Alien plant and animal control and aspects of ecological restoration in a small 'mainland island': Wenderholm Regional Park, New Zealand.

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Abstract Since 1965, ecosystem-focused ecological restoration has been undertaken in a small (60 ha) mainland island at Wenderholm Regional Park (134 ha), which lies on a peninsula on the east coast north of Auckland. A 60 ha coastal forest has been fenced to exclude livestock and retired pastureland has been reforested. Brushtail possums *(Trichosurus vulpecula)* and rats *(Rattus rattus* and *R. norvegicus)* have been reduced to very low densities and feral cats *(Felis catus)* and mustelids *(Mustela* spp.) have been controlled. Forest health and New Zealand pigeon *(Hemiphaga novaeseelandiae)* breeding success have improved and large invertebrates are now more abundant. By early 1999, Wenderholm was deemed suitable for experimental releases of birds, which had become locally extinct on the northern North Island mainland. In the first release, 21 North Island robins *(Petroica australis)* were translocated from nearby Tiritiri Matangi Island in March 1999. During the past two years, survival of site-attached robins has been high and they have fledged 46 young, thus the robins have been useful indicators of successful control of some invasive alien mammals. However, despite high productivity, recruitment has been insufficient to compensate for adult losses. Poor recruitment may be due to high rates of juvenile dispersal from the mainland island because of its small size. Linkages with nearby forest areas allow robins to disperse easily, and the ultimate success of the translocation is therefore uncertain. The dispersal distances of species intended for release need to be taken into account in the planning of any new mainland island.

Keywords Revegetation; New Zealand robin; translocation.

INTRODUCTION

Most unmanaged forest reserves on the New Zealand mainland harbour many of the invasive alien mammals introduced by Europeans (King 1990), as well as an increasing number of invasive alien plants (Esler 1987). These introduced species threaten much of New Zealand's remaining biodiversity (King 1984; Esler 1988; Wright and Cameron 1990; Saunders and Norton 2001). Conservation managers in New Zealand have achieved considerable success in removing a range of exotic mammals from offshore islands (Veitch and Bell 1990). During the past decade, the experience gained in removal of invasive species from islands has been applied successfully at some mainland sites (Saunders 1990, Innes *et al*. 1995, 1999, Saunders and Norton 2001). Mainland sites provide opportunities to restore communities which do not occur on islands, or to restore very large areas (Saunders and Norton 2001).

Intensive control of alien plants and mammals has been undertaken at Wenderholm Regional Park (hereafter referred to as Wenderholm, Fig. 1) since 1992, thus it is one of New Zealand's longer running so-called 'mainland islands' (see Saunders 1990, Saunders and Norton 2001). Invasive alien mammals which have occurred at Wenderholm include brushtail possums *(Trichosurus vulpecula)*, ship *(Rattus rattus)* and Norway *(R. norvegicus)* rats, house mice *(Mus musculus)*, rabbits *(Oryctolagus cuniculus)*, hedgehogs *(Erinaceus europaeus)*, feral cats *(Felis catus)*, stoats *(Mustela erminea)*, ferrets *(M. furo)*, weasels *(M. nivalis)* and red deer *(Cervus elaphus)*. Invasive alien plants, which threaten the native forest, include climbing asparagus *(Asparagus scandens)*, kahili ginger *(Hedychium gardnerianum)*, cotoneaster *(Cotoneaster glaucophyllus)*, tree privet *(Ligustrum lucidum)*, woolly nightshade *(Solanum mauritianum)*, periwinkle *(Vinca major)* and kikuyu grass *(Pennisetum clandestinum)*.

When Wenderholm became a park in 1965, a 60 ha coastal forest remnant on a headland was fenced to exclude livestock (Auckland Regional Council 1995). Intensive pest control, especially of possums, did not begin until 1982, and since 1990, invasive alien plants have been controlled.

