Ecological restoration of the invertebrate fauna on Quail Island (Ōtamahua)

Mike H. Bowie

Bio-Protection & Ecology Division

PO Box 84, Lincoln University

Lincoln 7647

Canterbury

New Zealand

email: <bowie@lincoln.ac.nz>

Abstract

The Quail Island Ecological Restoration Trust in partnership with Department of Conservation and Te Hapu o Ngāti Wheke of Rāpaki was established in 1998. The main aim of the Trust was to facilitate the restoration of indigenous vegetation and fauna on Ōtamahua/Quail Island and provide refuge for locally extinct or rare and endangered species of the Banks Peninsula region. The terrestrial invertebrate fauna has been surveyed as part of an ecological restoration programme for the island. The survey results identified eleven Banks Peninsula endemic species and several rare species on Quail Island. Eradication of introduced mammalian predators including rats and hedgehogs has been successful. Ninety percent of mustelids (stoats, weasels & ferrets) are trapped en route to Quail Island. Mice are the only remaining mammalian pest on Quail Island. The relationship between these introduced pests and abundance of larger invertebrate species is discussed. The suitability of wooden discs as habitat for ground beetles and leaf-vein slugs was investigated. Wooden discs cut from logs were used as substitutes for naturally occurring logs, which are absent in areas of native vegetation on Quail Island. Tree-mounted shelters were also constructed and used to monitor weta (Orthoptera) and spider species. These two restoration and non-destructive sampling techniques have led to the translocation of three invertebrate species from populations on from Banks Peninsula: ground beetle *Megadromus guerinii* (Carabidae), Banks Peninsula tree weta *Hemideina ricta* (Anostostomatidae) and leaf-vein slug *Pseudaneitea maculata* (Anthoracophoridae) to Quail Island. The success of these restoration techniques is discussed.

Key words: carabid, conservation, ecological restoration, hedgehog, monitoring technique, mustelids, New Zealand, rodents, Quail Island, slug, weta

Introduction

Quail Island (Ōtamahua) is in Lyttelton Harbour, east of Christchurch, New Zealand, and at 81 ha, is Canterbury's largest island. The majority of the original vegetation was removed in pre-European times (Burrows et al. 1999). Quail Island is a recreational reserve managed by the Department of Conservation. The Quail Island Ecological Restoration Trust in partnership with Department of Conservation and Te Hapu o Ngāti Wheke of Rāpaki, are currently restoring the plant and animal communities (Burrows et al. 1999, Genet and Burrows 1999, Norton et al. 2003, Jackson 2006). The main ecological restoration aims of the Trust are to: revegetate one third of island in native trees, remove mammalian pests, reintroduce native flora, fauna and fungi, and undertake environmental education (Norton et al. 2003).

Quail Island connects to Moepuku Point on the mainland at low tide via mudflats making reinvasion by some mammalian predators a constant threat to native fauna including invertebrates. Large flightless invertebrates such as tree weta and ground beetles (Carabidae) are particularly vulnerable to local extinction, because their nocturnal behaviour exposes them to mammalian predators, and their poor dispersal powers hinder reestablishment of populations (Lövei and Cartellieri 2000). Quail Island's distance from the closest forest remnants and the sea around the island provides a barrier to natural colonization large flightless insects, and will require human assistance to recolonize these species on the island (Bowie et al. 2003).

Efforts to eradicate rabbits using Pindone (1997-8) have resulted in only a few remaining on the island. Cats and mustelids (stoats, ferrets, and weasels) were initially eradicated from the island at the same time; however the trapping of two mustelids over 2001-2 on the island adjacent to the tidal mudflats that link with the mainland demonstrates the constant threat of reinvasion by these vertebrate pests (Bowie et al. 2003). The island is currently classified as a recreational reserve, and is managed as a multiple-use/restoration island (Towns et al. 1990).

Many Banks Peninsula invertebrates (including Quail Island's) have become extinct or endangered due to deforestation, farming practices and the introduction of predators (including hedgehogs, rats, mice, mustelids and cats) (Wells et al. 1983). Reintroduction of locally extinct invertebrates is possible; however very few techniques have been documented (Bowie and Frampton 2004, Bowie et al. 2006). Factors affecting reintroduction success and failures are poorly understood (Scott and Carpenter 1987, Griffith et al. 1989, Armstrong et al. 1994, Sherley 1994) and the need to have good scientific design in restoration monitoring is important in understanding the success of programmes in the long-term (Gibbs 1990, Armstrong et al. 1994, Atkinson 1994).

