantly higher at the grazed Whataroa site than at the ungrazed Whataroa site. Conversely densities of small seedlings were significantly higher at the ungrazed Waiho site, with the majority of seedlings occurring on raised surfaces created by rafted logs or occasional silt patches, than at either of the Whataroa sites where seedlings established on the ground. Sapling and tree densities were similar at both Whataroa sites, but significantly greater than at the Waiho site. There was a significant relationship between the density of saplings and trees with terrace age at the Whataroa sites. Gorse cover and seedling density were significantly related at both ungrazed sites, but not at the grazed site. Grazing and gorse cover both appear to have roles in totara regeneration on river terraces. The implications of current management for future forest development are discussed, and it is considered that these areas warrant designation as areas of significant indigenous vegetation because of their conservation potential.

Keywords: conservation; grazing; managed succession; New Zealand; *Podocarpus totara* var. *waihoensis*; regeneration; significant indigenous vegetation; south Westland.

Introduction

The forests of New Zealand's floodplains were extensively cleared for agriculture following European settlement and are now under-represented both in extent and within nature reserves (Park, 1983; Ministry for the Environment, 1997). This poses a challenge for the maintenance of indigenous biodiversity within these agricultural landscapes (Miller, 2000; Norton and Miller, 2000). Indeed New Zealand's biodiversity strategy requires that scarce and fragmented habitats (such as floodplain forests) are increased in area (Anon., 2000). This may be achieved through active revegetation (e.g. Hobbs, 1995; Saunders and Hobbs, 1995) or natural succession (e.g. Wilson, 1994; Burns *et al*., 2000).

Totara-matai (*Podocarpus totara*-*Prumnopitys taxifolia*) forest associations are particularly under-represented on the floodplains of the Westland district, South Island, relative to their original extent. Because of this, many of the remaining forest patches fit the criteria for designation as significant indigenous vegetation, in terms of the Resource Management Act 1991 and should be a priority for protection and enhancement where possible (McSweeney, 1982; Awimbo *et al*., 1996; Miller, 2002a). Because these patches occur on prime farmland, a limited resource in Westland, it is unlikely that landowners will look favourably upon extending existing patches through active revegetation.

Succession from floodplain or river valley terraces to podocarp-dominated forest in south Westland is described by Wardle (1974, 1980), and the role of disturbance events in structuring these forests is described in Duncan (1993), Ebbett (1998), Wells *et al*. (1998, 2001). Briefly, totara and matai tend to establish following large scale disturbance, typically after aggradation following flooding or earthquakes, or by the colonisation of recently formed river terraces or abandoned channels (Beveridge, 1973; Ebbett, 1998; Wells *et al*., 1998). The opportunity for successful establishment of totara, a light demanding species, is restricted to a relatively small period after a disturbance event, with regeneration ceasing once the canopy closes over (Ebbett and Ogden, 1998; Ebbett, 1998). Ebbett (1998) found that the regeneration phase for totara lasts 50-200 years, with matai entering *c*.50 years after totara. A dense canopy then forms 120-200 years after stand initiation (Ebbett, 1998; Wells, 1998).

The trajectory of natural succession is largely determined by differential species availability, site availability, and differential species performance (Pickett *et al*., 1987). Since European settlement traditional successional pathways to forest have been affected by the loss of seed sources and some seed dispersers, changed environmental conditions (e.g. hydrology), pasture maintenance, grazing, and the presence of introduced woody species such as gorse (*Ulex europaeus*) and tall grass species such as Yorkshire fog (*Holcus lanatus*). Grazing is known to affect succession in native plant communities, typically by reducing the abundance of palatable species and increasing the abundance of non-palatable species (but see Augustine and McNaughton,1998). While some early successional woody species, such as kanuka (*Kunzea ericoides*) or totara, can establish on bare ground or in short-statured pasture (Wardle, 1974; Beveridge, 1973; Allen *et al*., 1992; Wilson, 1994), the establishment of most native woody species is inhibited in retired pasture, or grassland dominated by tall introduced grass species such as cocksfoot (*Dactylis glomerata*) (Esler, 1967; Allen *et al*., 1992; Wilson, 1994).