A study of New Zealand pigeons *(Hemiphaga novaeseelandiae)* which began in 1988 (Clout *et al.* 1995a) showed low breeding success as a result of nest predation, probably mainly by ship rats. As a result, annual rat poisoning began in 1992. Rat and possum control was followed by significantly higher pigeon breeding success (Clout *et al.* 1995b, James and Clout 1995), improved forest health (Dijkgraaf 1997), and an increase in the abundance and diversity of some invertebrates (Craddock 1997). Wenderholm was seen as an ideal site for animal pest control, because being a peninsula, and partly separated from

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surrounding land by a state highway, reinvasion by some mammalian pests is slower.

Since 1995, some pastureland has been planted with early successional species such as manuka *(Leptospermum scoparium)*, kanuka *(Kunzea ericoides)*, karamu *(Coprosma macrocarpa)*, flax *(Phormium tenax)*, and cabbage trees *(Cordyline australis)*. The objectives of this planting are to enlarge the existing forest patch, to provide linkages with surrounding forest remnants, to restore some former wetlands, and to suppress invasive alien plants.

As a result of improved forest health and successful rodent and possum control, Wenderholm was chosen for an experimental release of North Island robins *(Petroica australis longipes)*(Lovegrove 1998). Robins had been locally extinct for at least a century (Oliver 1955; Heather and Robertson 1997). Robins were considered suitable because (see also Armstrong 2000): (1) They have persisted on the mainland despite introduced mammalian predators, (2) although they may coexist with introduced predators, robins are useful indicators of the numbers of some predators (e.g. rats) (Brown 1997; Etheridge and Powlesland 2001), (3) they have broad niche requirements, surviving in shrub lands, forest, and exotic forests, (4) they are relatively sedentary, thus more likely to remain close to the release site (Flack 1978, Lovegrove 1996), (5) they can be trained to take food, which facilitates capture, captive maintenance and post-release monitoring (Armstrong 1995), and (6) they are conspicuous and relatively unafraid of humans and thus ideal for conservation advocacy.

The major objective of the robin release is to establish a viable population, which might be harvested for future translocations. The key question is: can a small mainland island like Wenderholm support a viable population? Robins do occur in smaller habitat areas on islands free of most or all introduced predators: for example, black robins *(P. traversi)* persisted for many years in a 5 ha forest remnant on Little Mangere Island (16 ha) (Butler and Merton 1992); they occurred on Herekopare Island (29 ha) before being exterminated by cats (Fitzgerald and Veitch 1985); robins were successfully introduced to Motuara (40 ha) and Allports (16 ha) Islands (Flack 1978); and the population of 60 on Tiritiri Matangi Island occupies only 13.4 ha of mature forest habitat (Armstrong *et al*. 2000, Armstrong and Ewen in press a).

These self-sustaining populations on small islands contrast with the mainland, where populations seem now to be confined to large areas (>1000 ha) of forest (extrapolated from Bull *et al.* 1985). This distribution mimics that of the tomtit *(Petroica macrocephala)* in Northland (Ogle 1982), where tomtits now occur only in large forest remnants. These distributions presumably mainly result from the impacts on populations of habitat fragmentation and high levels of predation by introduced mammals (Flack and Lloyd 1978, Moors 1983, Atkinson 1985, Brown 1997). Thus the robin release at Wenderholm, and recent translocations to several other small to medium-sized mainland sites (e.g. Boundary Stream (700 ha) (Howard and Christensen 2000), Trounson Kauri Park (450 ha) (Miller 1997), Kakepuku (135 ha) (Hoverd 2000) and Paengaroa (100 ha) (D. P. Armstrong pers. comm.)), may provide an indicative test of how big a mainland island needs to be to support a viable robin population. The key difference between these sites, and large unmanaged forests with natural robin populations on the mainland, is that the release sites all have intensive control of invasive alien mammals. The assumption, even though small numbers of some alien predatory mammals will be present, is that the small mainland islands approximate offshore islands, which are free of these predators. Thus, like some small offshore islands, small mainland islands should be able to support viable robin populations.

In this paper, we describe the control of invasive alien animals and plants at Wenderholm, reforestation, and the release of North Island robins as part of an ecosystem-focussed ecological restoration programme.

