Ecology, management and research on Mokoia Island, Lake Rotorua, New Zealand

An abstract list and annotated bibliography

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An abstract list and annotated bibliography

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ABSTRACT

Mokoia Island is a wildlife refuge that lies within Lake Rotorua, Bay of Plenty, New Zealand. It is administered by the Department of Conservation, and is a key site for conservation management and research in New Zealand. This work lists articles relating to the ecology, conservation management and research that has occurred on Mokoia Island since 1937. To date, 87 published and 39 unpublished written works have been located, all of which are outlined here. The bibliography is an ongoing project and its authors welcome updates, additions, corrections or details of relevant articles. Mokoia Island is an example of successful island conservation restoration, with a wealth of available knowledge derived from the recent history of pest mammal eradication and species conservation research.

Keywords: Mokoia Island, ecology, management, research, bibliography

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1. Introduction

Mokoia Island (hereafter referred to as Mokoia) lies within Lake Rotorua, Bay of Plenty, New Zealand (Fig. 1). It is approximately 134 ha in size, with a central high point of 170 m above lake level (451 m above sea level). Mokoia is private land administered by the Mokoia Island Trust Board on behalf of its Maori owners; it has had wildlife refuge status since 27 March 1953. The Mokoia Island Wildlife Refuge is administered by the Department of Conservation (DOC), and is managed by the Rotorua Lakes Area Office, Bay of Plenty Conservancy. Mokoia is a key site for conservation management and research within New Zealand, due to the partnership and conservation focus of local iwi, the island's wildlife refuge status and its inherent characteristics:

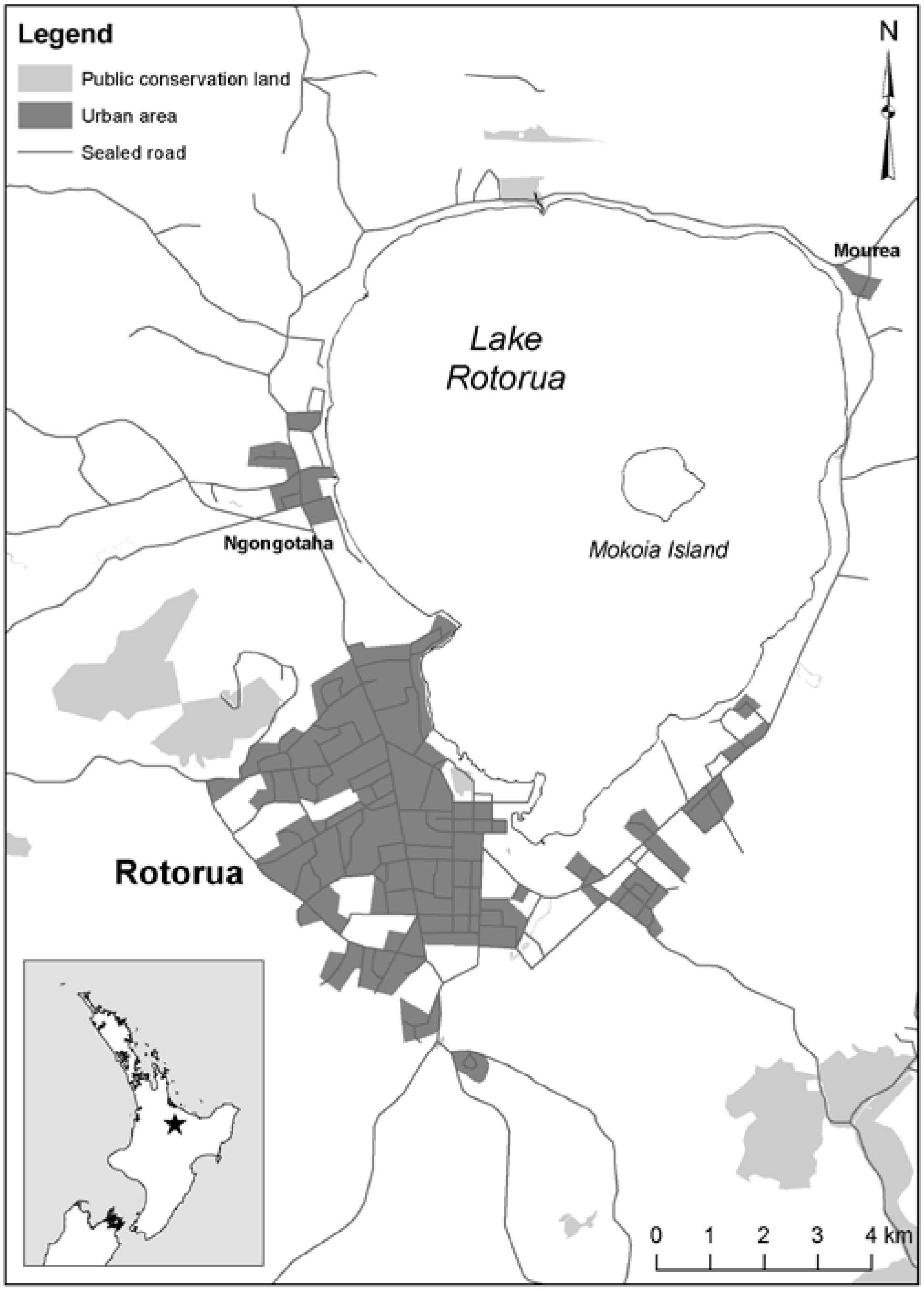
- A relatively large inland island (for New Zealand)
- Natural regeneration of the forest since the 1950s (Dumbell 1998)
- Closest distance to shore is over 2 km
- Close to a large provincial city (Rotorua)

This bibliography of 126 works focuses on the conservation management and research that has occurred on the island to date. It shows that Mokoia has been a case study of multiple natural management resource objectives over the last 50 years. There has been a broadening of conservation management horizons over this time. A chronology of events is given in Appendix 1. In the mid-1950s, the focus was on resource use and development, e.g. the 'hardening-off' of ring-necked pheasants by the former New Zealand Wildlife Service as part of the gamebird breeding programme. A multi-pest species eradication programme was initiated in the late 1980s, concurrent with threatened species research and management. A maintenance phase is currently the focus, as natural regeneration of forest canopy occurs. This maintenance phase, while reactive to biosecurity incursions such as rodents and stoats (*Mustela erminea*) reaching the island, still presents an opportunity for conservation management, particularly threatened species management.

