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Ecological restoration at Mainland Islands in New Zealand

A. Saunders [a,*], D.A. Norton [b]

[a] *Department of Conservation, PO Box 10-420, Wellington, New Zealand*
[b] *Conservation Research Group, School of Forestry, University of Canterbury, Private Bag 4800, Christchurch, New Zealand*

Abstract

While important advances have been made in recovering threatened species and restoring damaged habitats on offshore islands, effective conservation management is also required on the main (North and South) islands if representative elements of New Zealand's remaining biodiversity are to be protected. The recent initiation of Mainland Island projects constitutes an important step in that ecosystem-focused restoration goals are being pursued at mainland sites. The intensity and scope of pest control undertaken at Mainland Islands is greater than has normally been the case previously, as has been monitoring of results and conservation outcomes. Preliminary results suggest that declines in monitored species have been arrested and ecological processes revitalised. In addition to restoring values at individual sites Mainland Islands may be important places where our capacity to manage ecosystems more generally may be developed. Advances in our understanding of ecological processes and of responses to management using sound scientific procedures as part of operational programmes could lead to improved predictions to underpin management decisions. Refinements to management techniques and the development of appropriate skills, as well as enhancing public support and involvement could also be expected to have major benefits for conservation management more widely.

Keywords: Mainland Islands; Nature conservation; Ecosystem restoration; Predators; Herbivores; Adaptive management; Pest control; Threatened species; Public involvement; Stakeholders

1. Introduction

Like many island archipelagos New Zealand's biota has changed dramatically as a result of human colonisation. Many species have gone extinct and a relatively large proportion of those remaining are threatened with extinction. The main agents of decline have been habitat loss and fragmentation and the on-going impacts of introduced pests.

New Zealand conservation practitioners have achieved some remarkable successes in averting further extinctions and rehabilitating habitats on offshore islands. Vulnerable species have been translocated to predator-free islands in order to establish new populations. A growing array of introduced pests (particularly mammals) have been eradicated from islands up to 2000 ha in size, creating opportunities for species recovery and ecological restoration.

While this focus on offshore islands will continue, it is clear that it will not be possible to sustain all or even the majority of New Zealand's remaining indigenous biodiversity on offshore islands alone. There is a need to also achieve important conservation outcomes at mainland sites.

Six 'Mainland Island' projects were initiated by the New Zealand Department of Conservation in 1995 and 1996. Their key features are that they have ecosystem-focused restoration goals, they involve intensive and integrated pest management regimes, and activities, results and outcomes are closely monitored. Unlike true islands which are surrounded by water, Mainland Islands are located on the main (North and South) islands of New Zealand and lie adjacent to other areas not managed intensively for conservation purposes.

Because of the interrelationships between Mainland Island sites and their surrounding landscapes the "island" analogy is not definitive in a biogeographic context. The use of the term stems from the presence of obvious borders at some projects located in forest remnants within pastoral landscapes. Intensive pest control to limit the movement of pests into managed areas has been focused at forest–pasture margins in the same way

* Corresponding author.
E-mail address: asaunders@doc.govt.nz (A. Saunders).

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that surveillance, quarantine and contingency measures are focused around the coasts of pest-free true islands. The "island" analogy is even less relevant in relation to projects within habitat complexes where core management areas lie within a larger habitat continuum and management boundaries are less obvious. The term 'Mainland Island' is nevertheless evocative of a new generation of conservation projects aimed at restoring damaged ecosystems on the New Zealand mainland.

The "Mainland Island approach" is based on successes in removing herbivorous and carnivorous pests from offshore islands, and increasingly effective pest control programmes undertaken at mainland sites. Mainland Island pest control regimes are more intensive and have been maintained for longer periods than has normally been the case previously in New Zealand. In less than 5 years significant reductions in suites of targeted pests have been achieved and ecological changes have been attributed to the management applied. There are also indications that some of these projects have been important in educating people and empowering stakeholder involvement in conservation management programmes. While results suggest that these projects represent a new era in conservation management, major challenges remain to be addressed before comprehensive ecosystem restoration goals are achieved.

In this paper we outline the background to the emergence of Mainland Island projects on the New Zealand mainland, identify new challenges they present and discuss how they might contribute to future biodiversity conservation programmes.

2. Human impacts on the New Zealand biota

The history of human involvement in New Zealand ecosystems is both recent and dramatic. Although it was the last major land mass, apart from Antarctica, to be permanently colonised by humans, the impacts of settlement have been catastrophic on New Zealand's indigenous biota. Prior to human settlement, New Zealand was primarily forested below the climatic tree line (McGlone, 1983). However, in a little over 1000 years this landscape was transformed to one dominated by herbaceous vegetation, with total forest cover declining from c. 75 to 25%. The lowlands were most affected, with alluvial and sand-plain forests almost totally lost (Awimbo et al., 1996; Norton, 2000), while few natural vegetation sequences remain in lowland areas of the North Island in particular (Ogden, 1995). Ecosystems other than forests have also experienced dramatic declines. For example, some 90% of New Zealand's lowland wetlands have been lost (Finlayson and Moser, 1991). The reduction and fragmentation of natural vegetation has also been an important factor in the decline of New Zealand's indigenous plants and animals. The scale of these disturbances and the relatively short timeframes involved mean that impacts of past land clearance activities continue. Further extinctions are likely in small habitat remnants, in particular, as a result of not only the limited size of these remnants, but also their isolation from other similar habitats (Ogle, 1987; Molloy, 1995).