STUDY AREA AND METHODS

Study area

Wenderholm Regional Park (134 ha, 36°33'S, 174°43'E) lies on a peninsula on the east coast about 45 km north of Auckland (Fig. 1). The park is bounded by two tidal estuaries and consists of a hilly (up to 140 m) forested headland comprising about 80 ha, a partly-forested spit of con-

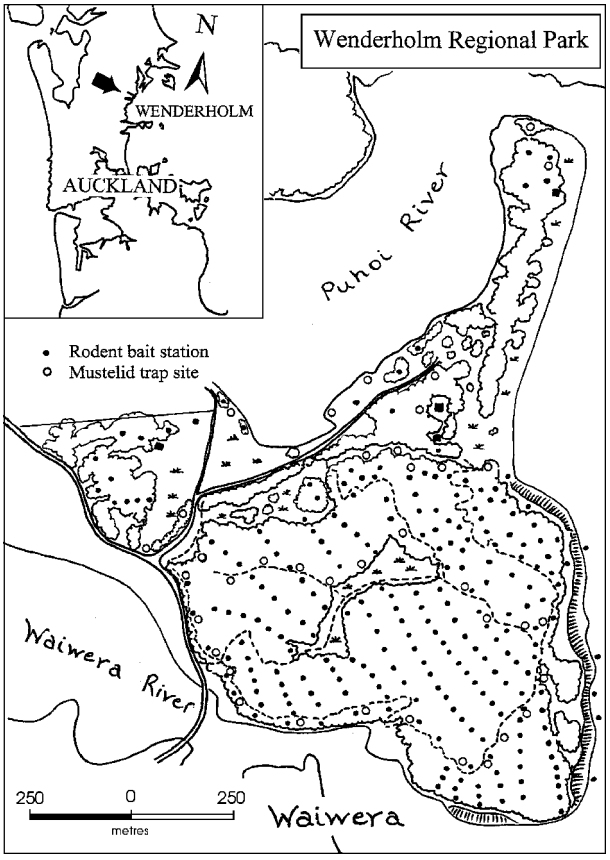

Fig. 1 Wenderholm Regional Park, showing areas of native forest and locations of rodent bait stations and mustelid trap sites.

solidated sands and open coastal pasturelands and wetlands bordering one of the estuaries. A state highway separates part of the park from the inland portion of the peninsula. Before Wenderholm became Auckland's first regional park in 1965, the land was grazed by sheep *(Ovis aries)* and cattle *(Bos taurus)*, and livestock had access to most of the coastal broadleaf forest on the headland. The taraire *(Beilschmiedia tarairi)*-dominated coastal forest on the Wenderholm headland has been identified as having significant values in a regional context (Mitchell *et al.* 1992, Auckland Regional Council 1999).

Livestock fencing and control of alien mammals

During the late 1960s, most of the headland was fenced with standard wooden post and seven-wire farm livestock fences to exclude sheep and cattle from the forest. Between 1982 and 1992, animal pest control concentrated on the control of brushtail possums by poisoning with sodium cyanide (delivered in a concentrated paste bait) and trapping (wire cage and Timms kill-traps). For a two-week period each year, the park was closed to the public to allow possum control using cyanide poison. Recently, other methods of possum control have also been used including Victor No. 1 leg-hold traps and Talon 20P anticoagulant (0.002% brodifacoum) poison. Since the forest area on the headland is quite small, monitoring of possum numbers was undertaken by means of trapping returns and visual assessment of damage to the forest, rather than residual trap catch monitoring, which is more suited to much larger areas (NPCA 2001).

