The evolution and execution of a plan for invasive weed eradication and control, Rangitoto Island, Hauraki Gulf, New Zealand

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Abstract A plan for management of invasive weeds on Rangitoto Island, in the Hauraki Gulf, Auckland, New Zealand, was developed during five years of weed control on the island. Rangitoto is a shallow marine basaltic shield volcano, with gently sloping fragmented lava flanks topped by a central scoria cone. Invasive weed control aims to protect the native plant communities and the unique plant successional processes from bare lava to forest. There are 72 species of invasive weeds destined for control or eradication, many of which are not managed as weeds elsewhere in New Zealand. A draft plan was devised in 1995 that considered distribution, impact on the native vegetation, and efficiency of propagule dispersal in setting priorities for control. The result was a strategy with a top priority of controlling around 20 species that had the potential to drastically alter the natural vegetation, but still had very limited populations. The second stage of the strategy was to control the remaining 50 species on a geographical basis, proceeding from the least-infested areas to the most densely infested, generally dictated by the distribution of the widely-distributed alien invasive *Rhamnus alaternus* (Rhamnaceae). The weed management plan has evolved over five years with improving control techniques, new herbicides, new weed finds, and better mapping and relocation systems.

Keywords Rangitoto Island; invasive weed control.

INTRODUCTION

Rangitoto is a 2331 hectare volcanic island situated within the Hauraki Gulf, near the city of Auckland, New Zealand (Fig. 1). The island is administered by the Department of Conservation as a Scenic Reserve, and is a popular day trip destination.

As part of managing Rangitoto, the Department aims to minimise threats to the island's natural plant communities. The central cinder cone and broken lava flanks of Rangitoto support a mosaic of *Metrosideros*-dominated forest and scrub that are scientifically important as a living example of vegetation colonisation and succession from fresh lava to native forest. Following the recent eradication of introduced mammalian browsers (declared complete in 2000), the main threat to the island's vegetation communities is posed by invasive weeds.

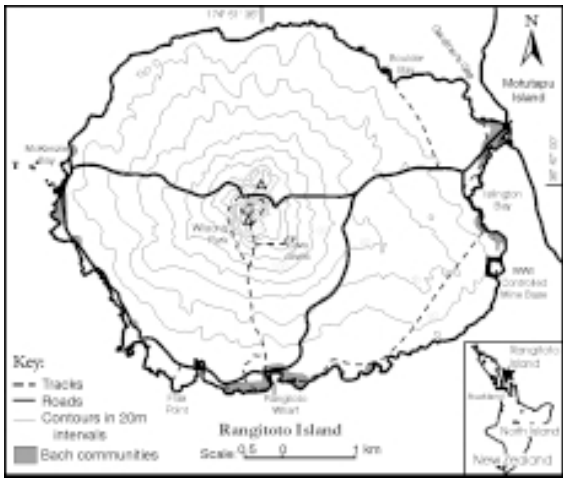

Fig. 1 Location and features of Rangitoto Island.

In 1995 funding became available for a weed management programme on Rangitoto. The large number of weed species meant that a detailed plan was needed to prioritise control action. This paper describes the process of developing a plan for managing the invasive weeds of Rangitoto. The plan evolved during five years of invasive weed control, going through three working drafts and becoming more comprehensive as our knowledge of the invasive weed problem on Rangitoto grew.

Natural History

Geology

The youngest and largest volcanic cone of the Auckland volcanic field, Rangitoto is described geologically as a shallow submarine Icelandic type shield volcano which formed during a single short eruptive event 600 to 700 years ago (MacDonald 1972; Julian 1992). Rangitoto is joined by a short causeway and bridge to the island of Motutapu, a much older landform which today is a pastoral farm with small pockets of forest.

Native vegetation

The forest structure and species associations found in the native vegetation on Rangitoto identifies more closely with the forests of the volcanic Big Island of Hawaii than with any other forest type in New Zealand. The canopy of the Rangitoto forests, like their Hawaiian counterparts, are dominated by trees of the genus *Metrosideros* (Myrtaceae).