Conservation work over the last 10 years has focused on restoration ecology, using bird translocations and their subsequent population response. Investigations have been led by Doug Armstrong and associates of Massey University, and Doug Armstrong has authored 21 research articles to date. Other key researchers of note are Isabel Castro (17 articles) and John Perrott (11 articles).

For a more extensive description, background and history of Mokoia, see both Andrews (1992) and Dumbell (1998). This bibliography is focused primarily on tracking the contemporary conservation initiatives and research that occur on Mokoia, although other pertinent information is also included. Square brackets '[ ]' within the bibliography listings indicate additional information, including referrals and comments by the authors. The keywords have been constructed for the purpose of this report.

Figure 1. Mokoia Island locality map.



1.1 CONSERVATION MANAGEMENT

1.1.1 Habitat management

Mokoia has undergone regenerative vegetation change over at least the last 50 years, following the cessation of kumara agriculture and coastal plant use in the 1950s (Andrews 1992). During the 1950s, the vegetation was early secondary, including areas of bracken (*Pteridium esculentum*) fernlands following recent fires (Beveridge & Daniel 1965). Fire was part of active management for dwelling sites, urupa, gardens and firewood (Field 1989; Andrews 1992), and at least one scrub-clearing fire is known to have burnt almost 20% (24 ha) of the island (Andrews 1992) during this time. Since then, the nature of the vegetation canopy cover has changed, so that dense, low, second-growth forest increased from approximately 70% in the 1960s (Beveridge & Daniel 1965) to approximately 90% in the late 1980s and early 1990s (Field 1989; Armstrong n.d., cited in Dumbell 1998). Domestic animals used by iwi included cattle, sheep, horses and pigs (Beveridge & Daniel 1965; Owen 1997). Twenty goats were also used to control blackberry (*Rubus fruticosus*) (Owen 1997) on the eastern flats of the island in 1985; however, they escaped into the surrounding bush (Perrot & Armstrong 2000). Within 4 years, these goats and their subsequent progeny heavily browsed the scrub and forest understorey, removing palatable plants (Owen 1997). Most of the large mammals were removed in the late 1980s, although horses remained until 1996, when the last two were removed to the mainland (Owen 1997) before a mouse eradication attempt. Mowing of the grass flats at the southeastern end of the island continues as part of the island's management.

Many authors have provided notes on the vegetation of Mokoia, describing it as predominantly secondary (e.g. Beveridge & Daniel 1965; Field 1989; Beadel 1990; Wallace 1993). The coastal vegetation influence was noted by Beveridge & Daniel (1965), and more fully outlined by Clarkson et al. (1991). Both papers noted the Maori inland cultivation and use of coastal plants, chiefly pohutukawa (*Metrosideros excelsa*), taupata (*Coprosma repens*) and whau (*Entelea arborescens*). Perrot & Armstrong (2000) also identify the deliberate introduction of native trees by Maori onto Mokoia, such as karaka (*Corynocarpus laevigatus*), totara (*Podocarpus totara*), puriri (*Vitex lucens*) and kowhai (*Sophora* spp.).

Additional key vegetation survey work comes from multiple visits to the island by members of the Rotorua Botanical Society from the early 1980s through to 2000. Ongoing updating of species lists, including threatened plant transfers (e.g. Cashmore 2000, 2001, 2004), continues. Approximately 300 vascular plants have been identified to date (refer to Appendix 2 for a full list of vascular plants). A description of the current vegetative state of the island is built from the Botanical Society's work and especially from the systematic survey by Perrott & Armstrong (2000). The island vegetation is still predominantly that of secondary succession, with dominant species being mamaku (*Cyathea medullaris*), fivefinger (*Pseudopanax arboreus*), kawakawa (*Macropiper excelsum*), mahoe (*Melicytus ramiflorus*), rangiora (*Brachyglottis repanda*) and kohuhu (*Pittosporum tenuifolium* ssp. *tenuifolium*) (Perrott & Armstrong 2000). Pohutukawa (*Metrosideros excelsa*) surrounds much of the island edge. Alder (*Alnus glutinosa*) and willow (*Salix* spp.), which were possibly brought by missionaries (Perrott & Armstrong 2000), exist on the fringes of southeastern grass flats.

The following is taken from Perrott & Armstrong (2000: 20):

> 'The vegetation is low and scrubby on the ridges, particularly near the summit, but there is a closed canopy with an open forest floor in gullies and near the lake shore. The canopy species are largest in gullies and bush edges, where mahoe, kohuhu (*Pittosporum tenuifolium*) and treefern (*Cyathea* spp.) dominate. On the south-facing slopes Mamaku (*Cyathea medullaris*) is the dominant canopy species. Amongst the patches of bracken (*Pteridium tenuifolium*) [*P. esculentum*] and blackberry on the north-facing slopes the dominant species are cabbage tree (*Cordyline australis*) and five-finger.'