The rodent poison grid (Fig. 1), established in October 1992, consisted of 217 fifty centimetre-long plastic Novacoil drainpipe bait stations placed at 50m x 100m spacings (see Innes *et al*. 1995). Bait stations reduced the risk of non-target poisoning, kept baits dry, and reduced bait wastage. We pinned bait stations to the ground with wire hoops to prevent possums moving them. We poisoned annually from spring to late summer (September to March) with anticoagulant rodenticide. To reduce the risk of selection for toxin resistance, each year we alternated between Talon 50 WB pellets, (active ingredient brodifacoum 50ppm, manufactured by ICI Crop Care, Nelson, N.Z.) and Storm Rodenticide (active ingredient 0.05 g/kg Flocoumafen, manufactured by Shell Agriculture) (Greene *et al.* unpub. data). Each bait station was loaded with six bait pellets at the start of the season and depending on take, topped up at weekly to monthly intervals. In 1999 the drainpipe bait stations were replaced with Philproof rodent bait stations, an improved design with pins to hold the baits in place. From 1999 onwards we used Pestoff Rodent Blocks (active ingredient 0.02 g/kg brodifacoum, manufactured by Animal Control Products Ltd., Wanganui, N.Z.) in these bait stations. These bait stations greatly reduce bait wastage, because rats cannot remove large quantities of bait.

In February 1999, a month before the robins were released, we installed permanent perimeter and central lines of mustelid kill traps (No. 6 Fenns) on the headland (Fig. 1). We spaced 43 double trap sets (see Sim and Saunders 1997) at approximately 100 metre intervals baited with fresh and plastic eggs. We placed the traps in a tunnel of 12 mm galvanised wire bird netting, covered with leaf litter to reduce visibility to non-target species. These traps were checked twice weekly.

We monitored rodent abundance before and after poisoning using a snap trap line consisting of between 25 and 36 stations at 50 m spacings running across the centre of the study area. Each station had two Ezeset rat traps, one baited with peanut butter and the other with cheese. The rat traps were run for three consecutive nights and indices of abundance were calculated according to the method of Nelson and Clark (1973). We also measured rodent abundance indirectly from the rate of removal of baits from the bait stations (Greene *et al*. unpub. data).

We controlled feral cats by shooting and cage trapping as necessary. Rabbits are not significant pests at Wenderholm. They were controlled by night shooting and poisoning with pindone anticoagulant baits, which were broadcast by hand in areas where rabbits were active, during the annual park closure periods.

Reforestation and control of alien plants

We studied areas of seral forest at Wenderholm to determine the proportions of the major species, so that these patterns could be copied in the plantings. We collected seed locally, and the nursery at the Auckland Regional Botanic Gardens grew the plants. Manuka and kanuka were grown in 10 cm x 10 cm peat pots, which could be conveniently stacked onto plastic bread trays, facilitating transport from the nursery to the planting sites. Other species were supplied in PB3 or PB5 bags. In early winter (May-June), the trees (aged 9-18 months) were planted at approximately one-metre spacings. Just before planting, manuka and kanuka were pruned to 0.3 m to encourage root development and reduce wind damage. Planting sites with invasive kikuyu grass were sprayed with 1% glyphosate herbicide up to a year before planting, sometimes more than once, to ensure effective control. The dead grass formed a deep mulch, which protected the young trees from wind and helped retain soil moisture. A sprinkle of slow-release fertiliser was provided for each tree. The plantings received very little aftercare apart from control of woody invasive weeds. We surveyed the park annually and mapped the sites of weed infestations. Weed control was carried out using physical and chemical methods following Veitch and MacArthur (1997).

Robin translocation

A proposal to translocate North Island robins to Wenderholm from nearby Tiritiri Matangi Island was prepared according to guidelines provided by the New Zealand Department of Conservation. The robins on Tiritiri Matangi Island were considered suitable for a translocation to the mainland, because the founding birds in that population were sourced from Mamaku on the North Is-

land mainland in 1992 (Armstrong 1995). The Department of Conservation granted permission to remove up to 30 robins (10 adult males, 10 adult females, and 10 juveniles) from Tiritiri Matangi. Capture, colour banding, captive maintenance, translocation, and monitoring methodologies followed closely those of Armstrong (1995). Monitoring included a systematic survey by up to 15 people along the grid lines each spring.