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Metrosideros excelsa (pohutukawa) and *M. robusta* (Northern rata) form a hybrid swarm which is thought to be progressively backcrossing to *M. excelsa* (Julian 1992). The forest ground layers on Rangitoto support many species which in northern New Zealand mainland forests grow as epiphytes, for example *Collospermum hastatum* (Liliaceae), *Griselinia lucida* (Cornaceae), and *Astelia banksii* (Liliaceae).

During the 600 years since Rangitoto erupted, native vegetation has colonised about 80% of the raw lava flows. The vegetation patterns of Rangitoto were described by Julian (1992) as being strictly governed by the underlying lava flow type. Briefly, the flows composed of large slabs or rafts of rock (close to the Hawaiian pohoehoe flows in nature) were colonised more quickly and today support a mosaic of continuous forest types, including the tallest and most well developed forest types. The fragmented (aa) flows support low scrub or vegetation islands dominated by *Metrosideros*. Some of these aa flows are still only 60% covered by vegetation, leaving large expanses of empty broken lava. If the natural colonisation process is allowed to proceed then it could be hundreds of years before the largest open aa lava areas become clothed in native forest.

Human history

Possums and wallabies

Possums (*Trichosurus vulpecula*) and wallabies (*Petrogale pencillata pencillata*) were introduced to Motutapu Island from Australia in the late 1800s. From Motutapu they quickly invaded Rangitoto. The combination of possums browsing in the canopy and wallabies browsing the lower forest tiers caused significant damage to the vegetation. Possums were consuming mainly *Metrosideros* foliage, in some areas defoliating the canopy so much that the ground tier plants beneath were dying. Both possums and wallabies were foraging widely on the ground, eating ferns, depleting shrubs and destroying seedlings (Julian 1992).

In 1990 possum and wallaby eradication commenced using aerial poisoning. This gave the vegetation immediate relief, as it resulted in a 90% reduction in possum and wallaby numbers. The eradication of possums and wallabies from Rangitoto and Motutapu Islands was declared complete in 2000 (Mowbray 2002).

While possums and wallabies were destroying the native vegetation of Rangitoto they were also keeping weeds in check. A possum and wallaby exclosure experiment established before possum and wallaby eradication began showed increases in the pampas grass (*Cortaderia selloana*), and prickly hakea (*Hakea sericea*) (Julian 1992).

Introduction of invasive weeds

There were several campaigns in the late 19th and early 20th centuries to "beautify" the harsh volcanic landscape of Rangitoto. Several planting days were held in the 1890s with members of the public encouraged to catch a ferry to Rangitoto, bringing plenty of their favourite plants out with them. A large range of garden plants were introduced by the three small bach (holiday home) communities which built up from 1911 to 1937 (Fig. 1). The most enterprising attempt at beautifying Rangitoto was by two Englishmen, Leary and Wilson, who planned a botanical park on the island, near the base of the summit cone. They went to considerable effort to bring cacti, figs, pines and paw-paws (Woolnough 1984). It is likely that Leary and Wilson also introduced *Erica lusitanica* (Ericaceae), and *Hypericum androsaemum* (Hypericaceae) which went on to establish in the summit cone area.

Approximately 60% of the plant species we now consider invasive on Rangitoto were probably introduced to the island as garden plants. The garden plants that have naturalised are typically succulent (e.g. *Crassula, Sedum, Aloe, Bryophyllum* spp.) or possess drought resistant features such as bulbs, corms or rhizomes (e.g. *Watsonia, Gladiolus, Iris, Nephrolepis, Asparagus* spp.).

The remaining 40% of invasive weed species have seeds distributed by birds, water, or light winds and could easily have made their way from mainland Auckland. Auckland has a large naturalised flora by New Zealand standards (615 species) (Auckland Regional Council 1998). The proximity of mainland Auckland (3 km) presents an ongoing weed invasion concern.

There are now at least 232 naturalised exotic vascular plant species on Rangitoto, compared with 286 native vascular species (Gardner 1997). Not all of the naturalised exotic species have become invasive, but many that have become invasive are relatively innocuous elsewhere, and this gives Rangitoto a weed flora that is unusual in New Zealand.