Introduced grasses inhibit the establishment and growth of woody seedlings because they reduce the availability of establishment sites, with a dense shallow fibrous root system (Grime, 1979), reducing light intensity at ground level, and physically smothering woody seedlings (Rogers, 1996; Widyatmoko and Norton, 1997). A number of species, including the native flax (*Phormium tenax*) and introduced gorse, have been demonstrated to act as nurse crops, providing sites for the establishment of native woody seedlings in retired grasslands (Healy, 1961; Lee *et al*., 1986; Wilson, 1994; Reay and Norton, 1999). Williams and Karl (1996, 2002) found that birds, such as silvereyes (*Zosterops lateralis*), are capable of dispersing totara seed, and are responsible for seed dispersal in gorse scrub. Eventually the flax or gorse is overtopped and succeeded by the native species (Wilson, 1994; Reay and Norton, 1999).

The maintenance of pasture on sites and soils favoured by totara and matai in south Westland has reduced the opportunities for the re-establishment of this forest type to recently abandoned river terraces that are usually owned by the Government and leased for cattle grazing. These areas have typically been viewed as having low conservation value because of weed infestation, agricultural land use, and lateral river movement. McSweeney (1982) suggested that grazing was inhibiting the recruitment and regeneration of totara, matai and kahikatea (*Dacrycarpus dacrydioides*) seedlings in forest patches in south Westland and, therefore, that the exclusion of stock from forest patches and sites such as young river terraces was the only way to ensure the survival of totara-matai forests. Conversely, Miller (2002b) found that while grazing affected the cover abundance of species in the shrub tier of kahikatea and totara-matai forest patches, it neither enhanced nor reduced the survival and recruitment of kahikatea, totara or matai seedlings. However, recruitment of *P. totara* var. *waihoensis* on grassed floodplains in south Westland may be facilitated by cattle grazing (Buxton *et al*., 2001).

If an appropriate management regime is to be established to facilitate regeneration of totara-matai forest it is necessary to determine whether grazing and gorse have positive or negative effects on the recruitment and regeneration of these species. This study initially sought to determine whether grazing was having a positive effect on the recruitment and regeneration of matai and totara alongside two rivers, and whether the number of seedlings, saplings and trees was related to gorse cover. However the lack of matai at any growth stage (*cf*. Ebbett, 1998) meant that we only focused on totara.

Study site

This study was conducted at two sites adjacent to the lower Whataroa River (43' 16"S, 170' 25"E), and one site adjacent to the Waiho River (42' 22"S, 170' 08"E), south Westland, New Zealand. Only two sites could be found that had not been grazed for more than two years. Cattle are currently grazed at a moderate stocking density (*c*. 12–15 stock units ha^{-1}) at one of the Whataroa sites, and were excluded from the other site by a fence about five years ago. This latter site was never heavily stocked (R. Pamment, landowner, Whataroa, NZ, *pers. comm*.). The Waiho site has not been grazed for about two years, but was grazed at a moderate stocking density (*c*. 12–15 stock units ha^{-1}) prior to this (R. Burnett, landowner, Franz Josef, N.Z., *pers. comm*.).

The lower Whataroa River lies in the Harihari Ecological District (ED), and the Waiho River lies in the Waiho ED (McEwen, 1987). Prevailing westerly winds and proximity to the coast result in a wet equable climate. Mean annual precipitation at the nearest climate stations, lower Whataroa and Whataroa 2, is 3711 mm and 4490 mm respectively, with little seasonal variation (Tomlinson and Sansom, 1994).

The Whataroa River sites consist of three terraces, with the first still subject to flooding. The part of the riverbed that forms the first terrace was abandoned by the river approximately 30 years ago (R. Pamment, *pers. comm*.). The gley recent soils of the Whataroa floodplain are derived from schist alluvium and consist of a fine sandy loam adjacent to the river banks through to fine sand across the floodplain. The Waiho site consists of part of the Waiho riverbed that has been isolated by a stopbank since the 1970s (M. Reedy, Department of Conservation, Hokitika, N.Z., *pers. comm.*). Old logs that were rafted and deposited by the river prior to establishment of the stopbank provide a number of raised surfaces. The recent soils of the Waiho floodplain are derived from greywacke, schist and granite and also consist of sandy and silt loams (Department of Scientific and Industrial Research, 1968), however most of the Waiho site consists of large cobbles with a thin layer of silt, and occasional deep patches of silt.