RESULTS

Livestock fencing and control of alien mammals

Since livestock was removed, the understorey has regenerated strongly. In damper areas the understorey is dominated by supplejack *(Ripogonum scandens)* and matata *(Rhabdothamnus solandri)*. On the seaward and northern slopes, kawakawa *(Macropiper excelsum)*, hangehange *(Geniostoma rupestre)*, *Coprosma rhamnoides*, and *Gahnia* spp. dominate the understorey. In many parts of the forest there has been significant regeneration of nikau *(Rhopalostylis sapida)* as a result of seed dispersal by New Zealand pigeons. Removal of livestock alone has greatly improved the forest for birds, as there is more abundant nectar and fruit in the shrub layer, as well as more foliage to harbour invertebrates.

Possums have been practically eradicated from the park as a result of intensive control since 1990 (Fig. 2). During 2000, a 500 ha buffer area inland from Wenderholm was trapped and poisoned using the methods described above, and possum numbers were reduced to below a 5% residual trap catch index (NPCA 2001; S. Hix pers. comm.).

Results from the rodent index line show that annual poisoning has reduced rat numbers to very low levels in all seasons since poisoning began (Table 1). However, in some years (e.g. 1992-1993, 1995-1996) the mouse population remained high or possibly increased. Bait-take from the bait stations followed a similar pattern in most years with 60-80% of baits taken in the first month of baiting. Thereafter bait take declined to around 15% (Green *et al*. unpub. data). There has been no evidence of rat predation at any robin nest (n=30) in the two breeding seasons to date.

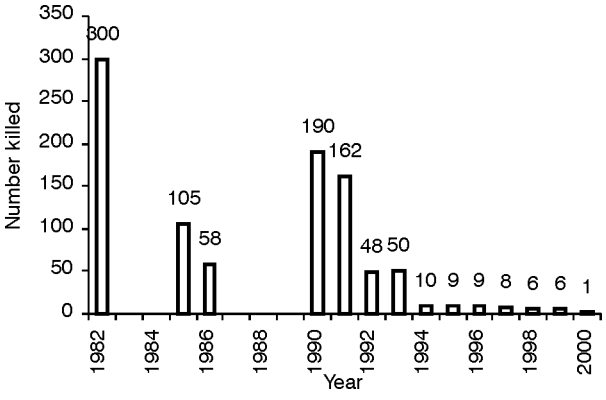

Fig. 2 Number of brushtail possums killed by poisoning and trapping at Wenderholm Regional Park from 1982 to 2000.

Table 1 Rodent indices (number trapped/100 trap nights) at Wenderholm 1990-2000 (after Greene *et al.* unpub. data). Index trap lines in 1990 and 1991 consisted of 72 traps operated for four consecutive nights, data from Clout *et al.* (1995a). Between 1992 and 2000, the index trap line consisted of 66 traps operated for three consecutive nights, and in 2001 it consisted of 50 traps operated for four consecutive nights.

Year	Rat index		Mouse index	
	Pre- [1] season	Post- [2] season	Pre- [1] season	Post- [2] season
1990	10.8		0.0	
1991	15.2		0.0	
1992-93	0.0	0.74	0.0	9.23
1993-94	0.0	0.0	1.49	1.48
1994-95	0.0	0.0	0.0	0.0
1995-96	0.45	0.0	5.84	21.47
1996-97	0.45		5.84	
1997-98	6.0	0.0	12.0	2.29
1998-99	0.52	0.0	2.06	0.0
1999-00	0.0	1.81	1.05	1.81
2000-01	3.37	1.71	5.06	10.85

[1] August, [2] April

Between February 1999 and February 2001, four ferrets, 14 stoats and nine weasels were caught in the Fenn traps. Two cats, one feral (cage-trapped) and the other tame were caught during the period.

Re-forestation and weed control

Between 1995 and 2000, about 28,500 native trees were planted over four hectares of the headland and in a small (0.5 ha) wetland. Four species formed 95% of the plantings, and were used in the following proportions: manuka 43%, kanuka 39%, karamu 7%, and kowhai 6%. The remaining 5% of plants included flax, cabbage tree, kahikatea *(Dacrycarpus dacrydioides)*, mahoe *(Melicytus ramiflorus)*, pohutukawa *(Metrosideros excelsa)*, karo *(Pittosporum crassifolium)*, whau *(Entelea arborescens)*, and puriri *(Vitex lucens)*. By the end of 2000, the oldest trees were already up to five metres tall and the plantings formed a dense shrubland along the forest edges, which has suppressed the invasive kikuyu grass. Intensive weed control, using the methods outlined by Veitch and MacArthur (1997) has greatly reduced infestations of climbing asparagus, kahili ginger, tree privet, and woolly nightshade. These species now require relatively small-scale annual maintenance programmes to keep them in check.