DEVELOPING A WEED MANAGEMENT PLAN FOR RANGITOTO

In 1995 funding became available for a weed control and eradication programme on Rangitoto. As a result of distribution surveys and consideration of biological characteristics as described below, we identified 72 species as having enough impact on the native vegetation to warrant management. These were the species which could significantly and adversely affect the long-term survival of native species, the integrity or sustainability of natural communities, or genetic variation within indigenous species (Owen 1998). With such a large number of weeds and limited resources it has been important to prioritise control actions and plan strategically.

Prior to this weed control programme, there had been no formal attempts at controlling weeds on Rangitoto, apart from several control operations concentrating on removal of wild pines (Segedin 1985).

Weed distribution surveys

Field surveys, a literature search, and advice from local botanists elucidated the naturalised species present, their distribution, impact or potential impacts, modes of spread, and controllability.

Field surveys were conducted over key sites to indicate invasive species distributions. Exotic naturalised species were surveyed and mapped:

- around the entire coastline, as this is the first point of land for birds bringing weed species from other sites and for wind-blown or sea-borne propagules to take hold;
- at sites of human occupation (i.e. quarries, baches and old bach sites and WWII military installations) for deliberate introductions and garden escapes;
- around roads and tracks, as bird highways, and because of the potential for people to carry weed seeds on clothing and vehicles;
- on the summit cone, having the most soil-like substrate and therefore supporting the greatest range of species;
- along three north-south transects through the island, following hunters' trap-lines to get an idea of what was in the interior.

The adjoining south-western third of Motutapu Island and the 13 residence gardens on Motutapu were searched for species which had the potential to spread onto Rangitoto.

Prioritising invasive weeds for management

Early in the development of the weed management plan, the invasive plant species were grouped into seven priority classes according to:

- the impact or potential impact they have on the native vegetation;
- how quickly they are able to spread; and
- their distribution across the island.

Degree of impact

The degree to which an invasive species impacts on native vegetation processes was accorded the most influence in setting priorities for control. We considered invasive species to have a high impact on native vegetation processes if they were:

- able to colonise the remaining bare lava, such as *Ulex europaeus* (Papilionaceae); or
- tree-sized when adult, often drought resistant or epiphytic species such as *Ficus rubiginosa* (Moraceae), *Rhamnus alaternus* (Rhamnaceae); or
- vines, able to climb and smother other vegetation, such as *Dipogon lignosus* (Papilionaceae); or
- able to form a dense ground cover that prevents the regeneration of native species, such as *Crassula multicava* (Crassulaceae).

Distribution and rate of spread

Most of the weeds on Rangitoto have limited distribution. Those species that were of limited distribution but had the potential to spread quickly (i.e. were in the colonisation 'lag' phase) were accorded a higher priority for control than those which we expected to spread slowly. There are some species that were of extremely limited distribution, in that they occurred only at one or two sites and had a high potential impact (e.g. *Ageratina riparia* (Asteraceae), *Ligustrum lucidum* (Oleaceae)). These weeds were accorded the highest priority for control, becoming the 'Class 1' weeds.

Species with limited distribution and slow spread came last on the priority list. Usually these plants have seeds that are not dispersed effectively, so while the species is a problem for the native vegetation in the immediate area, we expect it to remain in its current locality. There is still the danger that an apparent slow rate of spread is due to previous suppression by marsupial browsing. We continue to informally monitor the lower-priority species, to avoid being taken by surprise.

There are five invasive species that are distributed over the entire island: two species of pine (*Pinus radiata* and *P. pinaster*), *Ulex europaeus*, *Ageratina adenophora* (Asteraceae) and *Hakea sericea* (Proteaceae). This group was positioned in the middle of the priority list for control.

Following our initial categorisation, the priority ranking of invasive weeds was revised using a system of scoring each weed on its biological characteristics and potential impacts on the native plant communities of Rangitoto (Owen 1997; Wotherspoon and Wotherspoon 2001). There were no major alterations to the placement of weed species in the priority list as a result of this change in method, but the scoring system has advantages in clearly setting out the rationale behind the priority classes and forcing a complete and objective assessment of the weed flora.

The scores for each weed were used to group the weeds into three new priority classes. The Class 1 weeds, those with very limited distributions and serious impacts on the native systems, were drawn from the top half of the list, defined by their restricted distribution scores. The remainder of the top half of the list became Class 2, and the second half of the list became Class 3.