The invertebrate fauna provides the greatest contribution to biodiversity in terrestrial communities including islands, and is a critical component of their ecology (Hutcheson et al. 1999, Grove and Stork 2000).

However, invertebrates are often the forgotten fauna (Gibbs 1990, Bowie 2002) in ecological restoration programmes, yet their role in pollination, nutrient cycling, seed dispersal, food for vertebrates and other invertebrates suggests that they should not be overlooked when restoring ecosystems. This paper addresses several aspects of invertebrate restoration on Quail Island that may be part of any ecosystem management project and suggests some innovative methods of restoring and monitoring threatened species.

Invertebrate fauna of Quail Island

An extensive terrestrial invertebrate survey by Bowie et al. (2003) found over 667 species, 199 families and 30 orders of invertebrates from Quail Island. Approximately 77% of the species identified were New Zealand endemic species. Banks Peninsula endemics included five spider species *Misgolas borealis* (Forster), *Migas saxatilis* Wilton, *Maniho ngaitahu* Forster & Wilton, *Pahora kaituna* Forster and a *Stanwellia* sp. Other Banks Peninsula endemics found on Quail Island included the tenebrionid beetle *Mimopeus granulosus* (Breme), a cockroach *Celatoblatta* sp., a ground weta *Hemiandrus* sp., a silverfish *Heterolepisma* sp. Escherich, a millipede *Icosidesmus schenkeli* Carl, a cicada *Kikihia* sp. and a snail *Charopa pseudocoma* Suter.

Native Aphid

Three populations of the native aphid *Aphis cottieri* Carver (Carver 2000), thought to be endangered and threatened with extinction in the short term (Pawson and Emberson 2000), were found on the small-leaved pohuehue *Muehlenbeckia complexa* on the island and represented one of the largest known populations at the time (Bowie et al. 2003). The presence of *A. cottieri* on Quail Island provides an excellent opportunity to conserve this species through plantings and management of *M. complexa*. Before this aphid was found on the island, *M. complexa* had been vigorously pruned where it smothered recently planted natives. However, areas where populations of the aphid were found have since been managed to retain its host, giving it an excellent chance to thrive.

Rare Flies

An agromyzid fly, *Pseudonapomyza* sp.1 collected from a Malaise trap in a mature flax and kanuka stand on Quail Island is a new record for New Zealand. A rare species of crane fly, *Neoalexandria conveniens* (Tipulidae), also collected from the Malaise trap is only the second recorded site within Canterbury. Motanau Island is the only other known location (Bowie et al. 2003).

Carabids

Seven carabid species were found on Quail Island, of which four were New Zealand endemic, but none were endemic to Banks Peninsula (Bowie et al. 2003). In contrast, pitfalls from the mainland reference site at Orton Bradley Park yielded six native carabid species including two Banks Peninsula endemics, *Megadromus guerinii* (Chaudoir) and *Holcaspis suteri* (Broun). Other carabids found here, but not on Quail Island, included *Holcaspis intermittans* (Chaudoir) and *Megadromus antarcticus* (Chaudoir) (Bowie et al. 2003).

Mammalian pests

The main pests present on Quail Island in 1998 when the Trust was established were mice, rats (ship and Norway), hedgehogs, cats and mustelids (stoats and ferrets) (Brown 1998, Brown 1999).

Hedgehogs

Hedgehog presence was obvious by the presence of numerous scats on the mown walking tracks. Elytra (hard wing cases) of beetles such as Carabidae (ground beetles), Scaraeibidae (chafers) and Tenebrionidae (darkling beetles) were very easily seen in scats. Evidence of *Mimopeus granulosus* (Breme), a rare Banks Peninsula endemic tenebrionid species, was commonly found in scats and provides conclusive evidence that hedgehogs are a real threat to this and other invertebrate species.

Between 1999 and 2002, cage trapping, spotlighting and Fenn (size 6) trapping were used to remove a total of 59 hedgehogs from the island which equated to a density of 0.69/ha. The low density of hedgehogs was likely due to the lack of open water sources. The only water source available to them was a stock dam on the western side of the island, where over one third of hedgehogs collected were within 200m of the dam. Another hotspot of hedgehog catches was near where watering of plants had taken place at the same time and it is possible that water droplets on vegetation and pooling may have attracted them.

