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VEGETATION RECOVERY FOLLOWING FIRE IN THE WHANGAMARINO WETLAND

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by

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CONTENTS

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ABSTRACT

The flora and vegetation at Whangamarino wetland was monitored for up to eight and a half years following two cool fires in 1984 and 1989 to determine rates and patterns of recovery.

Vegetation and flora recovered to virtually the pre-fire condition within five and a half years. Species whose rhizomes survived the fire, e.g., *Baumea teretifolia*, *B. rubiginosa*, *Schoenus brevifolius* and, to a lesser extent, tangle fern (*Gleichenia dicarpa*), were able to re-sprout and grow rapidly in the initial post-fire period. Species that were killed, e.g., wire rush (*Empodisma minus*) and manuka (*Leptospermum scoparium*) had to re-establish from seedlings and thus underwent a slower recovery.

Adventive and early successional native species were prominent only in the first two post-fire years: this was probably due to the temporarily increased availability of nutrients and/or of open habitat. Overall the total vascular flora declined gradually throughout the monitoring period from an initial post-fire maximum. This indicates that, in the absence of further disturbance and as the succession proceeds, the flora is expected to become increasingly native dominated and impoverished.

1. INTRODUCTION

1.1 Background

Whangamarino wetland, covering 4870.7512 ha, is a Government Purpose Reserve (Wetland Management), administered by the Waikato Conservancy of the Department of Conservation, Hamilton. It is a complex of four oligotrophic peat bogs surrounded by more fertile mineralised and semi-mineralised zones which are fed by nutrient-rich water from several rivers (Humphreys 1991; Fig 1).

At least the two northernmost bogs are raised slightly above the level of the surrounds and are less influenced by nutrient-enriched ground water. Raised peat bogs, termed ombrogenous or high moor, are typically very acidic, have a high water table and are nutrient-poor, being dependent on rainfall for water and mineral supply (Thompson 1978). The flora is depauperate because few species are able to tolerate the low nutrient conditions, permanent waterlogging and pH values which may fall below 3.5.

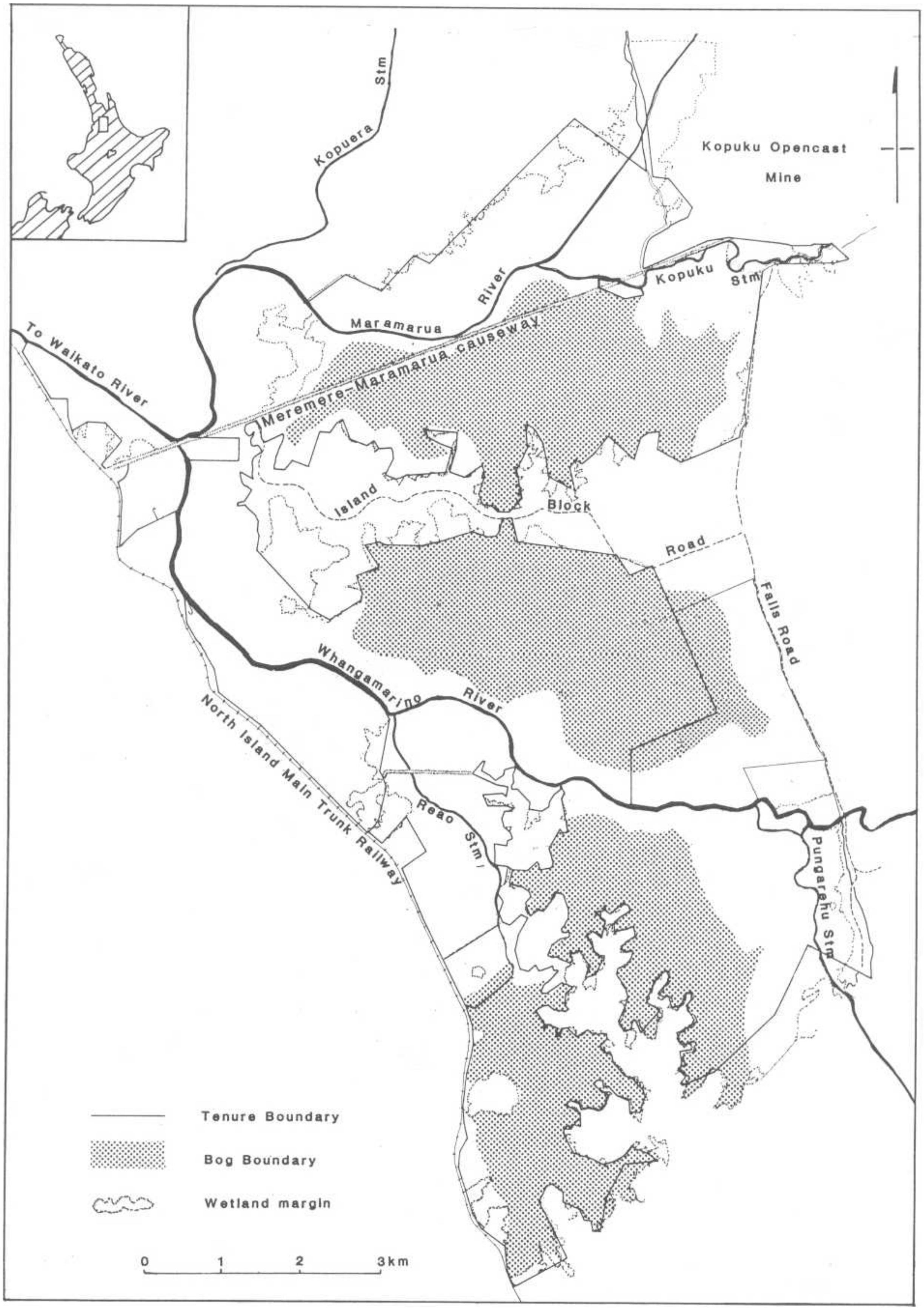

Figure 1 Whangamarino wetland peat hogs.

On 10 February 1984 and 13 January 1989 fires swept through vegetation in two of the oligotrophic peat bogs (Fig. 2) where large quantities of undecomposed surface litter had built up. This vegetation was dominated by manuka (*Leptospermum scoparium*), *Baumea* spp. (mainly *B. rubiginosa* and *B. teretifolia*) in areas with only shallow peat, and by wire rush (*Empodisma minus*) in areas where peat accumulation was greater.

The vegetation of Whangamarino wetland prior to the 1984 fire was mapped by Ogle and Bartlett (1981), and the vegetation along a c. 1 km wide strip centred on the Meremere-Maramarua causeway (see Fig. 1) immediately prior to the 1989 fire was mapped by Irving *et al.* (1989). The following vegetation types are based on the detailed descriptions of Irving *et al.* (1989) and are considered typical of the main peat bog types in the fire-affected areas. Vegetation type names follow Atkinson (1985) and species lists and cover abundance classes are given in Appendix 1.