WEED MANAGEMENT STRATEGIES

Management units

The island was divided up into manageable sectors for weed control. These sectors were further subdivided into numbered plots as initial control work was undertaken. The plots were sized so that they could be searched in a

day by a team of four, though during initial control the time taken to control the weeds often exceeded a day.

To counter the re-invasion potential from Motutapu Island, the south-western third of this island was designated a weed buffer zone. The buffer zone is large enough to include the high ridge closest to Rangitoto, hopefully catching most of the wind-borne weed seed, and we hope it encompasses most of the foraging activities of the local frugivorous birds. There was a suite of potential weeds growing in residents' gardens within this buffer zone, and six species of the 20 highest priority Class 1 weeds.

Management objectives

The life of the current phase of the Rangitoto Weed Control Plan takes us to 2006. There are two management objectives for each weed:

- a long-term management objective, based on what we considered achievable over approximately 15 years; and
- a five-year management objective, based on what we considered could be achieved over the five-year life of the plan, given the resources available.

The five-year management objectives were added to the plan recently. Weed control records from the previous five years are used to estimate the time and resources required to attain each goal. Both the five-year and long-term objectives will be reviewed in 2006, along with the rest of the weed management plan. Management objectives for each species are given in Table 1.

Eradication

Eradication is the goal for those weeds with a very limited distribution, for which the chances of unassisted re-introduction are effectively nil, and for which an effective control technique exists. Eradication is assumed to be complete when the control site has been cleared for a time period exceeding the known life of the seedbank. It is a difficult endpoint to define as the life of a seed in the seedbank can only ever be an estimate, and often nothing is known about the seedbank. We expect to have eradicated only three species by 2006, after 11 years of weed control (*Alocasia brisbanensis*, *Tradescantia fluminensis*, and *Spartium junceum*).

Control to zero density

Controlling to zero density involves maintaining a density of nil adult plants. It is the goal for those weeds with a limited distribution, but with either a very persistent (or unknown) seedbank or a strong likelihood of re-invasion from off the island. Control to zero density is the management objective for most of the weed species, considered achievable by 2006 for 35 species. We currently maintain 17 species at zero density (Table 1).

Sustained control

Sustained control aims to control the species to a defined density when it is unrealistic to maintain a nil density of adult plants, or when the species is only removed from situations in which it does the most damage, for example controlling gorse on open lava flows. This is the management objective used for weed species that are widespread across the island.

Control and eradication strategies

The strategy for control of the 72 weed species is to eradicate or control the class 1 species as a first priority then control species in classes 2 and 3 on a geographic basis - sector by sector. The decision was made early in the programme to focus control effort on the class 1 weeds - those weeds which have a high impact on the native vegetation, which were very limited in distribution, and have efficient seed dispersal mechanisms. Class 1 weed sites are visited and controlled every year. We have made good progress against these species, reducing many to zero density (Table 1), saving resources and time by controlling those problem weeds before the populations increased so much that control to zero density would not have been a realistic option.

An example of a weed species that in hindsight should have been controlled sooner is the vine *Dipogon lignosus*. This species occupied only a few square metres of forest canopy at the bach settlement of Rangitoto Wharf in 1990. By 1995 it had spread to cover almost one hectare of forest canopy in the same area, and had multiplied from a few vines to many hundreds. It is likely that this weed had been suppressed by possum and wallaby browsing which prevented it from establishing to a level where its invasive nature became apparent. While it is difficult to predict the responses of plants to major ecosystem change such as the removal of a browser, some control work around 1990 would have saved the many hours of mile-a-minute control work which is still going on in this area.

Weed control experience on Rangitoto has shown that all the weeds at a given site are best treated at the same time. Many of the weedy areas around bach communities have a ground tier dominated by the lower priority weeds *Nephrolepis cordifolia* (Davalliaceae) and *Crassula multicava*. Any area treated for a higher priority weed is rapidly invaded by these species and their dense growth obscures seedlings of higher priority weeds such as *Rhamnus* and *Asparagus asparagoides* (Liliaceae). Initial control of the class 1 weeds is now complete, and yearly follow-up control usually incorporates the lower priority weeds at the site.