1.1.2 Species management

The introduction of five weka (*Gallirallus australis*) (a pair with two chicks and another adult female) in 1952 by Bill Axbey, a ranger in the former New Zealand Wildlife Service (Axbey 1994), began modern translocation efforts of species management on Mokoia. This record accounts for one weka more than was indicated by A. Hall (pers. comm. 1964, cited in Beveridge & Daniel 1965). Axbey (1994: 24–28) noted that the 'great Gisborne weka hunt' of the early 1950s, which consisted of trapping weka around Gisborne and liberating groups of them into places where they were once present (e.g. Wairoa, Mahia, Waikaremoana, Te Whaite (Te Whaiti) and Opotiki), produced only one new population (Mokoia). An additional 12 weka were released in 1956 (A. Hall, pers. comm. 1964, cited in Beveridge & Daniel 1965). Owen (1997) noted that during the 1950s and 1960s, weka were often regarded as garden pests in Gisborne, and the former New Zealand Wildlife Service was given the responsibility of removing 'excess' birds.

Ring-necked pheasants were placed on the island in 1952, and effectively farmed there in cages for release in the wider Rotorua area as a recreational hunting resource until 1956 (Perrot & Armstrong 2000), when the programme was moved to the Ngongotaha hatchery. The birds required high levels of management, with daily feeding by rangers living on the island. Beveridge & Daniel (1965: 177) noted that 'several thousand podocarp seedlings, a few hardwood timber species (*Nothofagus menziesii*) and tawa, and kauri (*Agathis australis*)' were planted beneath the shrub canopy in the early 1960s. No kauri has been recorded since the 1960s. It is not known whether these 'hardwood timber' species were intended as a harvestable resource. Additionally, several thousand plants of at least 34 species were planted during 1968–70 (Wilcox 1990) (see Appendix 3 for a list of plantings). Wallace (1993: 2) stated that many of these early plantings (i.e. from the early 1960s to 1970) were destroyed by rats, and those that did survive have had 'little, if any influence' on the present (c. 1993) vegetation pattern. Beveridge & Daniel (1965) noted that a few pigs, the occasional cat, two tethered goats, Norway rats and one mouse (caught in a trap) existed on the island at the time of their research. Horses, cattle and sheep at this time were all confined to the eastern flats. A cattle skeleton found on the western side (in 'D' gully) showed that these animals did roam or graze periodically elsewhere (Wallace 1993).

More contemporary translocations focused solely on indigenous threatened species, for conservation reasons. In the early 1970s, two injured North Island brown kiwi (*Apteryx mantelli*) were released onto the island, although there is no evidence that they survived (Jansen 1990, cited in Owen 1997; Andrews 1992). Three further bird translocations occurred in quick succession in the early 1990s, over 3 years from 1991 to 1994. In 1991, 17 toutouwai/North Island robins (*Petroica australis longipes*), which had been sourced mainly from the Mamaku Plateau, with some from Pukaha Mount Bruce Wildlife Centre, were released onto the island (Jansen 1992, 1993; Lovegrove 1996). In 1992, 36 tieke/North Island saddlebacks (*Philesturnus carunculatus rufusater*) were reintroduced from Tiritiri Matangi Island (Armstrong & Craig 1995), producing the first inland population of saddleback since the 19th century (Armstrong et al. 2002). In 1994, 40 hihi/stitchbirds (*Notiomystis cincta*) were transferred from the one wild population on Hauturu/Little Barrier

Island (Owen 1997; Armstrong et al. 1999). While the populations of North Island robins and North Island saddlebacks have become self-sustaining, the hihi population fluctuated over the 8 years the birds existed on the island. As a result of the lack of breeding success, limited resources (e.g. labour for supplemental feeding and monitoring) and other competing conservation priorities, the hihi population (of 15 birds) was removed to Kapiti Island (14 birds) and Pukaha Mount Bruce (1 bird) (Owen 1997). As part of a broader Bay of Plenty Kiwi Conservation Programme, North Island brown kiwi (*Apteryx mantelli*) have been released onto the island since 2003. These kiwi have been sourced from Whirinaki Forest and Ohope Scenic Reserve (Owen 2003a, b).

The transfer of four threatened plants species have been attempted to date: two mistletoes (*Ileostylus micranthus* and *Tupeia antarctica*) and New Zealand watercress (*Rorippa divaricata*) in 1999; and the wooden rose (pua reinga, *Dactylanthus taylorii*) in 2000. More than 70 000 seeds of the latter were planted in 2000 (Cashmore 2000). An additional several hundred seeds of *I. micranthus* and *T. antarctica* were planted in 2004 (Cashmore 2004). To date, only *R. divaricata* has successfully taken (Cashmore 2000). A list of species planted is provided in Appendix 3.

Owing to the success of the North Island weka, North Island robin and North Island saddleback populations following translocation onto Mokoia, the island has been used as a source site for subsequent translocations of these species. Nineteen North Island robins were captured on Mokoia and transferred to Moturoa Island, Bay of Islands, Northland, in June 1999 (Owen & Asquith 2000). Forty-two North Island robins were transferred from Mokoia to Tuhua/ Mayor Island in 2003 (Heaphy 2003). Fifty-one North Island robins were transferred from Mokoia to the Waitakere Ranges (the Ark in Park project) in 2005. Eight or nine North Island weka were transferred to the Whirinaki Conservation Area in 2005 (Owen 1997). In 2006, North Island saddlebacks were transferred to Bushy Park (a restoration project run by the Royal Forest and Bird Protection Society of New Zealand), Wanganui (K. Owen, Bay of Plenty Conservancy, DOC, pers. comm. 2006). This represents a fourth-order translocation from the original natural North Island saddleback population on Hen Island. A vertebrate species list with transfer dates (where applicable) is provided in Appendix 4.

1.1.3 Pest management

A multi-pest species eradication programme began in the 1990s, in response to a request from the island's trustees to carry out a Norway rat (*Rattus norvegicus*) eradication programme (Owen 1997). This programme began with the removal of goats from the island in 1989 (Owen 1997). While the rat eradication was successful, mice (*Mus musculus*) remained on the island and became the focus of further efforts in 1996 and again in 2001 (Owen 1997), when they were finally reduced to zero density. Several possible rat sightings (Owen 1997), and other unidentified incursions (e.g. of stoats) have occurred in the subsequent years (Christensen 2005).