1.2. Vegetation types

Type 1 Manuka/Baumea sedge shrubland

Manuka up to 3 m tall was dominant and overtopped dense *Baumea* spp. *(B. teretifolia, B. rubiginosa, B. tenax). Coprosma tenuicaulis* and tangle fern (*Gleichenia dicarpa*) were also present. The small herbs *Lobelia anceps*, sundew (*Drosera binata*) and *Nertera scapanioides*, and clumps of sphagnum (*Sphagnum cristatum*) and other mosses formed a ground cover in more open areas.

Type 2 Baumea-manuka shrub sedgeland

This type dominated the area burnt in 1984 and, in the absence of further fires, should eventually develop into type 1; manuka/Baumea sedge shrubland. A dense canopy of *Baumea teretifolia*, *B. rubiginosa* and manuka, up to about 1.2 m tall, was interspersed with occasional wire rush, *Schoenus brevifolius* and *Tetraria capillaris*. Tangle fern, probably slightly lower than 1 m, was common. Sphagnum mounds, *Lobelia anceps*, and sundews (*Drosera binata*, *D. spathulata*) were frequent in the ground cover.

Type 3 (Manuka)-(tamingi)/wire rush shrub rushland

Occasional manuka and tamingi (*Epacris pauciflora*) overtopped a dense lower canopy of wire rush up to a height of 0.7 m. Also present were *Baumea rubiginosa* and *B. teretifolia*, tangle fern and *Schoenus brevifolius*. The ground cover was sparse because of the dense wire rush growth but in more open areas were sundews, *Lycopodium laterale*, sphagnum clumps, other mosses, and liverworts. This vegetation type, characterised by the abundance of wire rush, represents a later successional 'stage' than the previous two types.

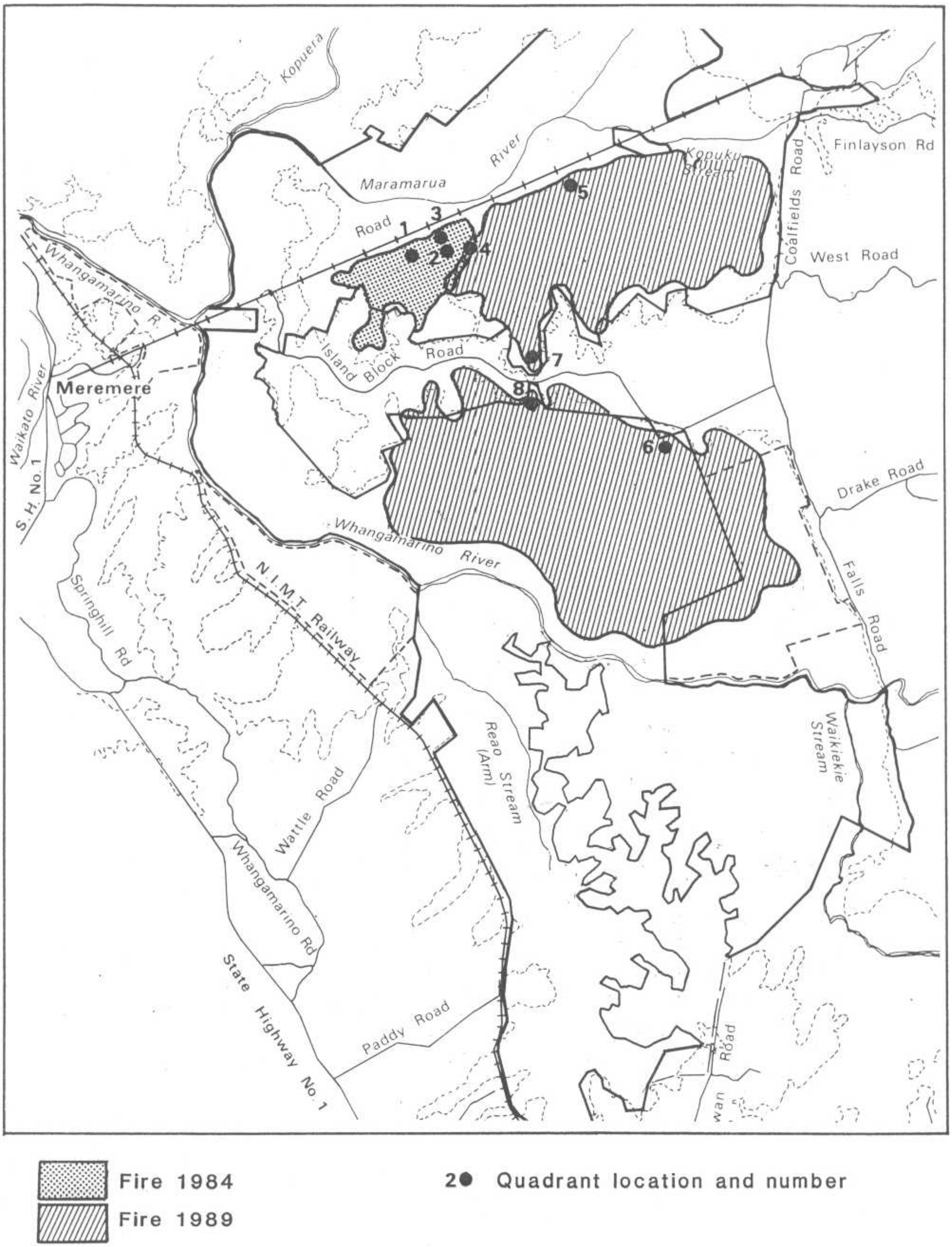

Figure 2 Whangamarino wetland; extent of recent fires, and quadrat locations.

2. METHODS

Seven permanent 5 m X 5 m quadrats were established within weeks of the 1984 (quadrats 1-3) and 1989 (quadrats 5-8) fires in areas of burnt vegetation (Fig. 2). Four permanent point baselines for non-area plots of *c.* 9 m^2 were also established in 1989, along a transect which incorporated the full spectrum from unburnt to twice-burnt vegetation (quadrat 4a = burnt in 1984 only, 4b = burnt in 1984 and 1989, 4c = burnt in 1989 only, 4d = not burnt in 1984 or 1989).

The quadrats were visited regularly; from every 1-2 months during the first post fire years to every *c.* 6-9 months during the last three years (monitoring period ended in June 1992). Vegetation height and cover (% visual estimate) at each quadrat were recorded and species lists compiled.

Regression analyses of height (maximum) and cover data for each of the five most common species or species group versus time since burning, were carried out using the computer programme SIGMAPLOT to indicate successional trends. In all cases the second order polynomial curves fitted were the most significant ($p<0.05$ for 90% of the analyses).

The species analysed were manuka, tangle fern, wire rush, *Schoenus* brevifolius and *Baumea* spp. The *Baumea* group comprised mainly *B. teretifolia* and *B. rubiginosa*, but probably also included *B. huttonii;* these species were not always distinguished by the various recorders during sampling.

Regression analyses of species number (native, adventive and total) versus time since burning were also carried out in a manner similar to that outlined above. The second order curves fitted were again the most significant; $p<0.001$ for all three analyses.