Although habitat loss and fragmentation continue to have a powerful influence, particularly in lowland areas, introductions of browsing and predatory mammals have had almost universal impacts throughout all New Zealand ecosystems. Many native animals have suffered range contractions or extinction due to the impacts of introduced mammals (e.g. Atkinson and Millener, 1991; Towns and Daugherty, 1994). Browsing goats (*Capra hircus*), deer (*Cervus* spp.) and brushtail possums (*Trichosurus vulpecula*) in particular have caused pronounced changes in the structure and composition of many forest and grassland communities (Rose and Platt, 1987; Cochrane, 1994; Allen et al., 1997; Rogers and Leathwick, 1997), while possums are also known to prey on indigenous birds such as kokako (*Callaeas cinerea*) and kiwi (*Apteryx* spp.); Brown et al., 1993). The impacts of introduced predatory mammals, especially rats (*Rattus* spp.), mustelids (*Mustela* spp.) and cats (*Felis catus*), on the vertebrate fauna has been catastrophic, a situation that has been described as an "ecological collapse" (Towns and Atkinson, 1991). Forty-nine percent of New Zealand's non-marine endemic birds are extinct (Bell, 1991), while most seabirds are now locally extinct on the New Zealand mainland. The high number of bird extinctions led Diamond (1984) to comment that "New Zealand no longer has an avifauna, just the wreckage of one." Apart from animal pests introduced weeds have invaded almost every part of New Zealand, threatening the viability of native plant communities by fragmenting suitable habitat and preventing native seedlings from establishing.

3. Responding to biodiversity loss

The ecological impacts of early Polynesian settlers were dramatic (McGlone, 1983), but Maori cultural traditions of kaitiaki (stewardship), and tapu and rahui (protection) that developed subsequently, reduced further biodiversity impacts because of the need to sustain key resources (Roberts et al., 1995). Nature conservation, however, was probably far from the minds of early European settlers who strove to "break the land in" for pastoral farming (Park, 1995). Early European conservation measures focused on legally protecting land as reserves, particularly at sites with important scenic values and where there was minimal conflict with other land uses. Following the establishment of Tongariro National Park in 1887, then only the fourth such park in

the world, other national parks and several hundred scenic reserves were established. These early parks and reserves included some important landscapes and plant communities but most were chosen primarily for their aesthetic qualities rather than for their ecological attributes and few were established at lowland sites where biodiversity loss was greatest.

It was not until the 1970s that a network of ecological areas was established by the New Zealand Forest Service to protect important biological communities and to provide scientific benchmarks in publicly-owned forests on the New Zealand mainland (Nicholls, 1974). This initiative was followed in the early 1980s by the Protected Natural Areas programme undertaken by the Lands and Survey Department (Kelly and Park, 1986). This programme was designed to address the problem of under-representation of many ecosystem types in the existing reserve system, especially non-forest communities. At the same time, alterations to the Reserves and National Parks Acts included ecological considerations in guidelines for selecting areas for protection. Following the reorganisation of government land management agencies in 1987 and the passing of the 1987 Conservation Act, the newly-created Department of Conservation has continued land acquisition and reservation programmes. In addition to government initiatives there has also been increasing interest among private land owners to seek formal protection of areas of private land with conservation values through a variety of mechanisms. As a result of legal protection measures some 30% of New Zealand's land area is now formally reserved, although lowland and marine areas, in particular, remain seriously under-represented (Anon, 1997).

Though important it is clear that legal protection alone has not been sufficient to prevent further ecological degradation (Norton, 1988). Many indigenous species have eventually disappeared from formally designated reserves in the absence of active management. The bush wren (*Xenicus longipes*) and North Island pio pio (*Turnagra capensis*) for example, and the North Island mistletoes (*Loranthaceae*) disappeared from protected areas relatively recently as a result of the impacts of introduced carnivores and herbivores (Norton, 1991; Heather and Robertson, 1996; Ogle, 1997). In addition to protecting natural areas from further vegetation destruction and modification, active management is clearly required to address the impacts of invasive species.

The potential of New Zealand's offshore islands as conservation management sites has been recognised for over 100 years. Richard Henry, the caretaker of Resolution Island off the Fiordland coast transferred flightless kakapo (*Strigops habroptilus*) and little spotted kiwi (*Apteryx oweni*) to Resolution on the 1890s in an attempt to establish populations safe from the impacts of alien predators. Unfortunately stoats (*Mustela erminea*) swam to the island and this initiative failed. It became increasingly apparent however, that 'marooning' vulnerable native species on predator-free islands was a key to averting further extinctions. As management techniques were refined the number of translocations to establish new populations of native species on islands has increased markedly (Veitch and Bell, 1990). Many current species recovery programmes include provision for translocations to offshore islands.

In addition to transferring native species to predator-free islands, introduced pests have been eradicated from some islands. Department of Conservation records show that 17 species of vertebrate (15 mammals and two birds) have been successfully eradicated from 140 islands around the New Zealand coast (O. McHalick pers. comm.). The removal of one or more alien pests has created new opportunities not only to recover threatened species, but also to restore ecosystems (Mansfield and Towns, 1997).