1.2 CONSERVATION KNOWLEDGE

The conservation knowledge of Mokoia stems from two forms of information collection: monitoring and research. The conservation monitoring on Mokoia is either outcome focused (i.e. changes in indigenous biota), or result focused (i.e. changes in pest species numbers or extent). Only three ongoing monitoring programmes are active on Mokoia—the tracking of long-term vegetation change using 20 m × 20 m vegetation plots (Wallace 1993), northern rata (*Metrosideros robusta*) and pohutukawa photopoints, and pest incursion monitoring following the Mokoia Island Pest and Quarantine Plan (Griffiths 2003) and the (Bay of Plenty Conservancy) Island Biosecurity Plan (Owen 2004). Some one-off monitoring projects have occurred as a response to specific management issues, such as poison effects on weka (Castro et al. 2000). The only other known form of monitoring (repeated information collection) covering Mokoia is remote sensing from aerial photography and satellite imagery. The use of aerial photography has been sporadic in the past, although the acquisition of aerial images looks set to become a more regular occurrence (Table 1).

Most new information relating to Mokoia stems from research. Of the 126 works listed in this bibliography, 50 are research articles that have been published (including scientific journal articles, society reports, conference proceedings and internal DOC publications), as well as four theses and seven unpublished research reports (one currently in press) (Table 2). The majority of the published works have focused on two species of birds, the hihi and the saddleback. The use of bird translocations as examples of restoration ecology has been a key focus of research on Mokoia, led primarily by Doug Armstrong of Massey University. The articles and papers are spread over many journals and publications, with 'Biological Conservation' (five articles published) and the 'New Zealand Journal of Ecology' (four articles published) publishing the most.

The number of published reports, papers and articles focusing on Mokoia Island has increased dramatically since the beginning of the 1990s. The earliest work found concerns the geology of the Rotorua–Taupo area, including a geological outline of Mokoia and some details of the geothermal features, such as Hinemoa's Bath (Grange 1937). A period of some 25 years passed

TABLE 1. AERIAL IMAGES COVERING MOKOIA ISLAND.
List courtesy of New Zealand Aerial Mapping Ltd.

NAME	DATE FLOWN	DETAILS
SN 50515c	19 Dec 2003	1:46 400 scale in colour
SN 50110c	21 Jan 2002	1:40 000 scale in colour
SN 25066	05 Jan 2001	1:40 000 scale in colour
SN 9445	19 Dec 1995	1:50 000 scale (panchromatic)
SN 5945	30 Oct 1981	1:25 000 scale (panchromatic)
SN 3190	11 Apr 1974	1:47 000 scale (panchromatic)
SN 1906	15 Oct 1966	1:25 000 scale (panchromatic)
SN 0255	05 Dec 1948	1:16 000 scale (panchromatic)

TABLE 2. RESEARCH ARTICLES AND REPORTS.

SUBJECT	PUBLISHED ARTICLES	UNPUBLISHED REPORTS	THESES
Historic	1		
Geothermal/geological	3		
Vegetation	6	1	
Invertebrates	1	2	
Saddleback	13	1	1
Hihi	15	4	3
North Island robin	4		
Morepork	1		1
Birds (other than those above)	4		
Rodents	5		

before the next body of work was produced, which only then included an ecological focus, i.e. geology and vegetation (Healy 1962), and rat ecology and poisoning (Beveridge & Daniel 1965, 1966). No research articles were found dating from the 1970s, but one was found from 1989, 23 from the 1990s, and 33 since 2000 (with one currently in press).

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2. Bibliography

Akers, K. 2004: Pest-free two years cause for celebration. *Weekender*, 19 March 2004.

[A popular magazine-type article outlining the pest-free 2+ years since mice were eradicated on the island.]

Keywords: conservation management, pest management

Alley, M.; Castro, I.; Hunter, J.E.B. 1999: Aspergillosis in hihi (*Notiomystis cincta*) on Mokoia Island. *New Zealand Veterinary Journal 47*: 88–91.

An intensive 2-year field study of 65 hihi (or stitchbirds) on Mokoia Island provided an opportunity to investigate the causes of mortality of this endangered species in a free-living environment. The birds were observed daily during the breeding season (October to March) and every 4 weeks during the remainder of the year. Any abnormalities in behaviour, voice and body weight were recorded and all sick or dead birds which could be recovered were taken to the laboratory for necropsy. Thirty-one birds died during the period of this study. Aspergillosis was found to be the cause of death in six of nine adult birds examined post-mortem. Some of the affected birds experienced subtle voice changes before becoming ill and all birds had granulomatous lesions in airsacs or lungs at necropsy. A further eight birds for which carcasses could not be found or which were autolysed showed similar clinical signs before death or disappearance. Because *Aspergillus* is an opportunist pathogen it seems likely that affected birds were immunosuppressed. This may have occurred during the breeding season which in this species is highly stressful. The presence of fungal material in bronchial exudate and the occurrence of the disease in mates, raises the possibility that aspergillosis in hihi may be contagious.

Keywords: research—wildlife disease, research—hihi, fauna, ecology, conservation management, wildlife disease, hihi, stitchbird, *Notiomystis cincta*

Alley, M.; Twentyman, C. 2003: Coccidial parasites in hihi and saddlebacks: in captive and island situations. Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North (unpublished report). 22 slides.