Robin translocation

We translocated 21 robins (nine adult and two juvenile males, seven adult and three juvenile females). Although this number was less than the original target of 30, we considered this sufficient to form the nucleus of a new population. The release site was located close to the seaward end of the reserve, and was chosen to maximise the distance the birds would need to travel to the inland boundary of the park. It was hoped that this strategy would result in most of the birds remaining inside the managed area.

Survival of translocated birds

At the start of the first breeding season, six months after release, at least 13 (61.9%) robins were still alive. These comprised six pairs inside the park, which had settled within 500 m of the release point, and a male, which settled in a contiguous forest area two kilometres outside the park. Some birds that dispersed after the release could have been missed, because apart from forest areas within about two kilometres of the park, other more-distant places were not searched immediately. By September 2000, eight of the founding birds remained, so that year one to year two survival (taken from the systematic spring surveys) was 61.5%. In July 2001, all eight founding birds were still alive.

Results of first two breeding seasons

During the 1999-2000 season, six pairs built 14 nests of which 10 (71.4%) were successful. Twenty-three young fledged (3.8 young per female). Four nests failed for various reasons, but none of these failures were due to rat predation. Four fledglings disappeared before they became independent. Some of these losses may have been due to morepork *(Ninox novaeseelandiae)* predation.

During the 2000-2001 season, five pairs built 16 nests of which 12 (75%) were successful. Twenty-three young fledged (4.6 young per female). Of the four nests that failed, three were abandoned and one was possibly preyed on (unknown predator).

Nests were built in a variety of sites, typical for robins (see Heather and Robertson 1997, Powlesland *et al*. 2000, Armstrong *et al*. 2000). At Wenderholm, nest sites ranged in height from 1-12 metres above the ground, with a mean height above the ground of 5.43 metres (n=30, SD=3.13). Three low nests sited between 1-2 metres were all successful.

Survival and recruitment of young

At least 19 of 23 young that fledged in 1999-2000 and 21 of 23 young that fledged in 2000-2001, are assumed to have become independent. By September 2000 only 4 of 23 of the 1999-2000 young (two males and two females) were known to be alive. Three had settled inside the park, where they had bonded with existing adults, and one had settled outside the park. Assuming that there are no other young birds surviving outside the reserve, recruitment was insufficient to compensate for adult mortality as the population (including birds outside the park) declined from 13 in September 1999 to 12 in September 2000.

DISCUSSION

Livestock fencing and control of alien mammals

After livestock was excluded, the forest developed a dense understorey. In addition to supplying food for birds, there are other benefits such as seclusion from predators for birds and their nests, and shelter. Control of rodents and possums at Wenderholm has been followed by: increased productivity in New Zealand pigeons (Clout *et al*. 1995a; Clout *et al*. 1995b; James and Clout 1995); greatly improved nectar, fruit, and seed production in the forest (Dijkgraaf 1997); greater abundance of invertebrates (Craddock 1997); and successful breeding in translocated robins (this study). Although rodent control using the existing 50m x 100m poison grid will continue, there is some concern about the residual effects of second-generation anticoagulants (Haydock and Eason 1997). Future rodent poisoning at Wenderholm may include changing to a more environmentally acceptable toxin. Annual possum control in the park and the surrounding buffer will continue, so it should be possible to maintain possum numbers permanently at very low levels. Until an effective method is found to remove mustelids, the permanent mustelid trap line will be maintained as a precautionary measure. We do not know whether any robin or robin nest was lost to mustelid predation at Wenderholm. Mustelids, especially stoats, although not as important as rats, are known predators of robin nests (Moors 1983), and stoats are believed to have preyed on some pigeon nests at Wenderholm (Clout *et al*. 1995b; James and Clout 1995).