Successes in establishing new populations and in eradicating alien pests can be attributed to the physical isolation of islands. Being surrounded by water, colonisation of islands by species with poor dispersal capabilities is limited. This means that many New Zealand species can be managed as discrete populations on islands, and that the risk of invasion by terrestrial pests is generally lower than at mainland sites. Based on recent successes, plans are now being prepared to eradicate suites of weeds and animal pests from further islands (Anon, 1998b).

Until recently few successes had been recorded in protecting and restoring biodiversity on the mainland. There is a relatively long history of control operations mounted against introduced herbivorous mammals, particularly deer, goats and possums. Since the 1930s considerable effort and resources have been expended to control these species, although success in relation to conservation objectives has been limited (Ogden, 1995). Where conservation objectives have been declared these have usually focused on soil erosion control and water catchment protection. Pest management in high priority conservation areas to protect vegetation and wildlife habitat values has been adopted only relatively recently (Parkes, 1996). In addition to more strategic approaches focused on critical pests, new control techniques have been developed constituting important advances. The development of aerial toxic bait application techniques, for example, has allowed possum populations to be effectively controlled over more extensive and remote areas than previously. Significant responses in plants vulnerable to the impacts of browsing mammals have been recorded.

In the last few years it has been shown that critical pests, including carnivorous predators as well as herbivores must be reduced to very low densities if biodiversity management objectives are to be achieved at mainland sites. In an experimental management programme in

central North Island forests for example, it was shown that possums and ship rats must be controlled to very low densities for several consecutive years in order to recover populations of the endangered kokako (Innes et al., 1999). Control regimes required to achieve low pest densities in this programme were much more intensive and sustained for longer periods than had normally been the case in pest control operations previously.

This programme focused on recovering kokako populations in forests in the central North Island was particularly important in that it was one of the first to demonstrate that in-situ species recovery was achievable on the mainland, rather than being limited to offshore islands. It was also important in that an adaptive management approach (Walters and Holling, 1990) was employed which allowed for scientifically robust conclusions to be drawn.

While the central North Island programme continues to be focused on kokako recovery at several reserves, observations of other ecological responses to intensive pest control (such as changes in vegetation composition, structure and phenology, increased invertebrate community diversity, and increases in the numbers of forest birds counted) at one of the reserves has led to a recognition that wider goals may be appropriate. A strategic plan drafted for the Mapara reserve in 1996 included a vision statement that 'Mapara is a national model in sustaining indigenous biodiversity and key endemic species of flora and fauna' (Bradfield, 1996). Given the progress which had already been made and a vision which included multiple species, this statement reflects an emerging awareness in the early 1990s that broader ecosystem-focused management goals may be appropriate and achievable on the mainland (Clout, 1989; Saunders, 1990).

4. The emergence of Mainland Islands

During 1995 and 1996 the Department of Conservation initiated six Mainland Island projects (Fig. 1). Three of these (Trounson Kauri Park, Boundary Stream Reserve, Paengaroa Reserve) are 'habitat islands' involving isolated forest remnants in essentially modified landscapes dominated by farmland. The other three (Northern Te Urewera National Park, Rotoiti Nature Recovery Project, Hurunui River) are 'habitat complexes' featuring core management areas within a larger complex of similar habitats. Areas range from 117 ha at the Paengaroa reserve, to the Hurunui project where the core management area covers over 6000 ha. In total over 10,000 ha of indigenous forest and grassland are currently being intensively managed at these six sites.

All of these Mainland Island projects have ecosystem-focused restoration goals. Management objectives include rehabilitating habitats, enhancing particular plant and animal populations, and informing stakeholders of activities and progress. The development of sustainable management regimes by which critical pests, in particular introduced herbivorous and carnivorous mammals, can be effectively controlled and their re-invasion limited to acceptable levels is a priority activity at these sites.

A total of 17 animal pests (15 vertebrates and two vespulid wasps) are being intensively controlled at Mainland Islands, with up to 11 species targeted for control at one site (Table 1). Weeds are being targeted for control at only two of the six Department of Conservation projects. At the Paengaroa reserve 14 weeds are being controlled, and a further two are targeted at the Boundary Stream project. While weeds are not considered a major problem at most of these projects, consideration is being given to initiating weed control near forest margins at projects centred in forest fragments in particular.

In most cases pest control is achieved through the use of poisoning and trapping grids established throughout core management areas. At the Trounson site, for example, a network of poison bait stations has been established based on a 100×50 m grid in order to effectively control possums and rodents — including house mice (*Mus musculus*) throughout the reserve (Fig. 2). In addition, a line of traps is maintained on the forest margin to catch feral cats and mustelids as they enter the reserve from neighbouring areas. Responses to the management applied, as well as changes in ecosystem parameters, are being followed with correspondingly intensive monitoring programmes at Mainland Islands.