Prior to the 1984 fire the vegetation of quadrats 1-3 was mapped as *Baumea* with manuka; that of quadrat 5 as manuka with *Baumea*, and the quadrats 4a-4d encompassed a mixture of both vegetation types. The vegetation of quadrats 6-8 was also mapped as either manuka with *Baumea* or *Baumea* with manuka (Ogle and Bartlett 1981), however, the post-1989 fire burnt rhizome mats indicated that wire rush was also present.

Prior to the 1989 fire the vegetation of quadrats 1-3 was mapped as *Baumea*-manuka scrub sedgeland; that of quadrat 5 was manuka/*Baumea* sedge shrubland, and both vegetation types occurred in quadrats 4a-4d (Irving *et al.* 1989). Quadrats 6-8 were outside the area mapped by Irving *et al.* (1989) but the vegetation, deduced from post-fire compositions, probably would have been classified as (manuka)-(tamingi)/wire rush shrub rushland.

3. RESULTS

3.1 Initial impact of fires

Both the 1984 and 1989 fires caused 'cool' burns. Most standing live vegetation and associated litter was removed but the peat surface was only slightly charred; the peat was saturated with water at the time of burn. The fires resulted in blackened dead standing manuka, charred, cropped clumps of *Baumea* and *Schoenus*, and occasional scorched mounds of sphagnum scattered over large areas of peat strewn with burnt vegetation debris and ash.

3.2 Rate and pattern of vegetation recovery

At one month following each fire, bare peat still largely dominated the landscape. However, a greenish hue had already developed due mainly to surviving stems of *Baumea* and *Schoenus:* these were typically sparse with fire-cropped tips (0.7 m maximum height). Shoots that had resprouted from surviving *Baumea* and *Schoenus* rhizomes were also present, but infrequent, and only a few centimetres tall.

Other plants that had resprouted from underground rhizomes or burnt bases such as tangle fern and flax (*Phormium tenax*) were even less common. Small seedlings of manuka (in all quadrats) and wire rush (only in quadrats 6-8, i.e., where common prior to burning) were occasional to abundant. Sundew (*Drosera binata*) was locally common in the ground cover, mostly growing on the bare peat; a few plants were flowering. Other species occasionally present were *Nertera scapanioides* (in fruit), Scotch thistle (*Cirsium vulgare*) and sphagnum.

After six months there were typically still some areas of bare peat. *Baumea* and *Schoenus* cover and height had increased considerably and numerous seedlings, including *Juncus planifolius*, *Lobelia anceps*, *Blechnum minus*, *Hydrocotyle heteromeria*, *Utricularia novae-zelandiae* (including *U. monanthos*), tamingi (*Epacris pauciflora*), fireweed (*Senecio minimus*), and the adventive weeds catsear (*Hypochoeris radicata*), *Conyza albida*, and Australian fireweed (Senecio bipinnatisectus). An occasional sphagnum mound had started to recover by this stage and resprouting fronds of tangle fern were noted emerging from some of the dead sphagnum mounds. Flowers were observed on *Baumea teretifolia* and *Schoenus.*

Within one year of the fires, additional species to flower were manuka, *Baumea rubiginosa*, Utricularia novae-zelandiae, *Lobelia anceps*, *Juncus planifolius*, fireweed and tarweed (*Parentucellia viscosa*). In the vegetation outside the quadrats several orchids were also flowering, these included *Thelymitra cyanea*, *T. formosa*, *Pterostylis micromega* and *Spiranthes sinensis.*

After two to four years the vegetation cover of most quadrats had increased considerably. Many early-colonising ground cover plants had declined or died out; those still persisting were confined to sparsely vegetated or open areas. Examples here include most adventive species, and the indigenous *Juncus planifolius* and *Drosera binata.*

3.3 Species height and cover trends

Trends in increases in species cover ($p<0.05$ for *Baumea,* manuka, *Schoenus* and wire rush) and height (in all cases $p<0.001$) with time since burning are depicted in Figs 3 and 4 (individual species regression analyses are in Appendices 2 and 3). These show that the sedges *Baumea* spp. and *Schoenus* were dominant, in terms of both cover and height, very early in the succession.

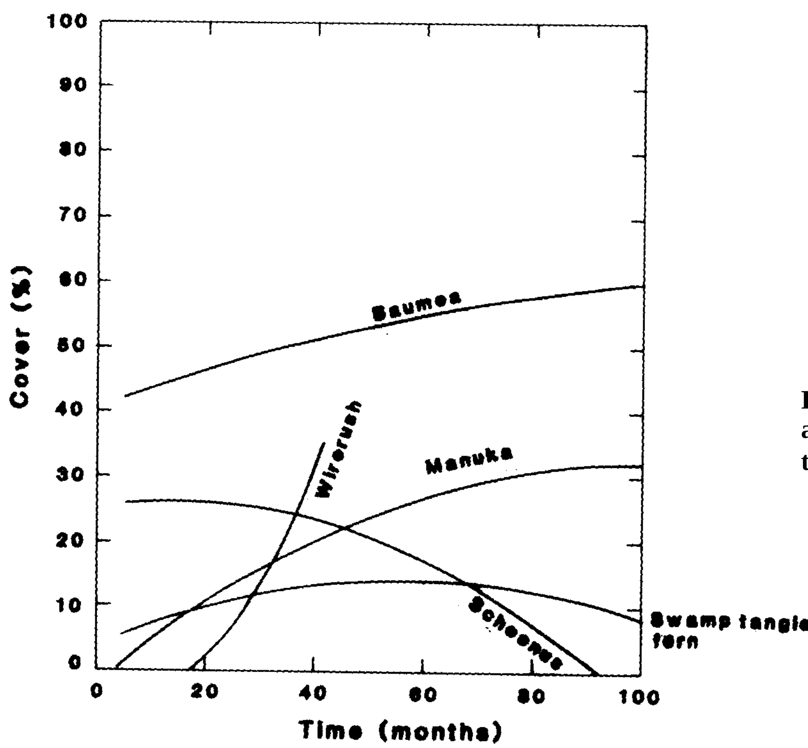

Figure 3 **Regression analysis of cover versus time since burning.**

The rapid growth of these sedge species was due to the survival of numerous rhizomes and stems. However, *Schoenus* cover gradually declined from peak levels during the first two post-fire years, and height declined (due to collapse of stems) following a peak at about four years. *Baumea,* in contrast, continued to increase in cover and height during the eight years or more that the monitoring occurred.

Tangle fern also established early in the succession due to resprouting from occasional surviving rhizomes, although cover and height were less/lower than for the sedges. Cover started to decline gradually after about five years, and height was starting to level off at around eight years.

Manuka seedlings established within weeks of the fires, and cover and height increased rapidly for six-seven years before the rates of increase slowed. Wire rush was monitored over only three years and five months following the 1989 fire, and therefore longer term successional trends could not be assessed. However, it established from seed early in the succession, but cover did not start to increase significantly until after two years.