The rearing of populations of endangered avian species under intense conditions involves the risk that protozoal parasites which normally inhabit the gastrointestinal tract, may increase in numbers to produce lesions that are sufficiently severe to kill juvenile birds or inhibit growth rates. Both hihi (*Notiomystis cincta*) and South Island saddlebacks (*Philesturnus carunculatus carunculatus*) have been found to be susceptible to coccidial disease which has systemic phases involving extra-intestinal tissues such as liver and spleen and this may make treatment of affected birds difficult. Adult birds shed oocysts only sporadically but large numbers of oocysts are passed by infected fledglings and this may contaminate the environment and produce severe infections in other chicks. Partial control of these parasites has been achieved in young hihi by regular monitoring of oocysts in the faeces and treatment with totrazuril. This may eliminate oocyst shedding but does not appear to be effective against the extra-intestinal parasites. Naive populations of saddlebacks may also be at risk when environmental levels of parasites become sufficiently large to produce mortalities and poor growth in fledglings. A more complete understanding of the nature and life cycle of these protozoal organisms would allow better control methods to be introduced.

Keywords: research—wildlife disease, fauna, ecology, conservation management, wildlife disease, North Island saddleback, *Philesturnus carunculatus rufusater*, hihi, stitchbird, *Notiomystis cincta*

Alley, M.; Twentyman, C. 2004: Systemic protozoal disease in hihi and saddlebacks. Conference report. *New Zealand Veterinary Journal 52*: 50.

Juvenile hihi or stitchbirds (*Notiomystis cincta*) and saddlebacks (*Philesturnus carunculatus*) are particularly prone to systemic protozoal infections when kept in high density populations. Granulomatous lesions in the intestine, liver and spleen are associated with proliferating intracellular schizonts. Affected birds become anorexic and lose weight or die suddenly without clinical signs. The protozoan in hihi appears most likely to be *Atoxoplasma* spp whereas that in saddlebacks is more likely to be *Plasmodium* spp.

Keywords: research—wildlife disease, research—hihi, research—North Island saddleback, fauna, ecology, conservation management, wildlife disease, North Island saddleback, *Philesturnus carunculatus rufusater*, hihi, stitchbird, *Notiomystis cincta*

Andrews, P. 1992a: Mokoia: a brief history. Bibliophil, Rotorua. 60 p.

[This book focuses primarily on the Maori history (pre- and post-European arrival) of Mokoia. It contains 26 sections, with one titled 'Island Flora and Fauna'. In it are noted the visits by early European botanists, Ernst Dieffenbach in 1841 who 'commented on the shrubs still growing in the former mission garden, and the variety of grasses, indigenous and exotic', and William Colenso in 1842 who was searching for a rare tree.]

Keywords: history, Maori

Andrews, P. 1992b: Wildlife on Mokoia. Unpublished report, held on file at Bay of Plenty Conservancy, Department of Conservation, Rotorua (Old File RWL-025). 2 p.

[This description of the wildlife on Mokoia and the history of the management operations carried out on the island is actually a draft of the 'Island Flora and Fauna' chapter of 'Mokoia: a brief history' (Andrews 1992a).]

Keywords: history, fauna

Anon. 1989a: Goat culling on island. *The Daily Post*, 6 September 1989.

[This article outlines the planned goat eradication programme on Mokoia, which involved DOC officers and the Rotorua Deerstalkers Association.]

Keywords: conservation management

Anon. 1989b: Mokoia Island rat eradication project plan. Department of Conservation, Rotorua (unpublished report). 45 p. (including appendices).

[The following is taken from the Objectives, Summary and Rationale.]

The aim of this project is to eradicate *Rattus norvegicus* from Mokoia Island in Lake Rotorua without endangering existing conservation values or public safety. It is planned to achieve eradication through saturation poisoning with "Talon 20p" (brodifacoum) poison. Lines will have to be cut where necessary to provide access to all parts of the island. All poison baits will be laid in bird proof bait stations. These stations will be placed at intervals along the cut lines and be loaded daily with bait over a 15 week period from 22 May to 31 August. The success of the campaign will be checked daily during the May August period and during follow up trips where index and attractant baits will be used to assess the rodent population. Prior to any poisoning taking place an index line will be run for 1000 nights. This will be our baseline and will be repeated at the completion of the operation and at suitable intervals there after to check for possible reinvasion or build up in rats which have escaped the poison campaign.

This project supports corporate objective three and is a valuable exercise in working in partnership with Maori owners to achieve conservation objectives. Eradication of rats from Mokoia Island will help restore this island to a more natural state. Although the island is privately owned the Wildlife Refuge status that it holds should guide the department and owners in its future management. This island has obvious potential as a site for public appreciation of conservation. With careful guidance the owners will benefit from this by promoting and marketing a conservation area for the paying public to enjoy.

Keywords: conservation management, pest management, Norway rats, *Rattus norvegicus*

Anon. 1990a: Around the region... *The Daily Post*, 19 June 1990.

[Short article on the proposed North Island robin transfer from the Mamaku Plateau onto Mokoia.]

Keywords: conservation management

Anon. 1990b: Species to join robin on Mokoia Island. *The Daily Post*, 30 June 1990.

[Article on the proposed North Island saddleback and stitchbird transfers onto Mokoia.]

Keywords: conservation management

Anon. 1991: Wildlife for Mokoia Is. *The Daily Post*, 21 June 1991.

[Article on the proposed North Island robin transfer from the Mamaku Plateau onto Mokoia.]

Keywords: conservation management

Anon. 1992a: Award for bird project. *The Daily Post*, 14 November 1992.

[Article on the Rotorua Lakes High School sixth form biology class winning the Tearaway Conservation Shield.]

Keywords: conservation management

Anon. 1992b: North Island saddleback. *Whakatane Beacon*, 3 May 1992.

[This article on the transfer of the North Island saddleback from Tiritiri Matangi Island onto Mokoia focuses on the involvement of the sixth form biology class from Rotorua Lakes High School.]