Totara-matai forest originally dominated the free-draining coarse soils of these floodplains, whereas kahikatea dominated the wetter siltier soils (McSweeney, 1982). The floodplains are now largely in pasture with small totara or totara-matai forest patches and individual trees scattered throughout. These trees, many of which are within 500 m of the river terraces, should provide an ample seed source. The terraces adjacent to both rivers are covered by gorse with occasional emergent totara, over totara seedlings, saplings, and grass. Prickly shield fern (*Polystichum vestitum*) and *Coprosma propinqua* are common at both sites, with mahoe (*Melicytus ramiflorus*) less common. Ground cover at the grazed site is a short turf, whereas the ungrazed sites are dominated by rank growth of adventive grass species such as Yorkshire fog.

Methods

At each site 7 variable length belt transects were established through the gorse, perpendicular to the river, starting from randomly located points along the riverbed. Transects were restricted to a maximum length of 300 m, or stopped when fenced pasture was reached. The numbers of small totara seedlings (<15 cm), tall totara seedlings (15 cm - 1.35 m), totara saplings (>1.35 m but <3 cm diameter at breast height (dbh)), and totara trees (≥3 cm dbh), and the dbh of all trees, were recorded within 20 m sections, 5 m either side of a tape measure set along the transects. Seedlings, saplings and trees were found to be spatially clumped within sites and transects. Gorse cover was estimated within each transect and ascribed to one of 6 cover classes (< 1%, 1-5%, 6-25%, 26-50%, 51-75%, 76-100%). The mid points of these cover classes, arcsine-square root transformed, were used for analysis.

Because of the low sample size, and because the data could not be adequately transformed to meet the assumptions of parametric analysis, attributes from the three sites were compared using conservative Kruskal Wallis tests adjusted for tied ranks. Where significant differences were detected ($P < 0.05$), *post hoc* Mann-Whitney *U* tests were conducted to determine differences between sites or terraces. Spearman's rank correlation (r_s) was used to examine the relationship between gorse cover and the number of totara stems.

Tree cores were taken from eleven trees ranging in size from 9–26 cm dbh on terraces 2 and 3 of the grazed Whataroa site. It was not possible to core all trees at 1.3 m, due to variable tree characteristics. Cores were air-dried, mounted, then sanded using successively finer grades of sandpaper until the growth rings were visible. Growth rings were counted under reflected light using a binocular microscope. Wells *et al.* (1998) calculated that 28 years should be added to the tree-ring age of totara in Westland to account for the time taken to reach coring size: we adopted this approach in our study.

Results

Totara seedlings, saplings and trees were present at both sites, but, as suspected (*cf.* Ebbett, 1998), no matai seedlings, saplings or trees were found either within or adjacent to the transects. Significant site differences were observed for all growth stages: small seedlings (χ^2 = 25.967, d.f. = 2, P < 0.001); tall seedlings (χ^2 = 12.128, d.f. = 2, P = 0.002); saplings (χ^2 = 7.651, d.f. = 2, P = 0.03); and trees (χ^2 = 19.578, d.f. = 2, P < 0.001).

There were significant differences in the number of small and tall seedlings at the grazed and ungrazed Whataroa sites (small seedlings: z = -3.881, P < 0.001; tall seedlings: z = -2.300, P = 0.02), with a higher density of both at the grazed site. Conversely there was no significant difference in the density of saplings (P = 0.23) or trees (P = 0.56) (Table 1). There was a significant difference between the number of trees at

Table 1. Mean density ± one standard error of seedlings, saplings and trees at the Whataroa and Waiho sites.

	Whataroa grazed	Whataroa ungrazed	Waiho ungrazed
Small seedlings	270 ± 86[1]	78 ± 59[2]	788 ± 198
Tall seedlings	711 ± 239[1]	137 ± 36[2]	887 ± 230
Saplings	263 ± 73	230 ± 43	112 ± 32
Trees	272 ± 74[3]	228 ± 48[2]	38 ± 21

[1]indicates a significant difference (P < 0.05) between the grazed and ungrazed Whataroa sites
[2]indicates a significant difference (P < 0.05) between the ungrazed Whataroa and Waiho sites
[3]indicates a significant difference (P < 0.05) between the grazed Whataroa and ungrazed Waiho sites
NB, the Mann-Whitney *U* test compares median not mean values.