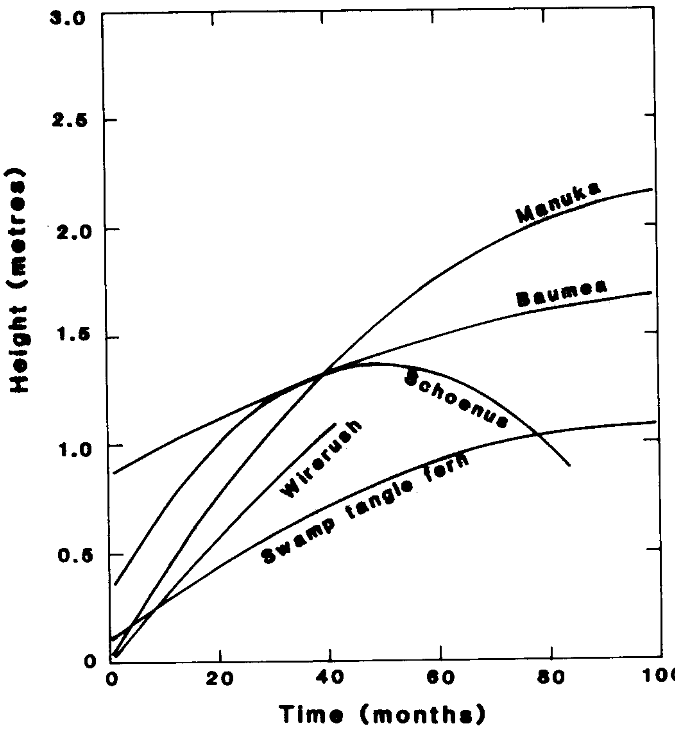

Figure 4 Regression analysis of height versus time since burning.

The cover and height of species in the 'control' site (quadrat 4d), i.e., unaffected by the 1984 and 1989 fires, are incorporated in Appendix 2 (A2.1, A2.2, and A2.4), and Appendix 3 (A3.1, A3.2, and A3.4). This site is considered representative of the manuka/Baumea sedge shrubland vegetation type and all data lie within the 95% confidence limits as depicted by the dotted/dashed lines in the appendices. This (supplemented by pre-fire data) indicates that cover and height had attained virtual pre-fire levels by the end of the 100-month monitoring period.

Baumea spp., *Schoenus,* tangle fern and manuka achieved 90% of maximum cover and 90% of maximum height (as depicted by the regression curves; see Appendices 2 and 3) by five years and eight months (Table 1). This suggests that the vegetation in the major part of the burnt area, i.e., those areas dominated by manuka and *Baumea,* has taken nearly six years to recover following fire.

Table 1 Time taken for selected species to achieve 90% of maximum height and cover.*

Species (or group)	90% Height (m)	Time (months)	90% Cover (%)	Time (months)
Baumea spp.	1.5	62	54	54
manuka	1.9	67	29	63
Schoenus brevifolius	1.3	34	23	38
tangle fern	1.0	68	13	32

Maximum time for 90% recovery = 68 months.

* **Maximum height and cover taken as at 100 months.**

Although wire rush had been monitored for only approximately three and a half years, trends already apparent in the height and cover curves, and current field knowledge suggest that this species will probably also recover to near pre-fire height and cover levels within six years.

3.4 Vascular species diversity

The numbers of species; total, native and adventive, versus time since burning are depicted in Fig. 5 (individual regression analyses are in Appendix 4). Some inconsistencies in the data may have occurred during winter sampling by not recording species whose above-ground shoots had died back, e.g., sundew, *Juncus planifolius,* orchids (species quadrat data are in Appendix 5).

However, several general trends are evident. Species numbers were low overall and dominated by natives (ranging from 62.5% to 100% of quadrat flora). The total flora typically reached a maximum directly following the fire and then gradually declined.

Most (but not all) adventive species established early but usually did not persist much beyond one or two years. A few adventive species also established in later years in areas disturbed by animals/humans, or in open areas. For example, in quadrat 2, Yorkshire fog (*Holcus lanatus*) established 76 months (6 years 4 months) following the fire, and by 91 months (7 years 7 months) it was reported to be spreading. The grass was growing beside a quadrat marker post which was being used as a perch by Australasian harriers, and guano enrichment of the peat was probably the main cause for its success.

Most of the native flora persisted throughout the monitoring period but underwent major changes in abundance. For example, the small ground cover early colonisers such as sundew, bladderwort, *Juncus planifolius* and *Lobelia anceps,* which were prolific immediately following a burn, became relegated to isolated open pockets where there was less competition from the sedge and/or rush-dominated vegetation.

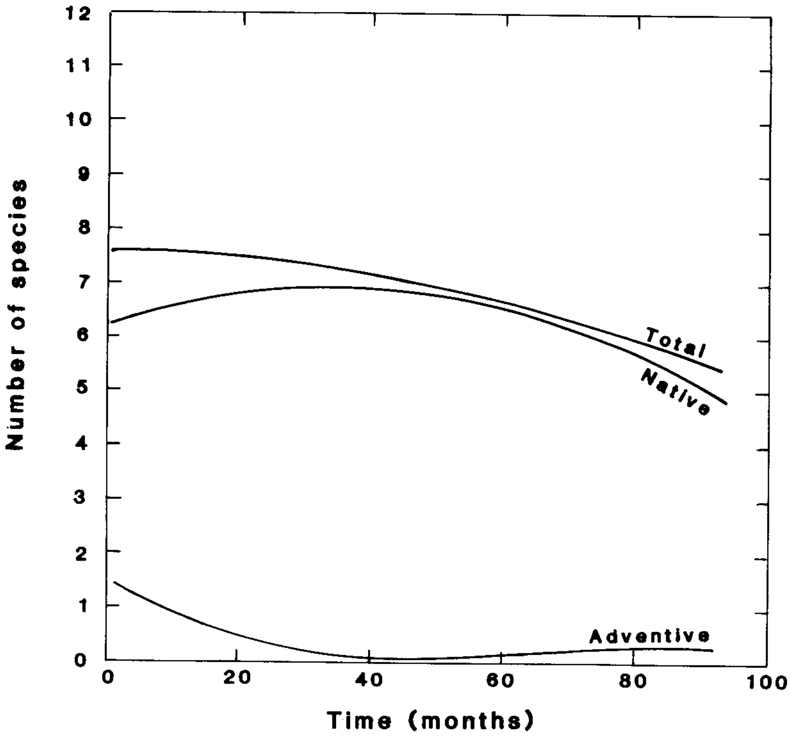

Figure 5 Regression analysis of species numbers versus time since burn-

Some of these, e.g., *J. planifolius*, *L. anceps*, may eventually disappear as the succession proceeds and the peat becomes increasingly more acidic and nutrient-poor. Sundews and bladderworts are able to trap and digest small insects or animals, providing additional nutrients, and reduced numbers are thus due more to competition from surrounding taller vegetation than to increasingly oligotrophic conditions.