Mustelid control strategy

Sixty-eight trap boxes were laid out in a grid formation about 120 m apart over the island in September 2001. Within seven months two mustelids were caught close to the mudflats indicating that they had arrived from the mainland via the mudflats. Since then, traps have been placed on King Billy Island and Moepuku Point, the closest mainland point to Quail Island with the aim to intercept the mustelids. To date, only five mustelids have been trapped on Quail Island, compared to seven trapped on King Billy Island and 36 on the tip of Moepuku Point. Several cats, hedgehogs and rats have also been trapped on Moepuku Point.

Rodent eradication

In August 2002 a Talon® (brodifacoum) poison operation using bait-stations was undertaken to eradicate rats and mice. A total of 555 bait stations were placed in a grid formation at 40 m intervals over the island. The stations comprised of yellow Pestoff bait stations (n = 351) and 450 mm lengths of 110 mm diameter black non-perforated plastic 'Novacoil' drain pipe (n = 204) with a covered 5 x 7 cm viewing window in the top. Ten Pestoff 20R rodent pellet baits (0.002% brodifacoum) were placed in each bait station (Kavermann et al. 2003).

A comparative analysis of bait-take and activity between the two bait station types used on Quail Island was undertaken. A significant difference (P<0.001) between the two bait station types was found, with the

Novacoil stations showing higher % bait-take and bait station activity compared to Pestoff stations (Kavermann et al. 2003).

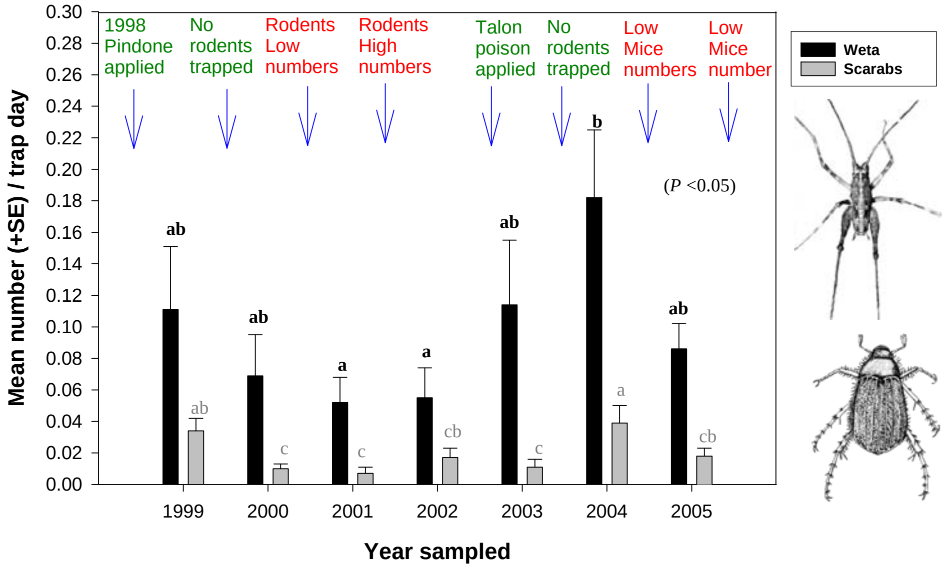
Bait disturbance

In September 2002, when bait-take had stopped, a single 20 g Talon 50 WB wax impregnated cereal briquette (0.005% brodifacoum), was placed with five Pestoff baits in each station as a precaution to possible aversion to the Pestoff baits. After two weeks without bait-take, single Talon 50 WB baits wrapped in tinfoil to minimise the effects of exotic slugs (*Deroceras* spp.), insects and decomposition due to moisture, were left in each bait station to poison any remaining rodents and allow activity to be monitored. Several weeks after mouse bait consumption ceased, unknown foraging appeared that was not characteristic of mouse foraging (Bowie and Ross 2006). Night investigations found that the small, smooth holes cut into the tin-foil and cereal bait were caused by cave and ground weta (Bowie and Ross 2006).

Response of invertebrates to rodent presence

The effect of rodents on invertebrates on Quail Island was assessed by annual invertebrate monitoring comparing the numbers of weta (*Pleioplectron simplex* and *Hemiandrus* sp.) and grass grub (Scarabaeidae) collected from 30 pitfall traps (described in Bowie et al. 2003). Traps were set over the damper southern half of the island for one month between December and January from each year from 1999 to 2005. Invertebrate trap catches were standardized by using the mean number per trap day. Rodents were monitored by rats caught in rat and Fenn traps (no. 4) and mice in Snap-E mouse traps, both baited with peanut butter. Rodent abundance was rated by the percent of traps containing rodents after a two-week period: i.e. absent (when none were trapped), low (≤ 10%), medium (>10% to 50%) and high (>50%).