the grazed Whataroa site and the Waiho site (z = -3.254, $P < 0.01$) but not for small or tall seedlings ($P = 0.10$, $P = 0.45$ respectively) or saplings ($P = 0.25$) (Table 1). Comparisons between the ungrazed Whataroa site and the ungrazed Waiho site showed significant differences for small seedlings ($z = -4.742$, $P < 0.001$), tall seedlings ($z = -3.435$, $P < 0.01$), saplings ($z = -2.876$, $P = < 0.01$), and trees ($z = -4.482$, $P = 0.02$) (Table 1). There were very high numbers of seedlings on old logs and occasional deep patches of silt at the Waiho site, and none on the extensive cobbled areas. Most trees and saplings at the Waiho site occurred at the end of the transects, furthest from the abandoned riverbed.

Table 2. Mean density ± one standard error of saplings and trees (> 3 cm dbh) on the three terraces at the Whataroa site.

	Whataroa site[1]			Waiho site
	Terrace 1	Terrace 2	Terrace 3	
Saplings	117 ± 8	297 ± 16	317 ± 14	112 ± 32
Trees	57 ± 10	195 ± 12	398 ± 15	38 ± 21

[1]Terrace 1 has significantly fewer saplings and trees than terraces 2 and 3 ($P < 0.05$). There was no significant difference in sapling or tree density between terraces 2 and 3. The density of saplings and trees at the Waiho site are provided for comparison; the site is of similar age to terrace 1.

Table 3. Spearman's rank correlations (r_s) of totara seedlings, saplings, and trees, with gorse cover (% arcsin-square root transformed). Gorse cover is significantly different at all sites ($P < 0.05$).

	Whataroa grazed	Whataroa ungrazed	Waiho ungrazed
Mean gorse cover	13%	43%	27%
Small seedlings	-0.276	0.464[1]	0.566[1]
Tall seedlings	-0.353	0.573[1]	0.467[1]
Saplings	-0.022	0.145	-0.091
Trees	-0.121	-0.002	-0.182

[1] indicates that the correlation is significant at the 0.01 level.

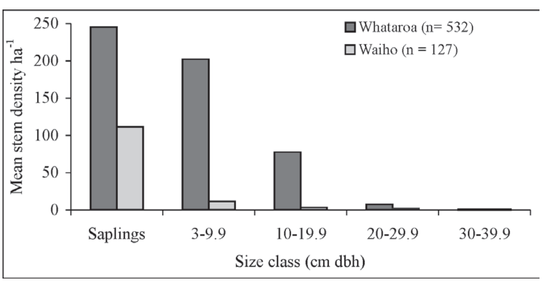

Figure 1. Mean density (stems ha^{-1}) of saplings and trees by size class (cm dbh) at the Whataroa and Waiho sites.

Differences across the terraces were observed for saplings ($\chi^2 = 13.564$, d.f. = 2, $P = 0.03$), and trees ($\chi^2 = 14.105$, d.f. = 2, $P < 0.01$) at the Whataroa sites. Pairwise comparisons showed significant differences between terraces 1 and 2 (saplings: $z = -3.190$, $P < 0.01$; trees: $z = -2.782$, $P < 0.01$) and terraces 1 and 3 (saplings: $z = -3.408$, $P < 0.01$; trees: $z = -3.429$, $P < 0.001$), but not between terraces 2 and 3 (saplings: $P = 0.98$; trees: $P = 0.12$). This indicates that there are significantly more saplings and trees on the two oldest terraces (2 and 3) than on the youngest terrace (1). The distribution of mean tree density (Table 2) suggests that there has been a progressive establishment of trees on the three terraces corresponding with terrace age, with a concurrent pulse of establishment of saplings on terraces 2 and 3. Sapling and tree density at the Waiho site is similar to that of the first terrace at the Whatroa sites, and these data are provided in Table 2 for comparison. The size class distribution of saplings and trees at the Whataroa and Waiho sites (Figure 1) is indicative of an on-going regeneration pulse of totara, with the age of establishment of the 11 trees that were cored calculated to be 45–63 years BP.