Keywords: conservation management

Anon. 1992c: Saddlebacks' island transfer goes well. *The Daily Post*, 13 April 1992.

[This article on transfer of the North Island saddleback from Tiritiri Matangi Island onto Mokoia focuses on the involvement of the sixth form biology class from Rotorua Lakes High School.]

Keywords: conservation management

Anon. 1993a: Birds fly south. *WWF New Zealand*. *Summer 1994*: 3.

[This article outlines the joint WWF-NZ-DOC project transferring 40 stitchbirds from Hauturu/Little Barrier Island to Mokoia. It notes sponsorship by the Todd Foundation, and the involvement of Dr Doug Armstrong of Massey University and the Rotorua Lakes High School.]

Keywords: conservation management

Anon. 1993b: Students help monitoring. *The Daily Post*, 4 November 1993.

[This article presents the involvement of the Western Heights High School's conservation club in monitoring weka numbers on Mokoia Island.]

Keywords: conservation management

Anon. 1993c: Tour to look at rare birds. *Weekender*, 23 April 1993.

[This article presents the involvement of the conservation club of Western Heights High School in monitoring weka numbers on Mokoia Island.]

Keywords: conservation management

Anon. 1995a: 'Friendly' toilets causing a stink on Mokoia Island. *The Daily Post*, 22 November 1995.

[Report on the use of three Bio Loos, or composting toilets, on Mokoia. These environmentally friendly and efficient toilets were criticised by local historian Don Stafford as visually unappealing and poorly situated.]

Keywords: conservation management, visitor use

Anon. 1995b: Little spotted kiwis coming to the Bay. *Whakatane Beacon*, Whakatane, 3 May 1995.

[Article on plans to bring 15 little spotted kiwi to Mokoia. This translocation programme did not proceed (K. Owen, DOC, pers. comm. 2006).]

Keywords: fauna, translocations, little spotted kiwi, *Apteryx oweni*

Anon. 1995c: Mice on minds of Rotorua students. *The Daily Post*, 17 July 1995.

[This article outlines a fact-finding trip to Mana Island, Wellington, by 12 senior biology students and two teachers from Rotorua Lakes High School. The group was accompanied by four DOC staff to learn about mouse eradication techniques to be used on Mokoia Island.]

Keywords: conservation management

Anon. 1995d: Stitchbirds doing well. *The Daily Post*, 3 March 1995.

[This article describes the successful first breeding season of stitchbirds on Mokoia Island. It notes that the initial banding caused injuries to the birds' legs, so bands were subsequently replaced. It mentions that trustees of the Todd Foundation contributed $34,000 to the transfer project.]

Keywords: conservation management

Anon. 1995e: Taking Mokoia Island under his wing. *The Daily Post*, 28 September 1995.

[This article notes the work of Paul Jansen, former DOC Species Protection Officer on Mokoia. He was involved in starting the rat eradication programme in 1989, and further restoration work with transfers of North Island robin, saddleback, stitchbird and the little spotted kiwi. The involvement of other DOC staff, the Mokoia Island owners and management committee, Rotorua Lakes and Western Heights High Schools is mentioned.]

Keywords: conservation management, fauna

Anon. 2003a: Pet cat sparks scare at wildlife sanctuary. *The New Zealand Herald*, 26 May 2003.

[Brief report on a pet cat taken to Mokoia hidden within the owner's (aged about six) clothing.]

Keywords: conservation management, island biosecurity

Anon. 2003b: Small birds lead big steps in restoration of ecology. *The Daily Post*, 28 May 2003.

[This is a brief report on the successful translocation of 42 North Island robins from Mokoia to Tuhua/Mayor Island. It contains a large photograph of a robin being banded.]

Keywords: conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Anon. 2004: Robins bouncing back on Mayor Island. *The New Zealand Herald*, 5 May 2004.

[This is a brief report on the successful translocation and first breeding season of North Island robins on Tuhua/Mayor Island, with 55 unbanded chicks seen over the summer. Forty-two robins were transferred from Mokoia during May 2003—BRC.]

Keywords: conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Anon. 2005a: (Draft) Mokoia Island weed management and vegetation restoration plan. Wildlands Consultants Ltd, Rotorua (unpublished report). 19 p.

[See Anon. (2005) below.]

Keywords: conservation management, ecological restoration, weed management, pest plants, plantings

Anon. 2005b: Ecological restoration and weed management at three sites on Mokoia Island. Wildland Consultants Ltd. Contract report for JONZ Corporation Ltd, Rotorua (unpublished report). 31 p.

Wildland Consultants were commissioned by the Mokoia Island Trust Board and Jonz Corporation Ltd. to review existing weed management strategies and ecological restoration methods for Mokoia Island. Several field surveys of exotic and indigenous vegetation on the island have been conducted over the past 15 years. From these surveys we identified three key restoration sites (the operational and visitor facilities, and two wetlands), and indigenous plant species suitable for restorative vegetation. Species have been selected primarily to protect existing vegetation and habitats against the encroachment and reinvasion of exotic weed plant species.

Keywords: conservation management, ecological restoration, weed management, pest plants, plantings

Anon. 2005c: Technology advances bird-song research. Massey University, Palmerston North. Unpublished report held on file at Bay of Plenty Conservancy, Rotorua (NHE-03-52). 1 p.

[Outlines research investigating avian cultural change of North Island saddlebacks, grey warblers and bellbirds as analysed by mathematical modelling of bird song. Notes that the research group will soon visit Mokoia.]

Keywords: research—bird song, fauna, ecology, bird song, North Island saddleback, *Philesturnus carunculatus rufusater*, grey warbler, *Gerygone igata*, bellbird, *Anthornis melanura*

Armstrong, D.P. 2000: Re-introductions of New Zealand robins: a key component of ecological restoration. *Re-introduction News 19*: 44–47.