The priority for control of sectors rests on the distribution of the more widely distributed, high priority class 2 weeds. The general strategy aims to slow the spread of weeds by controlling the least infested of the sectors first, working towards the most heavily infested areas. To contradict

Table 1 Invasive weeds of Rangitoto, grouped by control priority class. Management objective E=eradicate, Z=control to zero density, SC=sustained control.

Botanical name	Common name	Long-term management objective	Five-year management objective	Current status
Priority Class 1				
Acmena smithii	monkey apple	Z	Z	Z
Ageratina riparia	mistflower	Z	Z	
Alocasia brisbanenesis	elephant's ear	E	E	Z
Anredera cordifolia	madiera vine	Z	Z	
Berberis glaucocarpa	barberry	Z	Z	Z
Crataegus monogyna	hawthorn	Z	Z	Z
Ficus rubiginosa	Port Jackson fig	Z	Z	
Hakea salicifolia	willow-leaved hakea	Z	Z	
Hedera helix	ivy	Z	Z	Z
Iris foetidissima	stinking iris	Z	Z	
Jasminum polyanthum	jasmine	Z	Z	Z
Ligustrum lucidum	tree privet	Z	Z	
Ligustrum sinense	Chinese privet	Z	Z	
Lonicera japonica	Japanese honeysuckle	Z	Z	
Lycium ferocissimum	boxthorn	Z	Z	Z
Myoporum insulare	Australian ngaio	Z	Z	Z
Pennisetum clandestinum	kikuyu grass	Z	Z	Z
Phoenix canariensis	Canary Island palm	Z	Z	
Polygonum capitatum	pink headed knot weed	Z	Z	
Racosperma longifolium	Sydney golden wattle	Z	Z	Z
Rubus fruticosus	blackberry	Z	Z	
Senecio angulatus	cape ivy	Z	Z	Z
Spartium junceum	Spanish broom	E	E	Z
Tradescantia fluminensis	wandering jew	E	E	Z
Vinca major	periwinkle	Z	Z	Z
Priority Class 2				
Agapanthus praecox	agapanthus	Z	SC	
Agave americana	century plant	E	Z	
Ageratina adenophora	Mexican devil	SC	SC	
Araujia sericifera	moth plant	Z	SC	
Asparagus asparagoides	smilax	Z	SC	
Asparagus scandens	climbing asparagus	Z	SC	
Buddleia davidii	buddleia	Z	SC	
Chrysanthemoides monilifera	bone-seed	Z	SC	
Cortaderia jubata	purple pampas grass	SC	SC	
Cortaderia selloana	pampas grass	SC	SC	
Cotoneaster glaucophyllus	cotoneaster	Z	SC	
Crassula multicava	pitted crassula	E	SC	
Cymbalaria muralis	ivy-leaved toad flax	E	SC	
Dipogon lignosus	mile-a-minute vine	Z	Z	Z
Erica arborea	tree heath	Z	Z	Z
Erica lusitanica	Spanish heath	Z	Z	Z
Erigeron karvinskianus	Mexican daisy	Z	SC	
Gladiolus natalensis	wild gladiolus	Z	SC	
Hakea sericea	prickly hakea	SC	SC	
Hypericum androsaemum	tutsan	Z	Z	
Nephrolepis cordifolia	tuber ladder fern	Z	SC	
Paraserianthes lophantha	brush wattle	Z	SC	
Pinus spp.	pines	Z	SC	
Rhamnus alaternus	rhamnus	Z	SC	
Ulex europaeus	gorse	SC	SC	

Table 1 Continued. Management objective E=eradicate, Z=control to zero density, SC=sustained control.

Botanical name	Common name	Long-term management objective	Five-year management objective	Current status
Priority Class 3				
Aeonium x. *haworthii*	small pinwheel	Z	SC	
Aloe saponaria	soap aloe	Z	SC	
Bryophyllum diagremontianum	lizard plant	Z	SC	
Carica pubescens	mountain pawpaw	Z	SC	
Carpobrotus edulis	ice plant	Z	SC	
Centranthus ruber	valerian	Z	SC	
Crassula coccinea		Z	SC	
Chlorophytum chloronotum	spider plant	E	SC	
Epidendrum sinabaeum	crucifix orchid	Z	SC	
Eriobotrya japonica	loquat	Z	Z	
Gomphocarpus fruticosus	swan plant	Z	SC	
Impatiens sodenii	shrub balsam	Z	Z	
Lavandula dentata	lavender	Z	SC	
Lilium formosanum	lily	E	Z	
Maurandya erubescens	Maurandya vine	Z	Z	
Pelargonium spp.	pelargoniums	E	SC	
Polygala myrtifolia	sweet pea shrub	Z	SC	
Sedum mexicanum		E	Z	
Tecomaria capensis	cape honeysuckle	E	Z	
Watsonia bulbilifera	bulbil watsonia	Z	SC	
Watsonia meriana	watsonia	Z	Z	
Zantedeschia aethiopica	arum lily	Z	Z	