4. DISCUSSION

Stratigraphic studies of Waikato peat bogs indicate that fire due to lightning, spontaneous combustion or volcanic eruption is a natural phenomenon (McGlone *et al.* 1984, Newnham *et al.* 1989), usually occurring every one to several hundred years (frequency based on Kopuatai data, de Lange 1989).

Human-induced fires, associated with the arrival of the Polynesian and, more particularly, of the European, increased the frequency dramatically (Newnham *et al.* 1989). During the last century fires have regularly swept across the Whangamarino wetland, originating from land clearing activities and also from sparks from steam engines travelling along the main trunk railway which skirts the western boundary (D.K. Lloyd, pers. comm. 1992).

In the last couple of decades following phasing out of steam engines, a marked reduction in land clearing, and legal protection of the Whangamarino wetland, fires have generally been less frequent.

Fires have been shown to result in an increased availability of nutrients (NO_3-N, NH_4-N, PO_4-P, Mg and K) and increased light levels (Wilbur and Christensen 1983). This increased fertility is short-lived and by the second growing season concentrations of most nutrients are back to pre-fire levels.

Species with abundant small and/or wind-dispersed seed, e.g., fireweed, Australian fireweed and Scotch thistle, are able to take advantage of the increased nutrient levels and colonise immediately after the fire, however, their numbers soon decline as fertility levels decrease.

The intensity of the fire also has a significant effect on vegetation regeneration. Cool burns allow species whose above-ground parts cannot survive fire but which can resprout from protected parts, to regenerate rapidly. Examples here are *Baumea*, *Schoenus*, wire rush and tangle fern.

Hot burns destroy deeper layers of peat, and rhizome characteristics determine recovery patterns. Wire rush has an erect rhizome with roots which grow horizontally at or just beneath the surface of the bog (Campbell 1964) and, of the above-mentioned species, is the most susceptible to fire. Only occasional resprouting of wire rush from rhizomes in a few areas beyond the quadrats was noted at Whangamarino (R.M. Irving, pers. comm. 1993).

Tangle fern rhizomes are also shallow and are susceptible to damage by most fires. *Baumea* and *Schoenus* rhizomes grow at 2-5 cm below the bog surface (Campbell 1964); *Schoenus* has a tough rhizome with protective scales which enable it to survive some of the hottest fires. At Whangamarino *Baumea* and *Schoenus*, and in some places, tangle fern, were not killed and were able to recover quickly.

By comparison, at Moanatuatua Scientific Reserve following a hotter fire in 1972, all species except *Schoenus brevifolius* were killed and this dominated for the first few years following the fire. At 10 years *Baumea teretifolia* was dominant, and by 15 years wire rush dominated. Currently (21 years following the fire), *Sporadanthus traversii is* the most prominent species in the reserve (B.R. Clarkson, unpublished data).

Other published and unpublished studies (summarised in Timmins 1992) describe regeneration patterns similar to those observed at Whangamarino. At Eweburn Bog, Te Anau, vegetation recovery following a cool burn was monitored for four and a half years. By then total vegetation cover had reached 90% or more, however, the composition (vegetation proportions) was different to that existing prior to the fire, and a few species were 'missing'. It was predicted that the vegetation composition would slowly approach the pre-fire condition (Timmins 1992).

5. CONCLUSION

The monitoring of vegetation recovery following recent cool fires in Whangamarino wetland indicates that the vegetation recovered quickly, reaching near pre-fire height and cover levels in slightly less than six years. The order of species recovery was *Baumea* and *Schoenus* initially, followed by tangle fern, then manuka and lastly wire rush. The three first-mentioned species recovered fastest due to regrowth from surviving underground rhizomes. The two last-mentioned species established anew from seeds and therefore were prominent later in the post-fire succession.

The vascular flora trends were from a maximum diversity within the first one-two years of the fires, and then a gradual decrease in number as adventive species and the early successional native species declined and/or died. At the end of the monitoring, manuka, tangle fern, wire rush and *Baumea* spp. (*B. rubiginosa* and *B. teretifolia*) accounted for 95-100% of the total vegetation cover of each quadrat. These species are tolerant of the waterlogged, low nutrient and low pH conditions.

Fires set back the natural succession by removing vegetation and adding nutrients; the hotter the fire the greater the retrogression and the longer the vegetation will take to reach pre-fire structure and composition. The creation of new bare peat surfaces and/or the increased fertility levels allow small, normally absent or uncommon species such as bladderwort, sundew, *Lobelia anceps*, some orchids as well as adventive herbs, to become temporarily abundant.

Ultimately, in the absence of fire or other disturbance, the succession should proceed to an increasingly species-poor and native-dominated flora as the peat surface rises above the level of the surrounding terrain and becomes increasingly dependent on rainfall only for nutrient supply.

At the successionally more-advanced high moor peat domes at Kopuatai, Torehape and Moanatuatua, the native vascular species flora is impoverished, (e.g., 15 maximum at Moanatuatua; Butcher 1965) and the vegetation is overwhelmingly dominated by only one or two species, i.e., the restiads wire rush and *Sporadanthus traversii*. *S. traversii*, which is absent from Whangamarino, may establish as the succession here proceeds.

6. RECOMMENDATIONS

1. That Department of Conservation continue to monitor at one-two yearly intervals changes in burnt vegetation in at least two quadrats which are representative of the two main pre-fire vegetation types and of the two recent fires:

   (a) At least one of quadrats 1, 2 or 3; dominated by manuka and *Baumea*; burned in 1984.

   (b) At least one of quadrats 6, 7 or 8; dominated by wire rush; burned in 1989.

2. That Department of Conservation continue to control and contain fires within the Whangamarino wetlands especially those in or near the peat bogs. This will allow the natural succession to increasingly oligotrophic conditions and to an increasingly depauperate flora to continue.

3. If the maintenance of sizeable populations of early successional species (e.g., bladderwort, sundew, *Lobelia anceps*, *Juncus planifolius*, some orchids) or mid successional species (e.g., the rare orchid *Corybas carsei* numbers of which increased dramatically following small-scale removal of surrounding vegetation in the Raeo Arm of Whangamarino; Clarkson *et al.* 1993) were considered a priority, small areas could be periodically burned. Wide consultation would be needed and strict controls emplaced, before any such burn is implemented.