Figure 1: Response of weta and scarabs numbers to the rodent populations on Quail Island (1999-2005)
(Bars are Standard Error of Mean. Differing letters above bars denote significance for that taxa)



The changes in invertebrate abundance between 1999 and 2005 shows significant fluctuations that appear to correlate (inversely) with the rodent trap catches (Figure 1). In 1998 Pindone was applied for rabbits and this reduced rodent numbers to such an extent that they were not detected until two years later in 2000. The mean number of weta and scarabs remained low until after a talon (brodifacoum) bait station operation in August 2002 successfully eradicated rats. In 2004 weta and scarab numbers had increased significantly ('pairwise' comparisons LSD5%) to the highest levels before huge mouse populations built up in 2005-6. The significant higher numbers of weta and scarabs recorded in 2004 may be due to the eradication of rats from the Talon poisoning, whereas the peak in 1999 only controlled rodents to undetectable levels.

Non-destructive invertebrate monitoring techniques for conservation management

Wooden discs

Many restoration sites like Quail Island have little or no coarse woody debris (CWD) (Grove 2002) that provide habitat for large, flightless invertebrates such as carabids and stag beetles (Bowie et al. 2003, Bowie and Frampton 2004). The lack of mature forest to provide the tree-fall logs may mean that these beetles have no safe refugia to burrow under and may be vulnerable to predators such as rodents and other mammals. The use of wooden discs (Bowie et al. 2003, Bowie and Frampton 2004) as surrogate logs has been shown to be useful for monitoring carabids (Bowie 2007, Bowie and Vink 2006). Table 1 lists 14 carabids collected from under wooden discs placed in Port Hills and Lyttelton Harbour Basin region (adapted from Bowie et al. 2003, Bowie and Frampton 2004, Bowie 2007). Five of the carabids found were Banks Peninsula endemics, one species, *Onawea pantomelas* (Johns 2007) was a rare find (Bowie 2007). *Megadromus guerinii* was chosen for translocation to Quail Island due to its abundance and its close proximity at Orton Bradley Park. Fifty-four specimens of mixed sex (~1:1 sex ratio) were released under wooden discs on Quail Island.

Table 1: Carabidae found under wooden discs in western Banks Peninsula (adapted from Bowie 2007)

Cerabilia striatula (Broun)	AH, CK, OT2, SL1, SL2
Dicrochile whitei (Csiki)	KB1, OT2
Holcaspis angustula (Chaudoir)	AH, CK, OR, KB1, SL1
Holcaspis elongella (White)	AH, CK, OR, KB1, KB2, OT1, OT2, SL1
Holcaspis intermittans (Chaudoir)	AH, CK, CP, KB2, OT1, OT2
Holcaspis suteri Broun*	AH, CK, OR, CP, KB1, KB2, OT1, OT2, SL1
Lecanomerus latimanus Bates	KB1
Mecodema oregoides (Broun)*	AH, CK, CP, KB2, OT1, SL1
Megadromus antarcticus (Chaudoir)	AH, OR, KB2, SL1
Megadromus guerinii (Chaudoir)*	OB
Metaglymma moniliferum Bates	QI
Oopterus laevicollis Bates	CK, KB1, SL1, SL2
Onawea pantomelas (Blanchard)*	CK
Selenochilus piceus (Blanchard)*	AH

Key to sites mentioned in Table 1: AH = Ahuriri Scenic Reserve, Port Hills; CP = Cass Peak, Port Hills; CK = Coopers Knob, Port Hills; KB = Kennedys Bush, Port Hills; OB = Orton Bradley Park, Lyttleton Harbour Basin; OR = Orongamai, Port Hills; OT = Otahuna, Port Hills; QI = Quail Island, Lyttleton Harbour; SL = Sugarloaf Reserve, Port Hills
* = Banks Peninsula endemic

Weta motels

Weta motels are untreated wooden refuges containing an entrance hole (14 mm dia.) to exclude mice and a dark chamber for up to three adult tree weta (Bowie and Vink 2006, Bowie et al. 2006, Bowie 2007) (see Figure 2). In 2005 weta motels were used to collect and translocate 28 Banks Peninsula tree weta (*Hemideina ricta*) in situ from eastern Banks Peninsula sites. Motels containing weta were attached to kanuka trees on Quail Island. Twelve weta and three weta were observed in the motels seven months and 18 months after the translocation respectively. Other common taxa found in the motels included spiders. Twelve spider species were found in motels in the western Banks Peninsula region (see Table 2) (Bowie et al. 2006, Bowie and Vink 2006, Bowie 2007). About six of these species were commonly found in motels, some which (e.g. Therids and *Cambridgea* spp.) commonly laid eggs that produced spiderlings (Hodge et al. 2007).