this however, the first sector to receive control work was the very weedy central scoria cone, at the summit. The decision was made to control this sector first because the scoria substrate supported the greatest number of Class 2 weeds of any sector, a number of which were suspected to be capable of spreading onto the broken lava surface of the rest of the island. It was also a relatively easy substrate to work on, and rapid progress was made. Until 1996 Spanish heath (*Erica lusitanica*) formed between 30 and 60% of the canopy on the northern side of the cone, and is now at zero density. Tutsan (*Hypericum androsaemum*) formed a solid ground cover of 6 ha on the south side of the cone, and seemed to be extending its range downhill from Wilson's Park onto the lava flows. It has been controlled every year since 1996, and is now occasional throughout this area.

Control of the most widespread of the Class 2 species, the pines and *Ulex europaeus*, has proved to be best undertaken using helicopters. Pines were mapped by Differential Global Positioning System (DGPS) from a helicopter and have proved relatively cheap to control, using forestry contractors and helicopter access.

The most abundant and highest scoring of the Class 2 weeds is *Rhamnus alaternus*, so the strategy for control by sectors is essentially dominated by the need to gain control of this weed.

Rhamnus alaternus

Rhamnus is a weed of great concern in all the forest types on Rangitoto. It is a hard-wooded, small (up to 10m) dioecious tree that is able to establish under a light canopy or in full sun (Fromont 1995). It reaches maturity in only three years, has a fast growth rate (height increase of up to 800 mm per year on Rangitoto), and a bird-dispersed seed.

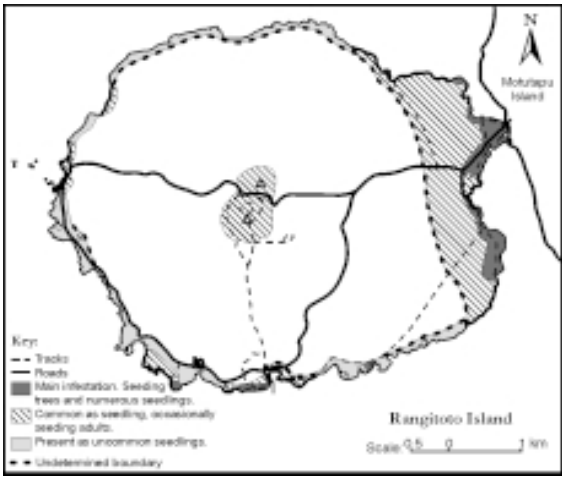

Fig. 2 Distribution of *Rhamnus alaternus* on Rangitoto Island.

Because its growth rate is faster than most native shrub and tree species, *Rhamnus* quickly dominates and extends islands of young vegetation on the lava flows. Without a substantial control programme for *Rhamnus* it is a fair expectation that it will spread across the remainder of Rangitoto, dominating and excluding pohutukawa from what are now open lava fields, outcompeting the subcanopy tiers in all forest types, and infiltrating the canopy of the lower scrubby vegetation types.

The extent of the *Rhamnus* infestation on Rangitoto can be seen in Fig. 2. While it is not present over the whole island, it is found all around the coast, and in the summit cone area. The main infestation comprises 187 hectares at Islington Bay and Gardiner Gap where Rangitoto and Motutapu Islands are joined (Fig. 2).

The control strategy aimed to control and maintain *Rhamnus* at zero density everywhere except for the main infestation at Islington Bay and Gardiner Gap before tackling the main infestation. We are very close to achieving this, and initial control of the main infestation began very recently by spraying *Rhamnus* and other weed species on the Motutapu cliffs from a helicopter.