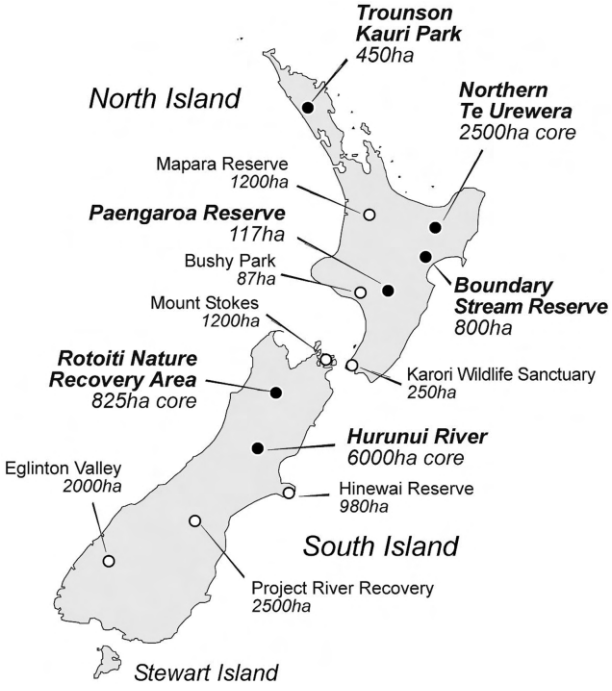

Fig. 1. Project areas referred to in text. Department of Conservation Mainland Islands are highlighted.

Table 1
Animal pests targeted for control at Department of Conservation Mainland Islands

Pest	Project					
	Trounson	Northern Te Urewera	Boundary Stream	Paengaroa	Rotoiti	Hurunui
Possum	X	X	X	X	X	X
Rabbit					X	
Hare					X	
Deer		X	X		X	
Pig		X	X			
Goat			X			
Stoat	X	X	X		X	X
Ferret	X	X	X		X	
Weasel	X	X	X			
Rat	X	X	X		X	
Mouse	X		X		X	
Cat	X		X			
Dog	X					
Magpie	X					
Myna	X					
Wasps					X	

Because ecosystem-focused restoration projects are essentially long-term it would be premature to expect significant progress towards restoration goals after only 3 or 4 years. Nonetheless some important achievements have already been recorded in relation to pest control objectives (Saunders, 1999). For example, possum and rat population densities have been reduced and maintained at extremely low levels for more than 12 months at several Mainland Island sites. The feral goat population at Boundary Stream has been reduced by 90% and cattle (*Bos taurus*) excluded at Hurunui for the first time in 125 years. At Rotoiti, wasps (*Vespula* spp.) have been successfully controlled to low levels for the first time ever in a large forest area (c. 400 ha; Table 2) and eradication of the invasive common ivy (*Hedera helix*) has almost been achieved at Paengaroa.

In response to pest control at Rotoiti, nestlings of the endemic parrot kaka (*Nestor meridionalis*) have successfully fledged where, in previous years, few were escaping the depradations of stoats (Wilson et al., 1998; Anon, 1999a). In the northern Te Urewera, kokako nesting success is higher than at most other sites where kokako are monitored (J. Hudson, pers. comm.). Similarly, at