[This article outlines the reintroduction of the North Island robin onto Mokoia (1987–91) and presents the rationale for the reintroduction: natural (vegetation) regeneration is taking place and Norway rats have been eradicated from the island. The author notes that robins have thrived on the island and that the population 'was recently harvested for a second re-introduction to Moturoa following eradication of predators there'—BRC.]

Keywords: research—North Island robin, fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*, pest management, Norway rats, *Rattus norvegicus*

Armstrong, D.P.; Castro, I.; Alley, J.C.; Feenstra, B.; Perrott, J.K. 1999: Mortality and behaviour of hihi, an endangered New Zealand honeyeater, in the establishment phase following translocation. *Biological Conservation 89*: 329–339.

We analysed mortality and behaviour of hihi, an endangered New Zealand honeyeater, in the first three months after translocation to 135 ha Mokoia island. Our aims were to assess: (1) whether mortality and behaviour were affected by the translocation process or post-release management, and (2) whether the fate of birds during this establishment phase affected the viability of the population. Forty hihi were translocated from the wild population on Little Barrier Island, released immediately in three different locations, and provided with sugar water feeders. Many of the birds suffered leg injuries due to the bands initially used, and up to 7 birds may have died from these injuries. Nevertheless, the mortality rate over the first three months was similar to the average rate over the first 3 years. Therefore, except for the bands used, there was no evidence of post-release mortality associated with translocation stress. Most hihi discovered the feeders quickly. However, feeder use varied greatly among birds and there was no evidence that access to feeders reduced mortality. Access to feeders also did not affect overall time spent foraging. However, birds using feeders allocated most of their foraging effort to invertebrate feeding, whereas birds not using feeders foraged mostly on flowers and fruits. Hihi dispersed quickly after release, and moved all over the island. Transmitters increased re-sighting rates over the first 3 weeks, but intensive observation during that period provided no useful information relevant to subsequent survival and reproduction. There was a slight tendency for birds to settle closer to their release sites than expected by chance, but there was no tendency for birds released together to form breeding pairs. We conclude that the viability of this population was not affected by any problems in the establishment phase. However, the population has had a consistently high mortality rate over the first 3 years, and its long-term viability appears poor. Our subsequent research is, therefore, addressing the factors that might be limiting the population in the long term.

Keywords: research—wildlife disease, research—hihi, fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Castro, I.; Griffiths, R. 2007: Hihi on Mokoia Island: a case study in adaptive management of a reintroduced population. *Journal of Applied Ecology 44*: 953–962.

Adaptive management involves deliberate manipulation of management actions in order to improve quantitative models used to make management decisions. We present results of an eight-year adaptive management program involving a reintroduced population of hihi (*Notiomystis cintca* [*sic*]), an endangered nectarivorous forest bird endemic to New Zealand. Previous failed reintroductions had led to the suggestion that insufficient food was available on the regenerating islands available for reintroduction and therefore that supplementary feeding was needed. When hihi were reintroduced to Mokoia Island in 1994, we began a series of manipulations designed to assess the effects of availability, distribution and quality or supplementary food provided and to assess the effect of controlling nest mites. Management protocols were decided annually in consultation with the hihi recovery group, the Department of Conservation, and the Maori owners of the island. Candidate models for factors affecting survival and reproduction were compared based on AIC (Akaike's Information Criterion), and the selected models combined into a population model used to project distributions of outcomes under potential management scenarios. These distributions incorporated uncertainty associated with model selection, parameter estimation and demographic stochasticity. The results showed that some actions (provision of sugar-water during breeding season, mite control) were essential for the population to have any chance of persisting, but that persistence was extremely uncertain under any management scenario. The population growth rate was constrained by a low adult survival rate that was unaffected by supplementary feeding, and research suggested this low survival was due to a problem (high density of *Aspergillus fumigatus* spores on the island) that could not be remedied through management. The Department of Conservation therefore decided to relocate the remaining birds from Mokoia after eight years, but the results from Mokoia have been used to produce sustained growth in other reintroduced hihi populations. Our results illustrate how key aspects of the adaptive management approach (flexible management, quantitative projections, incorporation of uncertainty) can be essential for improving management of reintroduced populations.

Keywords: research—wildlife disease, research—hihi, fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Castro, I.; Perrott, J.K.; Ewen, J. 1995: Effects of food supply and competition on the outcome of hihi transfers. WWF-NZ Progress Report. Ecology Department, Massey University, Palmerston North (unpublished). 5 p.

[A progress report on the hihi research funded by the World Wildlife Fund–New Zealand. The following is taken from the Objectives of the project:]

Our primary research objective is:

(1) To test, throughout the year, whether Mokoia hihi are limited by nectar/fruit supply in conjunction with competition from tui

Secondary research objectives are:

(2) To test the effectiveness of nest boxes for encouraging breeding

(3) To study the hihi breeding system to provide a basis for improving per capita reproduction

(4) To carefully monitor breeding and mortality to provide a basis for a longer-term study of population viability

(5) To carefully monitor movements and interactions of birds immediately after release.

The rationale for these objectives is outlined in our initial proposal and in previous reports. This report deals with objectives 1, 3, and 4.

[Contains five sections titled:] Research Methodology, Summary of Work to Date, Preliminary Management Recommendations, Work still to be completed and Budget Report.

Keywords: research—wildlife disease, research—hihi, fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Craig, J.L. 1995: Effects of familiarity on the outcome of translocations, I. A test using saddlebacks *Philesturnus carunculatus rufusater*. *Biological Conservation 71*: 133–141.