Surveillance

A recent analysis of the weed invasion threat identified Motutapu Island, Auckland City, and North Shore City as the most likely contributors to the Rangitoto weed flora (Julian 1999). A surveillance programme is included as part of the weed management plan. Surveillance concentrates on the coast closest to Auckland and the North Shore to try to detect new invasions shortly after they arrive.

OPERATIONAL METHODS - THE EXECUTION OF THE PLAN

Searching for and controlling weeds is meticulous work, requiring diligence and keen observation. The Rangitoto weed team works in groups of three to five, systematically searching and controlling each plot side by side in a line. One end person follows a plot boundary and the other end person reels out biodegradable cotton from a hip chain, the cotton line indicating the position of the next swath. For each plot the amounts of control time and herbicide used on each species is recorded. Comparison of these data from year to year, when the same method is used, indicates the progressive reduction of each weed.

We use GPS technology extensively. The rough terrain and an absence of landmarks make navigation over Rangitoto difficult, so recent improvements in GPS technology have revolutionised the way we map and relocate weed infestations on the ground. All helicopter work is guided by GPS, and we have used helicopters to map weed infestations from the air, later relocating them for control from the ground.

Chemical control is necessary on Rangitoto simply because digging weeds out is impossible over most of the island. Many of the weeds, to the best of our knowledge, had never been subjected to control before. We conducted a range of control trials in an effort to find effective herbicides and application methods. These included foliar spraying, painting the trunks with herbicide, (sometimes chipping the bark off first), and felling the weeds and painting the stumps. The trials initially involved replications of treated individuals and sites, and are now incorporated into the general control plan as we continue to refine the successful methods.

DISCUSSION

The 'how-to' aspects of weed control are crucial to the development of a weed management plan. Operational details such as available control methods, logistics of transporting or accommodating staff, and resources available, will ultimately dictate the outcomes of weed management. Operational details are just as important as the biological information about each weed, ecological information about the systems being protected, and weed distribution patterns, when devising a plan.

Above all we have found flexibility in a weed management plan to be very important. During the five years over which the Rangitoto Weed Control Plan developed, there were additions to the weed list, changes to the priority classes, evolving control techniques, new herbicides on the market, and improving GPS technology. All invoked changes to the plan, in varying degrees. To retain the flexibility needed to take advantage of new information, our weed control planning is fine-tuned annually. A short annual plan allows for priorities to be temporarily swapped, and for resources to be redirected to take advantage of changing circumstances or to correct setbacks.

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REFERENCES

Auckland Regional Council 1998. Auckland regional plant pest management strategy. Auckland Regional Council.

Fromont, M. L. 1995. Ecological research for management of *Rhamnus alaternus* L. Unpublished MSc thesis, University of Auckland.

Gardner, R. 1997. Vascular plants of Rangitoto Island. Unpublished report, Department of Conservation, Auckland.

Julian, A. 1992. The vegetation pattern of Rangitoto. Unpublished PhD thesis, University of Auckland.

Julian, A. 1999. Environmental weed threats to Motutapu and Rangitoto Islands. Volume 1-Strategy. Unpublished report, Motutapu Restoration Trust.

MacDonald, G. A. 1972. *Volcanoes*. Prentice-Hall Inc., Englewood Cliff, New Jersey, USA. 510p.

Mowbray, S. 2002. Eradication of introduced Australian marsupials (brushtail possum and brushtailed rock wallaby) from Rangitoto and Motutapu Islands, New Zealand. In Veitch, C. R. and Clout, M. N. (eds.). *Turning the tide: the eradication of invasive species*, pp. 226-232. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Owen, S. J. 1997. Ecological weeds on conservation land in New Zealand: a database. Department of Conservation, Wellington.

Owen, S. J. 1998. Department of Conservation strategic plan for managing invasive weeds. Department of Conservation.

Segedin, A. 1985. Rangitoto biological assessment and natural history. Unpublished report, Department of Lands and Survey, Auckland.

Woolnough, A. 1984. *Rangitoto. The story of the island and its people*. Angela Woolnough, Auckland. 72p.

Wotherspoon S. and Wotherspoon J. 2001: Rangitoto weed control plan. Unpublished report, Department of Conservation, Auckland.