Figure 2: Weta motel used on Quail Island and Port Hills

Table 2: Araneae (spiders) found in weta motels in western Banks Peninsula (adapted from Bowie, 2007)

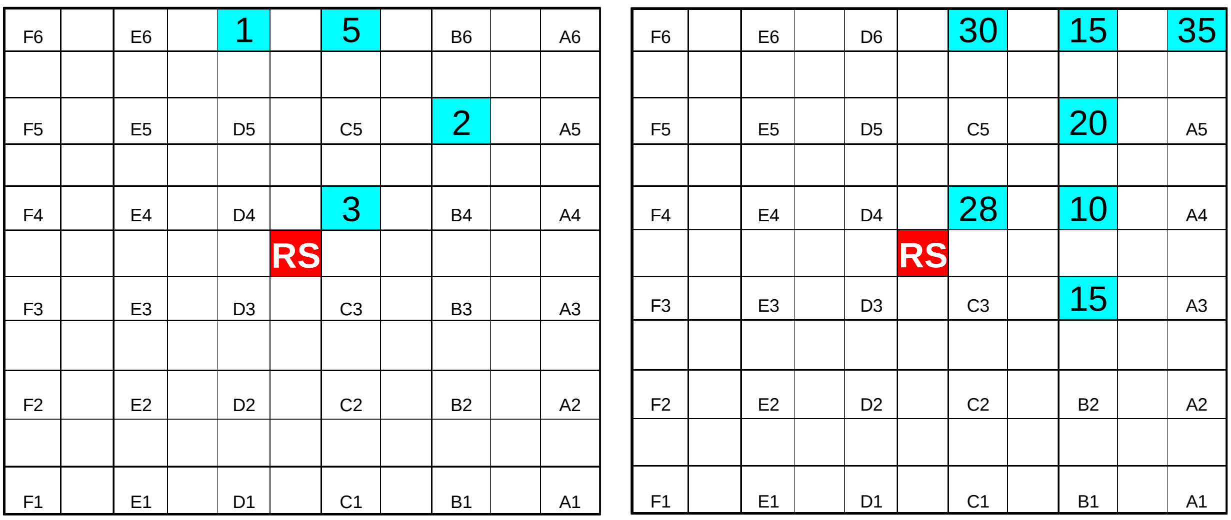
Family	**Species**
Araneidae	*Zealaranea crassa*? (Walckenaer) SL2
Agelenidae	*Neoramia janus* (Bryant) AH, CK, CP, KB1, KB2, OB
	Neoramia setosa (Bryant) AH, CK, CP, KB2, OR, OT1, OT2, SL1, SL2
Amphinectidae	*Maniho ngaitahu* Forster and Wilton* SL1
Desidae	*Nuisiana arboris* (Marples) AH, CK, KB1, KB2, OT1, OT2, SL1, SL2
Hexathelidae	*Porrhothele antipodiana* (Walckenaer) AH, CP, CK, OR, OT1
Malkaridae	Undescribed sp. SL1
Stiphidiidae	*Cambridgea peelensis* Blest and Vink CP, OT2
	Cambridgea quadromaculata Blest and Taylor H, CK, KB2, OR
Theridiidae	*Theridion zantholabio* Urq. AH, CK, CP, KB1, KB2, OR, OT1, OT2, SL1, SL2
	Achaearanea veruculata (Urq.) KB2, OT1, SL1
Zoropsidae	*Uliodon* sp. AH, KB1, OT2, SL1, SL2

Key to sites mentioned in Table 2: AH = Ahuriri Scenic Reserve, Port Hills; CP = Cass Peak, Port Hills; CK = Coopers Knob, Port Hills; KB = Kennedys Bush, Port Hills; OB = Orton Bradley Park, Lyttleton Harbour Basin; OR = Orongamai, Port Hills; OT = Otahuna, Port Hills; QI = Quail Island, Lyttleton Harbour; SL = Sugarloaf Reserve, Port Hills
* = Banks Peninsula endemic