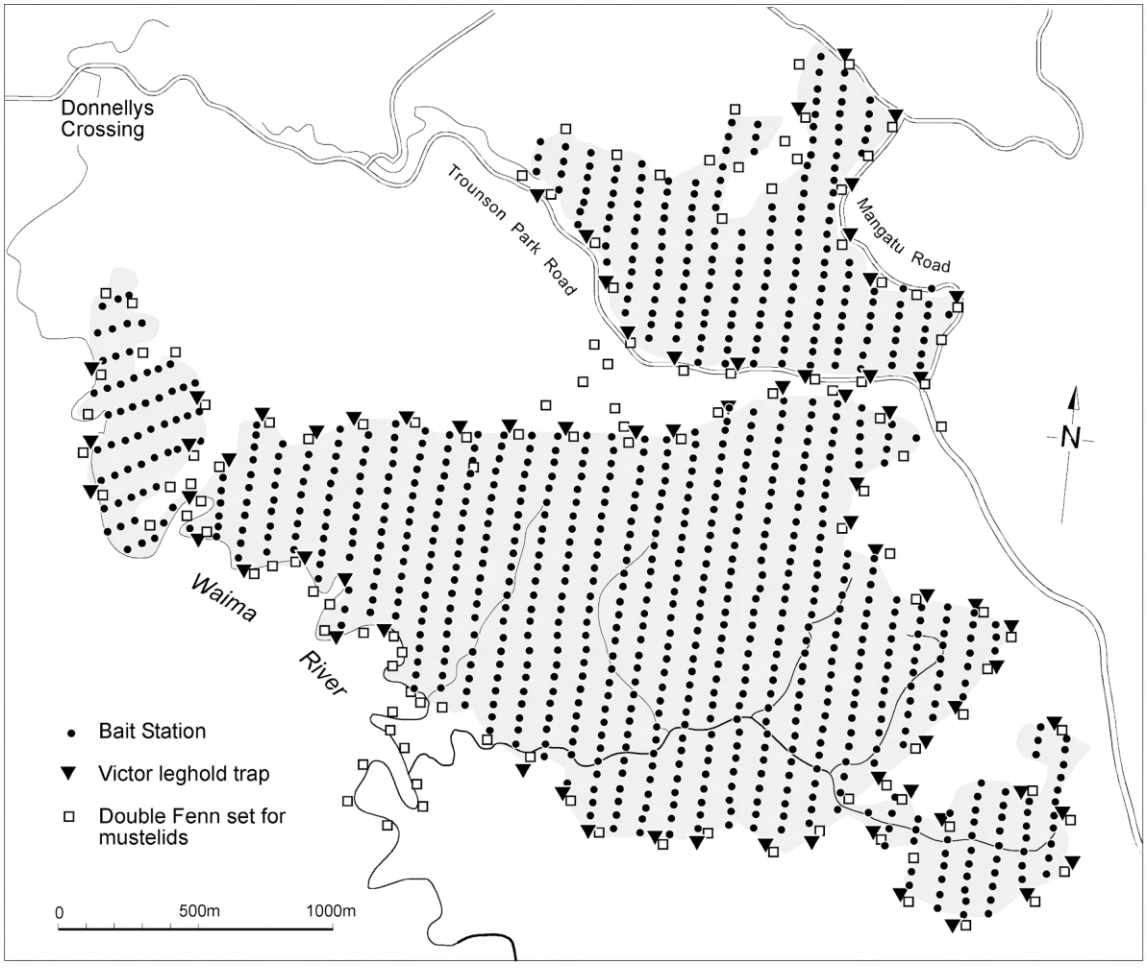

Fig. 2. Trounson Kauri Park showing intensity of poison bait station and trapping grids (from Saunders, 1999).

Trounson there has been a dramatic increase in numbers of the native pigeon, or kukupa (*Hemiphaga novaeseelandiae*) following the effective control of mammalian competitors and predators (Anon, 1999b). Recorded changes in the number and condition of monitored plants in response to the control of mammalian herbivores has been equally dramatic. For example, native mistletoes have shown marked increases in abundance at several sites following possum control (Table 3).

Apart from ecological benefits there are also indications that stakeholder support is growing as a result of activities at some Mainland Island projects. Events to celebrate the achievement of project milestones have been well attended by local residents and interest groups, as well as national political figures.

Apart from the six Mainland Islands funded by the Department of Conservation a number of other projects have been initiated at mainland sites which have ecosystem-focused restoration goals (Fig. 1). Some, such as in the Eglinton Valley, Mount Stokes and Bushy Park, have evolved from species recovery and pest control projects to wider community and ecosystem restoration goals. In others, projects have been initiated with ecosystem-focused restoration goals from the outset. Examples of the latter include the Hinewai Reserve and Project River Recovery in Canterbury, and the Karori Wildlife Sanctuary in Wellington city. Some of these projects are essentially aimed at rehabilitating habitats and recovering suites of threatened species rather than restoring ecosystems per se, but the intensity and integration of the management programmes undertaken means they nevertheless constitute an important advance from previous less intensive approaches.

The initiation of these projects reflects a combination of factors. Most importantly successes on offshore islands demonstrated the significant impacts of alien mammals on the native biota. They also indicated that it may be possible to recover threatened species and to restore damaged ecosystems on the mainland. An intent to achieve similar successes on the mainland using intensive pest management approaches developed on islands underpins this new generation of projects. Strategic policies have also changed recently in response to mounting public concerns about continued declines in biological diversity. The Convention on Biological Diversity, to which the New Zealand government is a signatory, notes the fundamental importance of in-situ conservation of ecosystems and natural habitats for the maintenance and recovery of viable populations of indigenous species (Anon, 1993a). This ecosystem-focused approach is mirrored in New Zealand government initiatives including the Environment 2010 Strategy (Anon, 1995) and the recently-released draft New Zealand Biodiversity Strategy (Anon, 1998a) both of which emphasise the importance of in-situ conservation of indigenous plants and animals. Proposed goals in the draft biodiversity strategy include provisions to 'maintain and restore a comprehensive and representative range of remaining natural habitats and ecosystems', as well as 'representative populations of all indigenous species in selected natural habitats'.

The New Zealand government's national conservation management agency, the Department of Conservation, has also declared its intention to focus on ecosystems wherever practicable and appropriate. Its vision document 'Atawhai Ruamano 2000' (Anon, 1993b) concluded that 'conserving biodiversity is primarily about ecosystem conservation'. In the Department's Strategic Business Plan 1998–2002 (Anon, 1998b), two key steps necessary for the protection of New Zealand's natural heritage are identified: 'Policies and plans that integrate species protection and ecosystem conservation work...' and 'restoration of high priority offshore and mainland island ecosystems and advancing recovery programmes for threatened species in accordance with an integrated approach to management...'. Implicit in the aims of both of these strategic plans is a shift from single species recovery alone, and the management of threats separately, to an integrated ecosystem-focused approach to management wherever practicable. These policies and strategies reflect a move towards an ecosystem-focused in situ management approach to nature conservation on the New Zealand mainland. Mainland Island projects represent an important step towards these strategic goals. In addition to technical advances and policy changes, public interest in conserving New Zealand's natural treasures, and in being actively involved in conservation projects has also grown markedly. A growing number of projects, including some with ecosystem-focused restoration goals, have been initiated by community groups.