The correlation between gorse cover and the number of short and tall seedlings was statistically significant at the Whataroa ungrazed site (short seedlings: $r_s = 0.46$, $P < 0.01$; tall seedlings: $r_s = 0.57$, $P < 0.001$) and the Waiho ungrazed site (small seedlings: $r_s = 0.57$, $P < 0.001$; tall seedlings: $r_s = 0.48$, $P < 0.01$) but not at the grazed site (Table 3). In fact there was a slight negative correlation between seedlings, saplings or trees, and gorse cover. The majority of small seedlings recorded at the ungrazed Whataoa site were observed to occur in or around old gorse bushes. There was no statistically significant relationship between gorse cover and sapling or tree density at any site.

Gorse cover was significantly different between all sites (grazed v. ungrazed Whataroa sites: $z = 21.87$, $P < 0.01$; grazed Whataroa v. Waiho: $z = 5.23$, $P < 0.05$; ungrazed Whataroa v. Waiho: $z = 29.14$, $P < 0.01$), with the grazed Whataroa site having the highest cover of gorse (Table 3). We observed that the density of old open gorse bushes at both Whataroa sites appeared to be similar, however, there were more young dense gorse bushes at the ungrazed Whataroa site. Conversely, there were few old open gorse bushes at the Waiho site, with the majority being young and dense.

Discussion

Pickett *et al.* (1987) considered that the trajectory of natural succession is largely determined by differential species availability, site availability, and differential species performance. This study found that totara (*P. totara* var. *waihoensis*) was present as seedlings, saplings and small trees on gorse-covered river terraces within 150–300 m of the Whataroa and Waiho Rivers, in both the presence and absence of grazing by cattle. This confirms that the local seed source is adequate; totara have the ability to establish at these sites under current and past conditions; and they are surviving to recruit into the larger tree size classes.

The density of totara seedlings that established at each site appears to be related to differences in the physical characteristics of the site, grazing management, and the presence of gorse. For example, establishment sites at the Waiho are limited, with few totara seedlings, saplings or trees found on the bare cobbles of the old riverbed; however there were very high densities of seedlings recorded on raised establishment sites provided by old logs or patches of deeper silt. The relatively small number of saplings and trees compared to the Whataroa sites, despite high seedling densities, may be due to poor survivorship of these seedlings through competition for resources, and/or the comparatively young age of the Waiho site.

Grazing appears to improve site availability for totara establishment on the Whataroa River terraces. Both study sites were grazed up until about 5 years ago, and the density of saplings and trees is similar at both sites, yet seedling density is significantly lower at the ungrazed site. Several New Zealand studies have demonstrated the reduced ability of native woody seedlings to establish and survive through rank grass growth (Esler, 1967; Allen *et al*., 1992; Wilson, 1994; Rogers, 1996; Widyatmoko and Norton, 1997), while Buxton *et al*. (2001) found that grazed plots on several south Westland floodplains had higher numbers of totara seedlings than ungrazed plots. This suggests that, in the face of rank grass growth, regeneration of totara may be favoured under a grazing regime of some sort.

These results appear to conflict with McSweeney (1982), who considered that totara did not regenerate in the presence of grazing. However he was referring to totara regeneration within forest patches, further stating that it *was* regenerating readily on forest margins and in adjoining scrubland. Ebbett (1998) and Ebbett and Ogden (1998) have determined that regeneration of totara ceases once the canopy closes over, as totara is a light demanding species. Miller (2002b) found no significant difference in the small number of totara seedlings in the grazed and ungrazed portions of Ballyhooly Bush, one of the areas that McSweeney refers to. It appears that McSweeney (1982) was observing a succession effect rather than a grazing effect.

It has been suggested that gorse may act as a nurse plant, facilitating the establishment of native woody species, particularly where soil conditions are deficient or stock are present (Healy, 1961; Lee *et al*., 1986; Wilson, 1994). In our study, the key role of gorse appeared to be the provision of establishment sites. Our observation was that high numbers of seedlings at the ungrazed Whataroa site established around and under older gorse bushes in the thin layer of gorse litter (dead needles and twigs) where there was no grass. Conversely we did not find seedlings in and amongst young dense gorse bushes. Williams and Karl (2002), Lee *et al.* (1986) and Wilson (1994) also found that native seedling and sapling establishment occurred in older gorse bushes rather than in young dense stands, while Reay and Norton (1999) observed that flax also provided establishment sites for woody seedlings in retired pasture on Banks Penninsula. The removal of grazing appears to favour the establishment of new gorse bushes at the Whataroa and Waiho sites. This suggests that, as these gorse bushes age and open up, more establishment sites will be available for totara seedlings.