Leaf-vein slug translocation

In 2004 leaf-vein slugs (*Pseudaneitea maculata*) were collected from Orton Bradley Park from weta motels and under wooden discs, and stored in an incubator at 12°C with leaves covered in sooty mould (*Capnodium* sp.). A total of twenty-six slugs and 32 eggs (laid while in captivity) were translocated to Quail Island and placed under wooden discs in an area recently planted (1998) with native trees. Surrounding the release discs was a 6 x 6 grid of discs with approximate 5 m spacing. Discs were sampled on the 30 April 2007 for the presence of the slugs or their eggs. In total 11 slugs and 153 slug eggs were found. There was a distinct pattern of slugs using discs north-east up the slope from their release point (Figure 3).

Figure 3: Locations of leaf-vein slugs and eggs found under a 6 x 6 grid of wooden discs. Numbers in shaded boxes represent the number of slugs (left grid) and eggs (right grid) found under the disc in that position. "RS" was the release site.



Conclusions

Invertebrate restoration and predators

An inventory of invertebrates found in areas under ecosystem management is a clear first step to restoring invertebrate fauna. Obvious differences in invertebrate fauna composition were found between the Quail Island and mainland sites (Orton Bradley Park and Port Hills) in close proximity. This is understandable given the habitat loss and vulnerability of the island to predator invasion. Many large flightless species such as carabids were absent from the island as has been found in other island studies (Bremner et al. 1984, Marris 2000). The relationship between the weta and scarabs collected in pitfall traps and relative rodent numbers on Quail Island supports this argument.

Rodents

The yellow colour of the Pestoff bait stations is unlikely to be the reason for the lower bait-take compared to the novacoil stations. A recent study by Spurr et al. (2007) found yellow bait stations performed as well as two other wooden stations and considerably better than Philproof bait stations for captive ship rats *Rattus rattus*. It is very likely that the entrance of the yellow Pestoff bait stations used on Quail Island was the main factor causing significantly less bait-take than the Novacoil stations with larger entrances.

Hedgehogs

The hedgehog eradication is thought to be the first successful eradication of hedgehogs where they were deliberately targeted. The method of spot-lighting hedgehogs on walking tracks at night was very efficient compared to trapping. It is likely that hedgehogs use the mown walking tracks as they are easier to move on than the dense exotic grass. Tracks also provide a large area to spot scats during the day and give a spatial orientation to where they reside, which is useful if trapping is an option. Moss and Sanders (2001) document the use of brodifacoum at Karori Wildlife Sanctuary to eradicate the majority of the hedgehogs; however there is a move away from anticoagulants due to the environmental effects of secondary poisoning (Bowie and Ross 2006). Given the environmental damage caused by hedgehog foraging (Jones et al. 2005) spot-lighting on tracks and trapping have been shown on Quail Island to be an effective alternative (Kavermann et al. 2003).

Non-destructive invertebrate monitoring

Wooden discs were shown to be a useful technique for providing a refuge for leaf-vein slugs and doubled as a non-destructive monitoring method slugs and their eggs. Slugs have also been found in weta motels on Quail Island and in the Port Hills (Bowie 2007). Many carabid species (see Table 1) could potentially be translocated to Quail Island using these discs to restore and monitor, once the habitat requirements have been met. The weta motels also show potential as translocation tools given the list of spiders that use them (see Table 2). Species that have produced egg sacs and spiderlings within these motels (Therids and *Cambridgea* spp.) are likely to have a greater chance of success if translocation proceeds.

These two techniques are simple to set up and provide great advocacy tools for community conservation projects. Invertebrates are not always easy to observe but the use of these techniques provides habitat refuges for children to easily observe invertebrates.

Response of invertebrates to rodent presence

Invertebrate (scarabs and weta species) abundance increased when rodent abundance was low or undetected after poison (Pindone and Talon) applications on the island. This was particularly evident when the rats were eradicated in 2002 and led to significant increases (P<0.05) in weta and scarab numbers which peaked in 2004. The subsequent increase in mouse numbers since rats were eradicated was not unexpected given evidence that rats do appear to inhibit mice populations (Sweetapple and Nugent 2005) and this has been described as a mesopredator release effect (Courchamp et al. 1999). Such a process predicts that when superpredators (e.g. rats on Quail Island) are suppressed, an explosion of mesopredators (mice) may ensue, leading to their shared prey (invertebrates in this case) being eaten to extinction over time.