Table 2
Wasp (*Vespula vulgaris*) nest and worker numbers before and after poisoning in 1999 (D. Butler unpubl. data, 1999)

Period	Treatment		Non-treatment	
	Nests ha^{-1}	Wasps has^{-1}	Nests ha^{-1}	Wasps ha^{-1}
Pre-poison	61	3117	26	526
Post-poison	2	4	25	459

Table 3
Response of mistletoes (*Alepis flavida* and *Peraxilla tetrapetala*, $n=46$) measured by foliage cover abundance one year after possum control at the Hurunui Mainland Island treatment and non-treatment sites (A. Grant unpubl. data, 1998)

Response	Treatment	Non-treatment
Increase	37	19
No change	50	10
Decrease	13	71

5. Towards an ecosystem management approach

A species-focused approach to biodiversity conservation has been employed in New Zealand for several reasons. Prior to the passing of the Conservation Act in 1987 and the establishment of the Department of Conservation, government legislation enforced a species focus for wildlife management, while species and habitat management responsibilities lay with different government agencies (Mansfield and Towns, 1997). Successes in recovering threatened species such as the South Island saddleback (*Philesturnus carunculatus carunculatus*) and Chatham Island black robin (*Petroica traversi*) from the brink of extinction no doubt encouraged additional efforts to prevent further species losses. Growing public concern about threatened birds such as takahe (*Porphyrio mantelli*) and kakapo probably also served to reinforce a species focus. Furthermore, because our ecological knowledge stems largely from investigations of species, and simple relationships between species, it is not surprising that biodiversity conservation management programmes have tended to focus on species rather than ecosystems. Performance towards species-focused objectives is also easier to measure than for programmes with broader ecosystem goals (Simberloff, 1998).

The importance of taking an ecosystem approach to conservation has been a strong theme in the conservation biology literature (Grumbine, 1994). It is now widely recognised that if conservation benefits are to be sustained management must be focused on ecosystem processes as well as on individual species. Because of the complex nature of the interdependencies that occur between ecosystem components (McNaughton, 1989; Lamont, 1992; Schulze and Mooney, 1994), changes to one species or process can have unexpected effects on other species. Management focused on individual species that does not address the underlying ecosystem problems will not necessarily result in the recovery of individual threatened species or communities (Norton and Reid, 1997).

Perhaps the most compelling reason for adopting a more ecosystem-focused approach to conservation management is the sheer scale of the problem of recovering threatened species individually. Recent estimates suggest that at least 1000 taxa of indigenous animals, plants and fungi are now threatened with extinction in New Zealand (Anon, 1997). This list is likely to grow as threatening processes continue and as more information is gathered. It is clear that there will never be sufficient time or resources to manage each taxon individually. Reflecting the potential efficiencies in employing a more integrated approach, recent species recovery plans have focused on recovering suites of species rather than single species (e.g. weta, Sherley, 1998; coastal cresses, Norton and de Lange, 1999).

6. Challenges in restoring mainland ecosystems

While there are strong reasons for taking an ecosystem-focused approach to conservation management, there are also some pragmatic reasons why this approach presents difficulties for management. Ecosystems are difficult to define and place boundaries around, while ecological processes are complex and dynamic and often occur at spatial and temporal scales far outside those normally dealt with in conservation management (Brussard et al., 1998). Management for one perceived problem can have unexpected and undesirable results in a wider ecological context. An observation that stoats 'switched' from eating predominantly rats to other prey items, including birds, following intensive rat control in a central North Island forest (Murphy and Bradfield, 1992) is an example of the "surprise factor" which can be expected in ecosystem-focused projects in particular. The abiotic components of ecosystems, such as nutrient and energy flows, are also very difficult to define and manage. A lack of understanding of ecosystem processes, and how ecosystems respond to management has also been identified as a fundamental constraint to progressing towards ecosystem restoration goals (Saunders, 1999). In this light it could be argued that, at best, ecosystem-focused management programmes may only ever be "multi species/multi threat"-focused rather than truly ecosystem-focused.

Clearly further effort is needed to refine strategic policies and to identify ecosystems where restoration and protection activities may be undertaken. There is also a need to identify ecosystem processes at which management may be most effectively directed. While management of ecosystem processes is implied in most discussions of ecosystem management, their definition and management is not necessarily straightforward. Key processes in New Zealand ecosystems, especially forested ones, are likely to include successional changes following natural disturbance, nutrient cycling, and the maintenance of dispersal mutualisms. These processes have been substantially affected by invasive mammals and resultant changes in them have the potential to lead to substantial long-term changes in ecosystem composition and structure (Rogers and Leathwick, 1997; Clout and Hay, 1989; Beggs, 2001). An ecosystem-focused approach to conservation management must be based on a good understanding of the way in which these and other processes have been affected. Management programmes need to be developed which deal with these threats in a manner that enables key processes to be restored. To date only the Rotoiti project of the six Department of Conservation Mainland Islands has a process-focused goal statement; 'Restoration of a beech forest community with emphasis on the honeydew cycle' (Butler, 1998). In addition to recording changes in wasp numbers, honeydew levels were also measured in order

to gauge progress in relation to this process-focused goal. Consideration is currently being given at several other projects to interpret changes in relation to processes such as nutrient cycling and parasitism.

Reducing the costs of Mainland Islands also constitutes a major challenge. Because intensive, on-going management regimes are required in order to control multiple pests, Mainland Island projects are relatively expensive. The Department of Conservation allocated $NZ1.8 million in the 1998/1999 financial year to its six Mainland Island projects. This sum equates to approximately $165 per ha managed. In contrast, extensive and infrequent pest control regimes are normally much cheaper. For example, NZ$175,000 was allocated for feral goat and possum control over 30,000 ha of Paparoa National Park for the same time period (c. $NZ6 per ha; Terry Farrell, pers. comm.). What is not clear, however, is the nature and extent of conservation outcomes from less intensive pest control operations. It will be important to compare the ecological benefits as well as the financial costs of different management regimes if sound resource allocation decisions are to be made.