Reforestation and control of alien plants

Reforestation at Wenderholm has created shrub lands, which should enhance regeneration of the coastal forest, and shade out exotic weeds such as kikuyu grass. Reforestation should be integrated with weed control, because fast-growing canopy-forming species such as kanuka can greatly reduce future weed control costs. As the plantings grow taller, litter is forming, and seedlings of mapou *(Myrsine australis)*, kawakawa, and various sedges *(Carex* spp.) are appearing. Weed control will need to continue, especially of shade-tolerant bird-dispersed species such as climbing asparagus, kahili ginger, and woolly nightshade. Climbing asparagus has the ability to transform forest floor communities by smothering native shrub layer species, and completely covering areas of leaf litter favoured by robins. The annual weed surveys are proving their worth, because incipient infestations of new or known species can be detected and removed before they become a greater problem.

Table 2 Survival of robins at three mainland island release sites in the North Island during the first full year after release. All three sites had similar management regimes to control introduced predatory mammals. Data for Boundary Stream after Howard and Christensen (2000) and Paengaroa (D. P. Armstrong pers. comm.).

Location	No. alive year one	No. alive year two	% survival (±95% confidence limits
Wenderholm	13	8	61.5 (34.5-88.5)
Boundary Stm	24	17	70.8 (51.8-89.5)
Paengaroa	19	12	63.2 (41.2-85.2)

Table 3 Productivity of robins at three mainland island release sites in the North Island during the 1999-2000 breeding season. All three sites had similar management regimes to control introduced predatory mammals. Data for Boundary Stream after Howard and Christensen (2000) and Paengaroa (D. P. Armstrong pers. comm.).

Location	Breeding pairs	Young fledged	Fledged /pair
Wenderholm	6	23	3.8
Boundary Stream	8	20	2.5
Paengaroa	11	16	1.5

Robin translocation

A small population of robins now exists at Wenderholm. Compared with a number of other sites (Armstrong *et al.* 2000; Hoverd, 2000; Howard and Christensen 2000; Powlesland *et al.* 2000), the birds have survived well and bred very successfully (Tables 2 and 3). As an indicator species, the robins show that the levels of nest predation by rats are negligible, suggesting that the rodent poisoning at Wenderholm has been at least as effective as at two other mainland islands (Tables 2 and 3). However, the first year's survival and recruitment figures at Wenderholm show that insufficient young survived to replace losses. It is possible that more young will be recruited in subsequent years, thus it is probably too early to judge whether robins will successfully establish in the park.

However, if recruitment after the 2000-2001 season is again insufficient, a key aspect for future management at Wenderholm will be to enhance the survival of the young after they leave their natal territories. At least one young bird dispersed out of the park, and there were probably others. Mortality of young outside the park is probably high, because apart from possum control, there has been no other predator management specifically targeting rats, cats, and mustelids. The creation of another managed area, where two birds have already established contiguous territories two kilometres outside the park, might allow young produced in the two sites to recruit in both directions, benefiting both populations. At present young dispersing from the park are lost into a large surrounding sink of unmanaged habitat.

Dispersal of robins out of the park will be an ongoing factor at Wenderholm, because forest corridors link the park with other forest areas further inland. If the dispersing birds survive and breed, this is beneficial, as it allows robins to colonise new areas. However, easy dispersal makes establishing a larger core population inside the mainland island at Wenderholm more difficult. While it is possible to establish viable populations on even small offshore islands, mainland islands probably need to reach a minimum effective size (determined by the dispersal distances of the various species being conserved inside them) before they can support viable populations (Ron Moorhouse pers. comm.). This emphasises the need to protect the existing population inside and outside the park either by creating another managed area to encompass the birds outside it or by extending the existing managed area to include them. The aim over the next five years should be to establish a population of at least 20-25 pairs at Wenderholm. Work on Tiritiri Matangi Island (Armstrong and Ewen in press) indicates that a population of this size, given sufficient protection, should be stable in the long term.