Continuing invertebrate and vertebrate monitoring on Quail Island will be invaluable to understanding changes associated with ecological restoration and in identifying indicator species that will contribute to the knowledge of restoration processes.

Acknowledgements

Thanks the Community Trust, Pacific Development and Conservation Trust, and the Lincoln University Fund for Research Excellence for financing this research. Thanks the Department of Conservation (Canterbury Conservancy), members of the Quail Island Ecological Restoration Trust Advisory Committee for their support and John Watson and Anna Paltridge for their help on Quail Island. Thanks also to Colin Burrows (Canterbury University) and Colin Meurk for their continued support and encouragement.

References

Armstrong, D.P., Soderquist, T. and Southgate, R. 1994. "Designing experimental reintroductions as experiments." In *Reintroduction biology of Australian and New Zealand fauna* (ed. M. Serena), pp. 27-29. Surrey Beatty & Sons, Chipping Norton.

Atkinson, I.A.E. 1994. Guidelines to the development and monitoring of ecological restoration programmes. *Department of Conservation Technical Series No. 7.* Department of Conservation, Wellington, New Zealand.

Bowie, M. 2002. "Restoring the forgotten fauna of Quail Island/Ōtamahua." *Forest & Bird* 306: 42.

Bowie, M.H. Marris, J.W.M. Emberson, R.M. Andrew, I.G., Berry, J.A. Vink, C.J. White, E.G. Stufkins, M.A.W. Oliver, E.H.A. Early, J.W. Klimaszewski, J. Johns, P.M. Wratten , S.D. Mahlfeld, K. Brown, B. Eyles, A.C. Pawson, S.M. and Macfarlane, R.P. 2003. "A terrestrial invertebrate inventory of Quail Island (Ōtamahua): towards the restoration of the invertebrate community." *New Zealand Natural Sciences* 28: 81-109.

Bowie, M.H. and Frampton, C.M. 2004. "A practical technique for non-destructive monitoring of soil surface invertebrates for ecological restoration programmes." *Ecological Management and Restoration* 5(1): 34-42.

Bowie M, Hodge S, Banks J, Vink C. 2006. "An appraisal of simple tree-mounted shelters for non-lethal monitoring of weta (Orthoptera: Anostostomatidae and Rhaphidophoridae) in New Zealand nature reserves." *International Journal of Insect Conservation 10:* 261-268.

Bowie, M.H. and Vink, C.J. 2006. Measuring diversity and abundance of invertebrates in Ahuriri, Coopers Knob and Orongomai reserves in the Port Hills, Canterbury. *Lincoln University Wildlife Management Report No. 40.* Report prepared for the Port Hills Ranger Service, Christchurch City Council. 19pp.

Bowie, M.H. and Ross, J.G. 2006. "Identification of weta foraging on brodifacoum bait and the risk of secondary poisoning for birds on Quail Island, Canterbury, New Zealand." *New Zealand Journal of Ecology 30(2):* 219-228.

Bowie, M.H. 2007. Measuring diversity and abundance of invertebrates in ten Port Hills reserves, Canterbury. *Lincoln University Wildlife Management Report No. 42.* Report prepared for the Port Hills Ranger Service, Christchurch City Council. 19pp.

Bremner, A.G., Butcher, C.F. and Patterson, G.B. 1984. "The diversity of indigenous invertebrates on three islands in Breaksea Sound, Fiordland, in relation to the distribution of introduced mammals." *Journal of the Royal Society of New Zealand* 14: 379-386.

Brown, D. 1998. *Quail Island rabbit eradication project*. Final report, June 1998.

Brown, D. 1999. *Quail Island rabbit eradication and pest management.* Trip report 21-25 May, 1999.

Burrows, C.J. Wilson, H.D. and Meurk, C.D. 1999. "The ecological restoration of Ōtamahua/Quail Island: terrestrial flora and vegetation cover of the island." *New Zealand Natural Sciences* 24: 127-50.

Carver, M. 2000. "A new indigenous species of *Aphis* Linnaeus (Hemiptera: Aphididae) on *Muehlenbeckia* (Polygonaceae) in New Zealand." *New Zealand Entomologist* 22: 3-7.

Courchamp, F., Langlais, M. and Sugihara, G. 1999. "Cats protecting birds: modeling the mesopredator release effect." *Journal of Animal Ecology* 68: 282-292.

Genet, R. and Burrows, C. J. 1999. "The ecological restoration of Ōtamahua/Quail Island. 1. The island's physical setting and history, and planning for ecological restoration." *New Zealand Natural Sciences* 24: 113-125.