Apart from strategic and conceptual issues there are significant challenges involved in developing effective and sustainable pest management regimes at Mainland Islands. Although suites of pests have been controlled to very low levels at some sites, there is continual re-invasion pressure as individual pests endeavour to recolonise management areas. Minimising the movement of critical pests across management area boundaries constitutes one of the most pressing practical challenges facing restoration practitioners at these sites. The defensibility of Mainland Island sites against pest invasions is likely to be influenced by several factors including the range of pests present, proximity to other pest populations, and topography. Natural boundaries such as rivers, lakes and ridges may limit the movements of some pests, but in most cases such barriers cannot be relied on to provide adequate protection from immigrating pests. The shape of the management area may be a key consideration (Fig. 3). If true islands (Fig. 3A) are most defensible against invasions by terrestrial pests because they are surrounded by water, it is not unreasonable to assume that mainland peninsulas (Fig. 3B), which are largely surrounded by water, may be more defensible than other mainland sites. Several projects involving intensive pest control are already underway on peninsulas. A combination of fences and intensive trapping and poisoning is used at most of these projects to control the re-invasion of targeted pests at the base of the peninsulas.

Vegetation remnants in essentially modified landscapes may be seen as 'habitat islands' in that their boundaries are relatively well defined (Fig. 3C). Habitat islands are probably less defensible than peninsulas in that terrestrial pests can enter relatively easily from a number of points around the boundary. There are, however, some advantages in defending habitat islands in that pest control can be effectively focused at or near habitat margins, allowing for the creation of buffer zones. Small forest remnants on gentle terrain in an essentially pastoral landscape, for example, may be easier to defend than an area of forest within a larger forest complex. While it could be argued that there is little to be gained in intensively managing small habitat fragments, much of New Zealand's remaining indigenous biodiversity, at least in the lowlands, occurs in such places (Anon, 1994). The development of restoration management regimes at habitat islands which may be applied in small habitat remnants elsewhere is likely to result in important conservation benefits in a regional and national context.

Habitat complexes (Fig. 3D), where a core management area is located within a larger complex of similar habitat, are probably the least defensible. Some projects within habitat complexes have no obvious topographical features marking management area boundaries, and pest invasions are difficult to predict and detect. Habitat complexes, however, present opportunities to expand operational areas as management regimes are refined. The core management area of the Northern Te Urewera project, for example, has already expanded from about 500 ha to over 2000 ha after 5 years of management. Similarly, determining the attributes of different types of boundaries, and the shape of conservation management areas in relation to their defensibility against invasions by critical pests is also likely to have important strategic implications.

7. Where to from here?

Mainland Island projects have already been important in showing that intensive control of multiple pests is achievable at mainland sites. There are also indications that as a result of management regimes in place populations of native species have been enhanced and ecological processes re-vitalised. Most importantly, these projects have demonstrated that further declines in biodiversity are not necessarily inevitable on the mainland. It is also clear, however, that there are significant challenges which must be addressed if mainland ecosystems are to be effectively and sustainably managed in the future.

In addition to achieving conservation goals at particular sites there is a need to develop our ability to manage ecosystems so that principles and techniques may be adapted and applied more widely. Mainland Islands have considerable potential to act as strategic projects where our capacity to effectively conserve indigenous biodiversity on the New Zealand mainland, in particular, may be developed.

Perhaps their greatest contribution will be in enhancing our understanding of how ecosystems function, and how they respond to different management regimes. Any advance in knowledge which resulted in an improved ability to predict conservation outcomes would serve to reduce the risks and costs of conservation management programmes more generally. Risks associated with a lack of understanding are particularly high in ecosystem-focused restoration projects at mainland sites which represent an increase in complexity from conservation projects on small, remote offshore islands. The scale and intensity of management at Mainland Island projects means that a more systematic approach is required to objectively evaluate changes.

Mainland Islands are providing an increasing focus for conservation research in New Zealand. In many cases project staff are working cooperatively with researchers in designing and implementing data sampling and interpretation programmes. A culture of science-based management is emerging. Provided such cooperative approaches continue to be encouraged there is potential for Mainland Islands to become key sites for the promotion of science-based management activities as well as for research. The identification of strategic research themes for ecosystem restoration which can be supported by conservation management agencies, research providers and funding bodies remains an important challenge.

This cultural change towards science-based management should be seen in the context of a residual perception held by many operational staff that research, and even research with direct application to conservation management, is a luxury. Urgency remains a key element in many New Zealand conservation projects, as it does elsewhere (Soulé, 1985). At Mainland Islands, where ecosystem restoration rather than species recovery goals alone have been declared, there is an opportunity to balance the need to undertake management before further biodiversity losses occur with the need to better-understand key issues so that greater conservation benefits may be sustained. Employing an adaptive management approach may allow for a balance to be reached between the need to actively intervene to prevent further declines, and a need to enhance our understanding of ecosystem processes. Furthermore, because field staff are directly involved in research activities there is a greater likelihood that the research will remain appropriately focused, and that results will be quickly applied.