At Wenderholm we have assumed that provided mammalian predators are managed effectively, 60 ha of forest will be large enough to sustain a robin population. We also assume that a small protected area will be better than a large unprotected one. This is based on robins surviving in small areas on the various islands mentioned above. However, robins survive on small islands only if they are predator-free: for example they disappeared from Herekopare (29 ha) and Mangere (113 ha) Islands after cats arrived (Fitzgerald and Veitch 1985; Butler and Merton 1992) and from Big South Cape (400 ha) and Solomon (25 ha) Islands after ship rats arrived (Atkinson and Bell 1973). Robins persisted on larger islands with some introduced predators: for example Little Barrier Island (3000 ha) with feral cats and Pacific rats *(Rattus exulans)* (Turbott 1961), and on Kapiti Island (2000 ha) with possums, feral cats, Pacific rats, and Norway rats (Wilkinson and Wilkinson 1952). On the mainland, robins have persisted with the full suite of introduced mammalian predators, but only in very large forest areas. The recent (1997) local extinction of robins at Boundary Stream (700 ha) (reintroduced in 1998 after a mainland island was created), is a good example of an extinction event in a smaller mainland forest block. The current restriction of natural robin populations in the central North Island to larger forest areas parallels the distribution of the tomtit *(Petroica macrocephala)* in Northland (Ogle 1982).

Wenderholm might be a useful testing ground to show just what the lower size limit is for a viable robin population in a small mainland island. If robins fail to establish, then this will be a useful case study, because there are increasing demands from land care groups to release locally-extinct native birds into small privately-owned mainland is-

lands. To study this aspect further, it would be useful to compare translocations of robins to a number of small mainland islands such as Wenderholm with a number of larger mainland islands. However, to separate possible site differences from habitat size, an adequate sample size would be required. Since only a few robin translocations are done each year, such a study in any one year is probably logistically impossible. However, over the next few years, information on releases to large and small sites will accumulate, and this may show some interesting trends. For example during 2001, robins have already been released at several new sites including Mangaokewa (200 ha, H. Speed pers. comm), Karori Sanctuary (250 ha, R. Empson pers. comm.), Waotu (two reserves of 22 ha and 10 ha, G. Stephenson pers. comm.) and Hunua (a 600 ha mainland island within a 15,000 ha forest (T. Lovegrove unpubl. data). Plans are also afoot to release robins at Bushy Park (85 ha, D. Armstrong pers. comm.) and at Mapara (1400 ha, H. Speed pers. comm.) during 2001 and 2002.

The present population of five robin pairs at Wenderholm may be vulnerable to chance factors and therefore be too small to be sustainable; thus a second release might be necessary. However, we suggest that the population should be monitored for at least another year before any more birds are released. Robin populations have successfully established in the past from very small numbers of founders (as few as five) (Flack 1976; Butler and Merton 1992). This is supported by analysis of the establishment of robins on Tiritiri Matangi (Armstrong and Ewen 2001), which suggests that a second release at Wenderholm is probably not too urgent, and much could be learned from further management and monitoring of the existing population.

CONCLUSIONS

Ecological restoration at Wenderholm demonstrates that it is possible to control a wide range of invasive animals and plants in a small mainland island, and to keep populations of certain invasive alien species at low levels. For invasive mammals this has been achieved with an annual pulse of poisoning and trapping rather than continuous control. The local geography (a peninsula) has probably facilitated this by slowing re-invasion by some mammals. There is already evidence that a number of ecological processes have been re-vitalised as shown by improved forest health, increased numbers of invertebrates, and improved productivity of some native bird species. The outcome of an experimental release of North Island robins is still uncertain. While the translocation shows that robins can survive and breed very successfully at Wenderholm, and that they are probably useful indicators of the success of rat control, this 60 ha mainland island could be too small to support a viable population in isolation from surrounding forest areas. The limiting factor may be juvenile dispersal distances, however more information on this is needed. The dispersal distances of species intended for release need to be taken into account in the planning of any new mainland island.

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