7. ACKNOWLEDGEMENTS

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APPENDIX 1

Species lists and cover abundance of main peat bog vegetation types

(Pre 1989 fire; source = Irving *et al.* 1989)

Cover abundance: species cover was estimated using the cover abundance scale:

1 = present (<l%) 2 = 1-5% 3 = 5-25%
4 = 25-50% 5 = 50-75% 6 = 75-100%

* = adventive species

Species	Common name	Cover abundance
ALL MANUKA/BAUMEA SEDGE SHRUBLAND		
Shrubs		
Coprosma tenuicaulis	swamp coprosma	3
Leptospermum scoparium	manuka	5
Dicotyledonous herbs		
Centella uniflora		1
Drosera binata	sundew	3
Hydrocotyle pterocarpa		2
Hypericum japonicum		1
Lobelia anceps		2
Nertera scapanioides	bog nertera	3
Monocotyledons		
Baumea rubiginosa		4
B. tenax		3
B. teretifolia		4
Carex maorica		2
C. secta var. *secta*		1
C. virgata		1
Chiloglottis cornuta		1
Empodisma minus	wire rush	2
Isolepis distigmatosa		1
Juncus planifolius		1
Lemna minor	duck weed	1
Phormium tenax	flax	2
Pterostylis banksii		1
P. "linearis"		1
**Spirodela oligorrhiza*	purple-backed duck weed	1
Ferns & fern allies		
Blechnum minus	swamp kiokio	3
Gleichenia dicarpa	tangle fern	4
G. microphylla	umbrella fern	2
Hypolepis ambigua		1
H. distans		2
H. lactea		1
**Osmunda regalis*	regal fern	2
Paesia scaberula	ring fern	1

Species	Common name	Cover abundance
A1.2 *BAUMEA* -MANUKA SHRUB SEDGELAND		
Shrubs		
Leptospermum scoparium	manuka	6
Dicotyledonous herbs		
Centella uniflora		2
Drosera binata	sundew	3
D. spathulata	sundew	1
Hydrocotyle pterocarpa		2
Lobelia anceps		3
Utricularia novae-zelandiae	bladderwort	3
Monocotyledons		
Baumea huttonii		2
B. rubiginosa		3
B. teretifolia		6
Eleocharis sphacelata	spike sedge	1
Empodisma minus	wire rush	2
Phormium tenax	flax	1
Pterostylis "linearis"		2
Schoenus brevifolius		2
Sparganium subglobosum	burr reed	1
Spiranthes sinensis	ladies tress orchid	2
Tetraria capillaris		3
Ferns and fern allies		
Blechnum minus	swamp kiokio	3
Gleichenia dicarpa	tangle fern	5
Lycopodium laterale	clubmoss	2

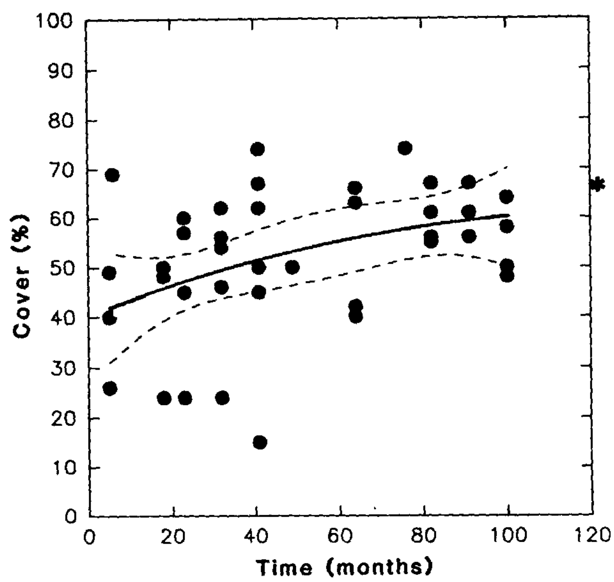
A1.3 (MANUKA)-(TAMINGI)/WIRE RUSH SHRUB RUSHLAND		
Shrubs		
Epacris pauciflora	tamingi	3
Leptospermum scoparium	manuka	4
Dicotyledonous herbs		
Drosera binata	sundew	3
D. spathulata	sundew	1
Lobelia anceps		1
Monocotyledons		
Baumea rubiginosa		2
B. teretifolia		3
Empodisma minus	wire rush	6
Schoenus brevifolius		3
Ferns & fern allies		
Gleichenia dicarpa	tangle fern	4
Lycopodium laterale	clubmoss	2

APPENDIX 2

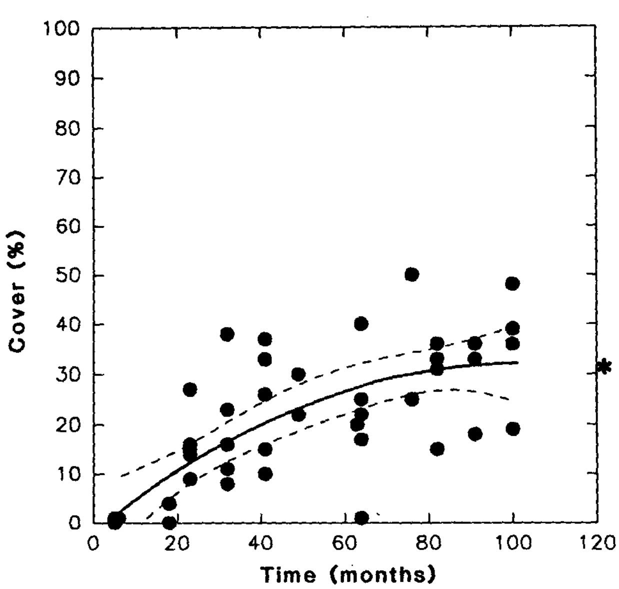
Regression analyses - Cover versus time since burning

Species (or group)		p	n
A2.1	*Baumea* spp.	0.01	41
A2.2	manuka	0.001	45
A2.3	*Schoenus brevifolius*	0.05	17
A2.4	tangle fem	ns	38
A2.5	wire rush	0.02	12

ns = not significant



A2.1 ***Baumea* cover**



A2.2 **Manuka cover**

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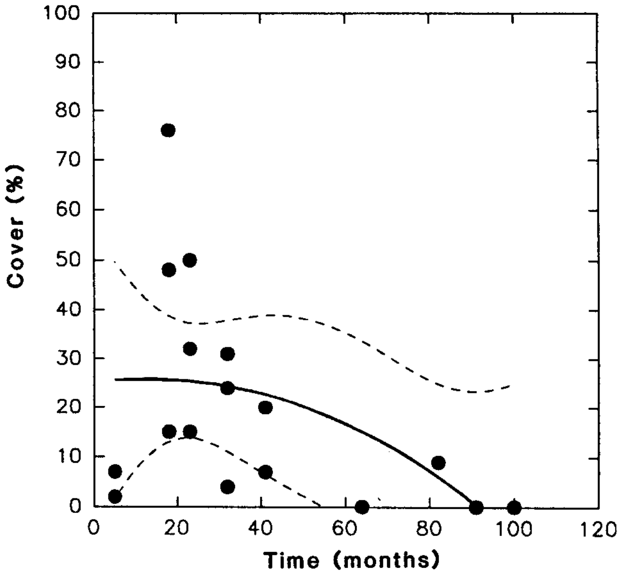
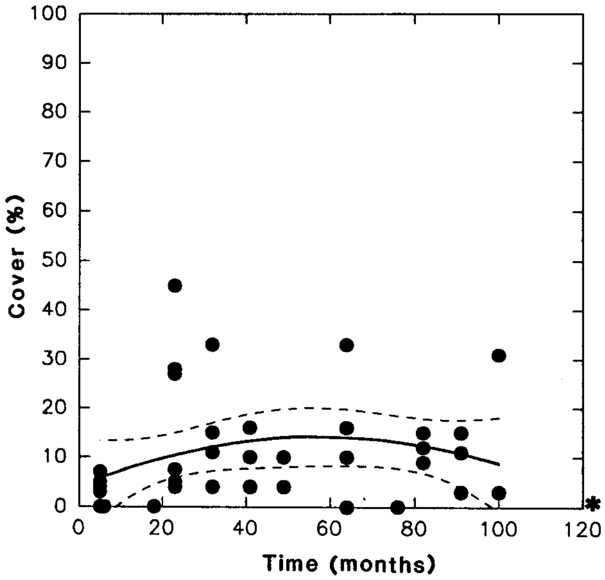
* Quadrat 4d ('control' site) species data (only *Bauanea,* manuka, tangle fem present) have been included.