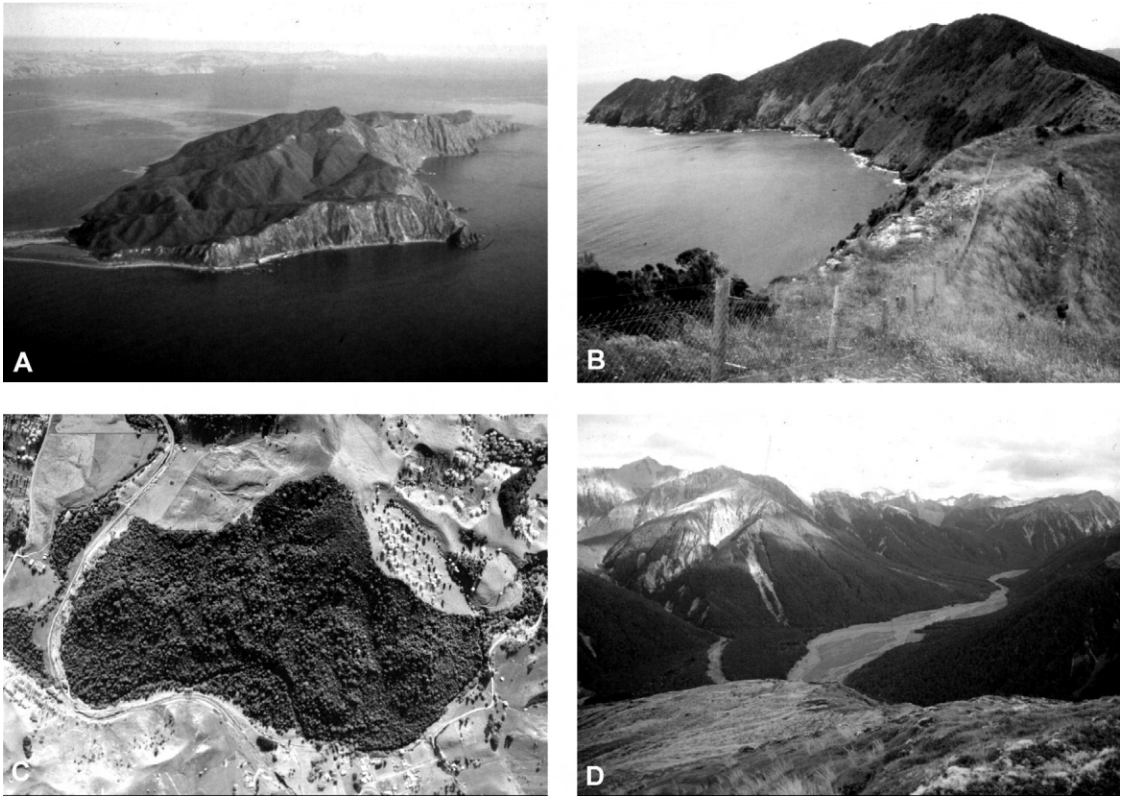

Fig. 3. The shape of conservation sites where terrestrial pests are being intensively managed may influence their defensibility against re-invasion. (A) Kapiti Island, off the Wellington coast, is separated from mainland terrestrial pest populations by a 4 km stretch of sea. (B) Cape Lambert in the outer Marlborough Sounds, northern South Island, is a peninsula with sea on three sides and a possum-proof fence at its base. (C) The Paengaroa reserve in the central North Island is a habitat island — a small forest remnant surrounded by developed farmland. (D) The upper Hurunui River catchment management area in Canterbury extends from the valley floor to the dividing ridges and has no natural boundaries. Photograph C by Terralink, others by the Department of Conservation.

Their ecosystem focus means that Mainland Islands could also be sites where conservation management objectives may be refined. If ecosystem management goals are to be achieved a shift in focus will be required from species alone, to managing interactions between species, and to ecological processes. The preparation of multi-species recovery plans and pest management strategies indicate that such a shift is already taking place in New Zealand. Eventually some conservation activities may focus on entire catchments and even landscapes where the objective is to manage interactions between ecosystems. From this perspective Mainland Islands may be seen as part of an evolving spectrum of conservation management activities which extends from managing populations and species, through community and ecosystem-focused projects, one day extending to landscape and even regional scales. Realistic movement towards ecosystem and landscape management goals is most likely to result in representative examples of New Zealand's remaining indigenous biodiversity being conserved. The implementation of more holistic conservation management programmes will continue to depend to some extent, however, on lessons learned from species-focused projects. Species and ecosystem-focused projects should be seen as complimentary, rather than mutually exclusive.

Because the results of management as well as conservation outcomes are monitored Mainland Island projects also offer opportunities to assess the costs and risks associated with sustained pest management. There is potential for costs to be reduced significantly through better timing and targeting of pest control operations, and to improve the effectiveness and efficiency of management through the development of improved techniques. Mainland Islands may also serve as training grounds where conservation workers, stakeholders and other interested people may receive training in order to reduce operational costs and risks at other projects.

Public interest and involvement in conservation management projects appears to be growing. In addition to increases in visitor numbers and requests for information at the Department of Conservation projects, there is evidence of strong public support for community initiatives such as the Karori Wildlife Sanctuary in Wellington city. Because they are generally more accessible to people than most offshore islands, Mainland Islands offer important opportunities for people to visit and participate in conservation management (Norton, 1993). In view of the costs of on-going intensive management programmes, the participation and "ownership" by stakeholder groups in conservation activities may be a key to maintaining many conservation projects for meaningful ecological periods. It can be anticipated that a few "flagship" projects, if strategically located and managed primarily for education and advocacy objectives, may result in additional community-led conservation projects being initiated.

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