Gorse may also have other facilitative roles (Callaway, 1995) such as providing perch sites for birds (i.e. totara seed is bird-dispersed), or providing establishment sites with a more favourable nutrient status (i.e. gorse is an N fixer). Williams and Karl (2002) found that gorse was utilised by small seed-dispersing birds and these were responsible for bringing in much of the seed from local sources. Unfortunately our data do not allow the relative significance of these roles to be determined.

Our data indicate that recruitment of totara at the Whataroa sites started at least 70 years BP on the older terraces, although the main pulse of colonisation appears to have started *c*. 40–50 years BP. The youngest Whataroa terrace and the Waiho site have only been available for colonisation in the last *c*. 30 years, hence the relatively low numbers of saplings and trees on these surfaces. This regeneration pattern is consistent with the results of Ebbett (1998) and Wells (1998). Ebbett (1998) found that totara between 20-40cm dbh in South Island forest patches were between 40 and 180 years old, while Wells (1998) found that the peak recruitment of totara in the Karangarua catchment, south Westland, tended to be between 25 and 75 years after flood or earthquake disturbance.

Many of the forest patches on the developed floodplains of the Waiho and Whataroa rivers of south Westland have regenerated following clearance of the original forest; these tend to be dense stands of totara, with suppressed recruitment of seedlings and saplings (Miller, 2002b). Wells (1998) observed similar young dense stands of totara (maximum age 120 years) on 250–350 year old river terraces in the Karangarua catchment, south of the current study area.

While matai and angiosperm species are an insignificant component of these young stands, matai is co-dominant with totara, and angiosperm species are more abundant, in floodplain stands that pre-date European settlement (Miller, 2002b; Wells, 1998). Wells (1998) also recorded angiosperm-dominated forest with only scattered mature conifer species and very few conifer seedlings or saplings in the Karangarua catchment. These forest stands may be evidence of succession from conifer forest in the absence of periodic disturbance, as predicted by Duncan (1993).

Management implications

Luken (1990) notes that, to meet conservation goals, management may be required to influence the course of succession or biotic development. In many situations the removal of grazing is considered to be an important first step. However this will not necessarily result in a return to pre-disturbance conditions, as many of the physical processes that influenced the pre-European course of succession have changed. This view is reinforced by Hobbs and Norton (1996), who refer to multiple trajectories of succession and alternative, often unpredictable, stable states as a consequence of changed environmental conditions.

In the current situation we predict that both the grazed and ungrazed sites will regenerate into totara-dominated forest if undisturbed by natural events such as river incutting and catastrophic flooding, or from pasture development through burning or crushing of the gorse. We predict that they will initially follow different pathways, with seedlings at the ungrazed sites requiring further gorse growth and senescence to provide suitable establishment sites. We suggest that grazing and the growth of totara forest on these river terraces may not necessarily be conflicting objectives, at least in the short term. Prescribed grazing to meet conservation goals may appear counter-intuitive, but it is not a new concept and has international precedents (e.g. Bullock and Pakeman, 1997). Although conservation and production goals will eventually diverge as the developing totara forest reduces the availability of grass, the management response at a landscape level need not be ‘all or nothing’ prior to the divergence of goals.

Point-in-time studies, such as this one and McSweeney’s (1982), are limited in that they can only suggest a trajectory of succession under different management regimes. Monitoring is required to determine the most appropriate conservation policy and management regime, particularly if a balance is sought between conservation and production interests (Norton and Miller, 2000). It is important to resolve this issue because, while the gorse-covered riverbed margins of agricultural land in south Westland have traditionally been viewed as having low conservation value, this study has highlighted that they could be the totara forests of the future. As found in this study, such areas may have a critical role in restoring under-represented vegetation types and biological communities, provided they are recognised and managed appropriately. Importantly, a site where a vegetation-type that is under-represented relative to its previous extent is regenerating is as much an area of *significant indigenous vegetation* as is a patch of tall forest.

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