Gibbs, G.W. 1990. "The silent majority: a plea for the consideration of invertebrates in New Zealand island management." In *Ecological Restoration of New Zealand Islands* (eds D.R. Towns, C.H. Daugherty and I.A.E. Atkinson), pp. 123-127. Conservation Sciences Publication 2. New Zealand Department of Conservation.

Griffith, B., Scott, J.M., Carpenter, J.W. and Reed, C. 1989. "Translocation as a species conservations tool: status and strategy." *Science* 245: 477-480.

Grove, S.J. 2002. "Tree basal area and dead wood as surrogate indicators of saproxylic insect faunal integrity: a case study from the Australian lowland tropics." *Ecological Indicators* 1(3): 171-188.

Grove S. J. and Stork N. E. 2000. "An inordinate fondness for beetles." *Invertebrate Taxonomy* 14: 733–739.

Hodge, S., Vink, C. J., Banks, J. C. & Bowie, M. H. 2007. "The use of tree-mounted artificial shelters to investigate arboreal spider communities in New Zealand nature reserves." *Journal of Arachnology* 35: 129-136.

Hutcheson, J.A., Walsh, P. and Given, D.R. 1999. "Potential value of indicator species for the conservation and management of New Zealand terrestrial communities." *Science for Conservation 109*. Department of Conservation, Wellington, New Zealand.

Jackson, P. 2006. *Ōtamahua/Quail island – a link with the past*. Department of Conservation and the Otamahua/Quail Island Restoration Trust. 102pp.

Johns, P.M. 2007. New genera and species of rare New Zealand endemic carabids (Coleoptera: Carabidae). Unpublished report. 10pp.

Kavermann, M. Bowie, M. and Paterson, A. 2003. The eradication of mammalian predators from Quail Island, Banks Peninsula, Canterbury, New Zealand. *Lincoln University Wildlife Management Report No. 29.* Report prepared for the Department of Conservation and the Quail Island Ecological Restoration Trust.

Lövei, G.L. and Cartellieri, M. 2000. "Ground beetles (Coleoptera, Carabidae) in the forest fragments of the Manawatu, New Zealand: Collapsed assemblages?" *Journal of Insect Conservation* 4: 239-244.

Marris J. W. M. 2000. "The beetle (Coleoptera) fauna of the Antipodes Islands, with comments on the impact of mice; and an annotated checklist of the insect and arachnid fauna." *Journal of the Royal Society of New Zealand* 30: 169–195.

Norton, D.A., Leighton, A. and Phipps, H. 2003. *Ōtamahua /Quail Island Restoration Plan*. Unpublished report prepared for the Otamahua/Quail Island Ecological Restoration Trust. Conservation Research Group, Canterbury University.

Pawson, S.M. and Emberson, R.M. 2000. The conservation status of invertebrates in Canterbury. *Conservation Advisory Science Notes 320*. Department of Conservation, Wellington, New Zealand, 66pp.

Scott, J.M. and Carpenter, J.W. 1987. "Release of captive-reared or translocated endangered birds: what do we need to know?" *Auk* 104: 544-545.

Sherley, G. 1994. "Translocations of the Mahoenui Giant Weta *Deinacrida* n. sp. and *Placostylus* land snails in New Zealand: what have we learnt?" In *Reintroduction biology of Australian and New Zealand fauna* (ed. M. Serena) pp. 57-63. Surrey Beatty & Sons, Chipping Norton, U.K.

Spurr, E.B., Morriss, G.A., Turner, J., O'Connor, C.E. and Fisher, P. 2007. Bait station preferences of ship rats. *DOC Research & Development Series* 271. Science & Technical Publishing, Department of Conservation, Wellington. 21pp.

Sweetapple, P. and Nugent, G. 2005. "When the rats are away the mice really do play!" *Kararehe Kino Vertebrate Pest Research* 6: 9-10.

Towns, D.R., Atkinson, I.A.E. and Daugherty, C.H. 1990. "The potential for ecological restoration in the Mercury Islands." In *Ecological Restoration of New Zealand Islands* (eds. D.R. Towns, C.H. Daugherty and I.A.E. Atkinson) pp. 91-108. Conservation Sciences Publication 2. New Zealand Department of Conservation.

Wells, S.M., Pyle, R.M. and Collins, N.M. 1983. *The IUCN Invertebrate Red Data Book.* IUC Conservation Monitoring Centre. Gland, Switzerland. 632pp.