• 95% confidence limits are indicated by dashed lines.

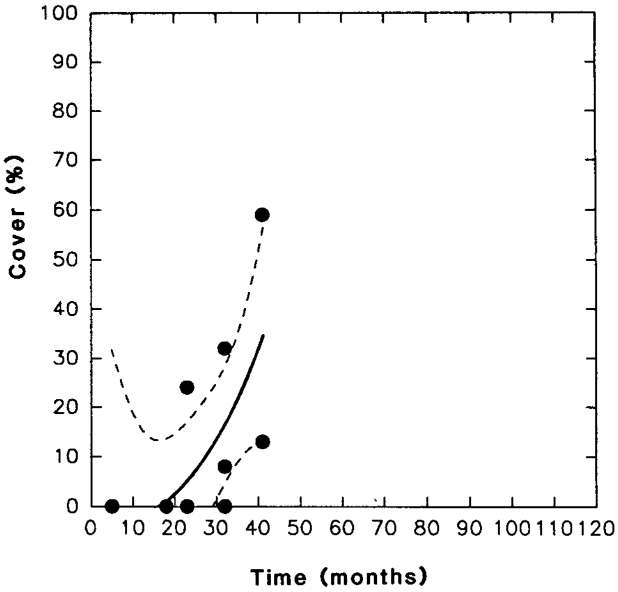
A2.3 Schoenus cover





A2.4 Tangle fern cover

A2.5 Wire rush cover

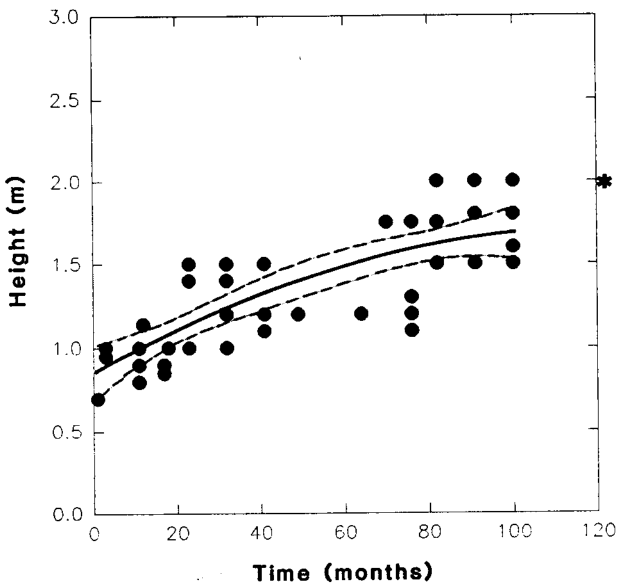


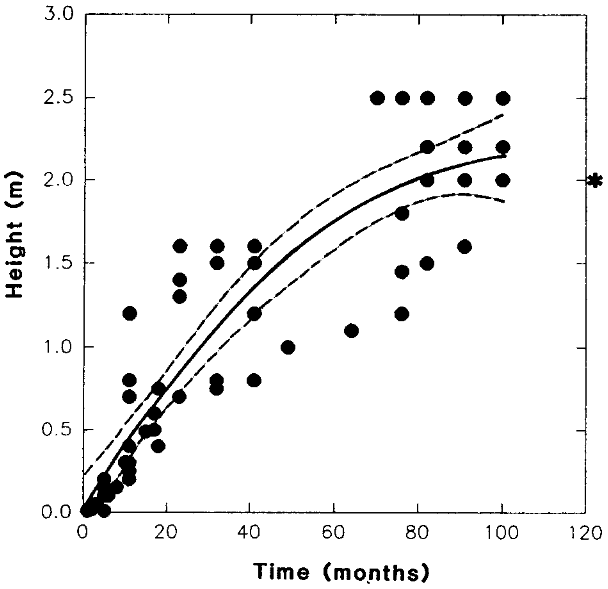
APPENDIX 3

Regression analyses - Height versus time since burning

Species (or group)		p	n
3.1	*Baumea* spp.	0.001	51
3.2	manuka	0.001	57
3.3	*Schoenus brevifolius*	0.001	25
3.4	tangle fern	0.001	50
3.5	wire rush	0.001	19

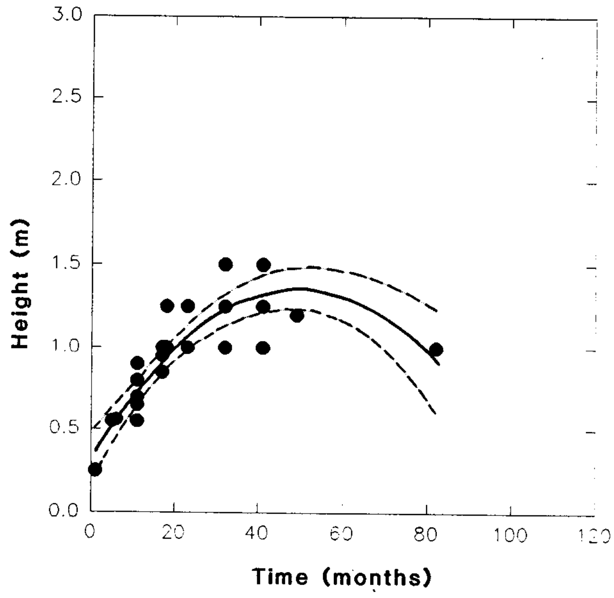
A3.1 *Baumea* height

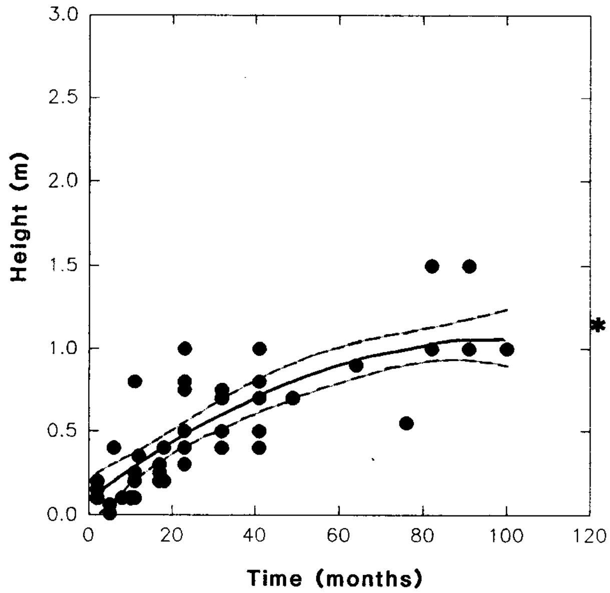




A3.2 Manuka height

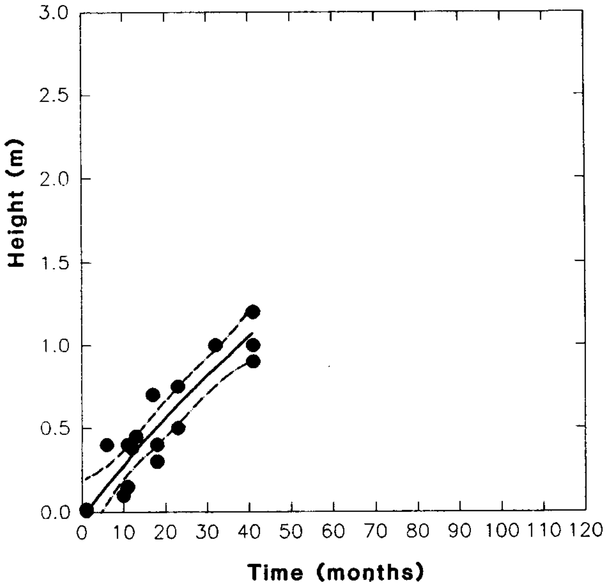
A3.3 ***Schoenus*** **height**





A3.4 Tangle fern height

A3.5 Wire rush height



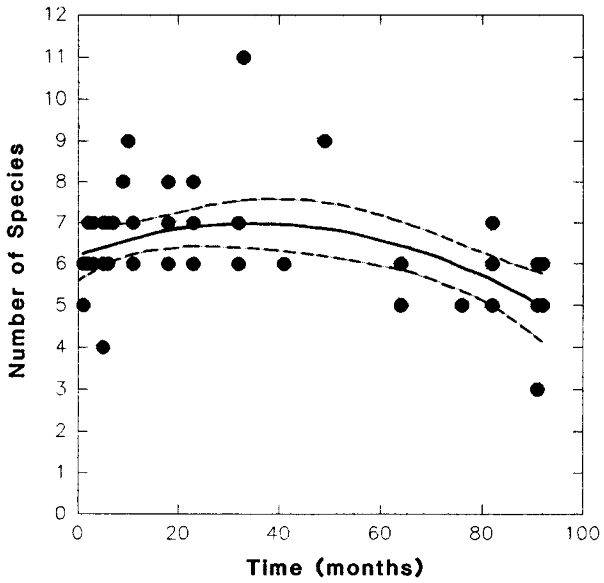
APPENDIX 4

Regression analyses - Number versus time since burning

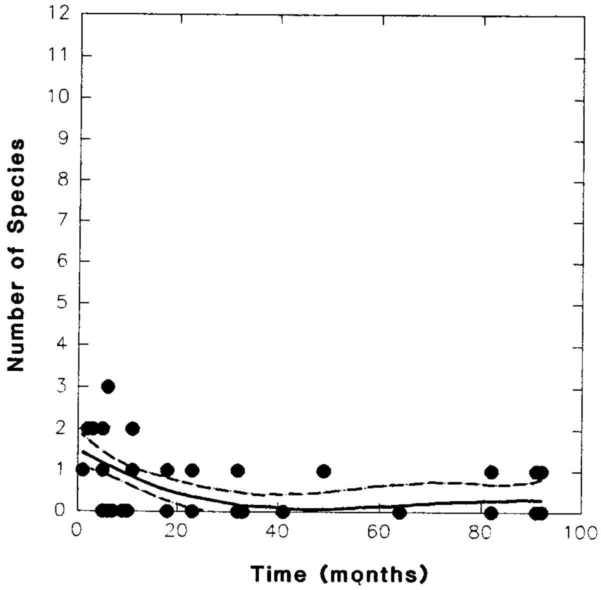
Group		p	n
4.1	native species	0.001	51
4.2	adventive species	0.001	51
4.3	total species	0.001	51

ns = not significant.

A4.1 Native species

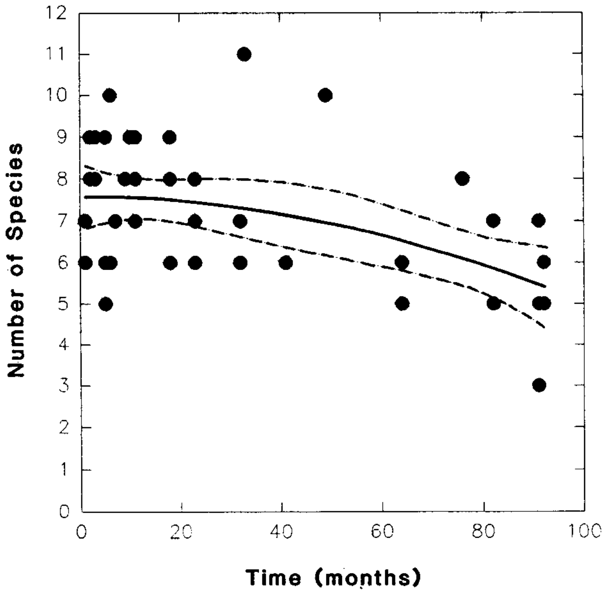


A4.2 Adventive species



For all graphs 95% confidence limits are indicated by dashed lines.

A43 Total species



APPENDIX 5

Vascular species recorded in quadrats following fire

Baumea rubiginosa	
B. teretifolia	
Blechnum minus #	swamp kiokio
* *Cirsium vulgare #*	Scotch thistle
Conyza albida #	broad-leaved fleabane
Drosera binata	sundew
D. spathulata	sundew
Empodisma minus	wire rush
Epacris paucifiora	
Epilobium sp. #	
Gleichenia dicarpa	tangle fern
* *Gnaphalium coarctatum #*	purple cudweed
* *Holcus lanatus #*	Yorkshire fog
* *Hydrocotyle heteromeria #*	
* *Hypochoeris radicata #*	catsear
Juncus planifolius #	
Leptospermum scoparium	manuka
Lobelia anceps	
Lycopodium laterale	
Nertera scapanioides	bog nertera
* *Osmunda regalis*	regal fern
* *Parentucellia viscosa #*	tarweed
Pterostylis "linearis"	
Phorntium tenax	flax
* *Rubus fruticosus* agg1	blackberry
* *Salix cinerea* 1	grey willow
Schoenus brevifolius	
* *Senecio bipinnatisectus #*	Australian fireweed
S. minitnus	fireweed
Sparganittm subglobosum #	burr reed
Spiranthes sinensis	ladies tress orchid
Tetraria capillaris	
Thelyntitra longifolia	
Utricularia delicatula	
U. novae-zelandiae (including *U. monanthos*)	

1 Removed
* Adventive
# Short-lived presence in quadrats