Translocation, the intentional release of a species in a new location, plays an important role in the conservation of endangered species. Consequently, there is a critical need for research on factors affecting the outcome of translocation attempts. This study addresses the hypothesis that founder groups will do better if they are made up of individuals that are familiar with one another. The hypothesis is based on research on birds showing that familiarity between mates and neighbours leads to lower aggression and higher reproductive success. Our test involved a translocation of the North Island saddleback *Philesturnus carunculatus rufusater*, a New Zealand forest bird restricted to islands free of mammalian predators. We created two founder groups of 18 birds each, one made up of birds from a single small forest patch, and including five known pairs, and the other a mixture of birds from several patches, with no pairs. We released the groups in different parts of an island, and assessed the effects of familiarity on survival, dispersal, pair bonding and reproduction. The two groups showed similarly high survival, and both dispersed widely. Pair bonds formed more quickly among the familiar birds, even though only one of the five original pairs stayed together after translocation. While pairing among unfamiliar birds tended to be delayed, they achieved a similarly high rate of pairing by the start of the breeding season, and reproductive output was similar for familiar and unfamiliar pairs. We therefore found no evidence that using familiar individuals would improve the outcome of bird translocations. We note that familiarity could be more important with other species and/or in other circumstances. However, we also note the potential costs of using familiar individuals.

[The paper contains a map of saddleback locations on Mokoia 28–30 October 1992.]

Keywords: research—translocations, research—North Island saddleback, fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*

Armstrong, D.P.; Davidson, R.S. 2006: Developing population models for guiding reintroductions of extirpated bird species back to the New Zealand mainland. *New Zealand Journal of Ecology 30*: 73–85.

Population models are useful tools to guide management as they allow us to project growth and persistence of wildlife populations under different scenarios. Nevertheless, good data are needed to produce reliable models, and this requirement is problematic in some situations. North Island saddlebacks (*Philesturnus rufusater*) were reintroduced to Boundary Stream Mainland Island in September 2004, and this was the first time this species had occurred in an unfenced mainland area since their extirpation in the 19th century. This situation creates a challenging scenario for population modelling, as this species has never been studied in the presence of mainland predators, and management of these predators will be the key factor determining whether the population survives. In this paper we present an approach for developing a "prior model" before a reintroduction takes place. We use data from the reintroduced saddleback population on Mokoia Island to develop a model of how saddleback populations are regulated in the absence of mammalian predators. We use this model to project growth of a reintroduced population when vital rates are reduced by predation and also to project responses of source populations to harvesting of birds for translocation. We then incorporate data from the reintroduced North Island robin (*Petroica longipes*) population at Paengaroa Mainland Island to model the relationship between population parameters and predator tracking rates. The combined model can be used to predict the level of predator control needed to ensure growth of the saddleback population, but the prediction is contingent on guessing the relative vulnerability of robins and saddlebacks to predation. We envision using a Bayesian approach to update such prior models as site-specific data become available after reintroduction.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, toutouwai, North Island robin, *Petroica australis longipes*

Armstrong, D.P.; Davidson, R.S.; Dimond, W.J.; Perrott, J.K.; Castro, I.; Ewen, J.G.; Griffiths, R.; Taylor, J. 2002: Population dynamics of reintroduced forest birds on New Zealand islands. *Journal of Biogeography 29*: 609–621.

We studied dynamics of four populations of New Zealand forest birds for 5–9 years after reintroduction to islands. We primarily aimed to predict whether these populations were viable, and what, if any, management was needed to maintain them. However, the small scale of these islands also provided an opportunity to study density-dependent population growth over a short time frame. Location: We studied New Zealand robin (toutouwai, *Petroica australis*) and stitchbird (hihi, *Notiomystis cincta*) populations reintroduced to Tiritiri Matangi, a 220-ha offshore island near Auckland, and saddleback (tieke, *Philesturnus carunculatus*) and stitchbird populations reintroduced to Mokoia, a 135-ha island in Lake Rotorua. These islands are free of mammalian predators, but have highly modified habitat following clearing and regeneration. Methods: We closely monitored each population, individually marking all or most of the birds and in some cases experimentally manipulated population density or food supply. We used model selection procedures to understand factors affecting survival, fecundity and dispersal, and developed stochastic simulation models. Results: The Tiritiri Matangi robin and Mokoia saddleback populations grew without management and appear to be viable. Both showed strong evidence of density-dependent growth, with fecundity (saddlebacks) and juvenile survival (both populations) declining with increasing density. Neither stitchbird population appears viable without management and supplementation experiments showed reproduction and/or survival to be limited by food supply. The Tiritiri Matangi population appears viable as long as supplementary feeding continues. However, the Mokoia population has a high mortality rate regardless of supplementary feeding, resulting in tenuous viability even with intensive management. Mokoia stitchbirds suffer from infection by *Aspergillus fumigatus*, a pathogenic fungus that is prevalent in highly modified habitats and more abundant on Mokoia than Tiritiri Matangi. Main conclusions: Some forest birds can thrive in regenerating forest on islands and strong evidence of density dependence can be detected in such populations in as little as 5 years. This allows density-dependent models to be developed, providing guidance when island populations are harvested for further translocations. Other species are limited by food supply in regenerating environments, a problem potentially overcome by management. However, prevalence of *A. fumigatus* may render highly modified environments uninhabitable by some species regardless of management.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, wildlife disease, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Davidson, R.S.; Perrott, J.K.; Roygard, J.; Buchanan, L. 2005: Density-dependent population growth in a reintroduced population of North Island saddlebacks. *Journal of Animal Ecology* *74*: 160–170.

Reintroductions provide a good opportunity to study density-dependent population growth, as populations can be studied at a range of densities and the change in density is not confounded with environmental conditions. An understanding of density dependence is also necessary to predict dynamics of reintroduced populations under different management regimens, and assess the extent to which they can be harvested for further reintroductions. We monitored a North Island saddleback (*Philesturnus rufusater*) population for 6 years after reintroduction to Mokoia, a 135-ha island in New Zealand that was made suitable for saddlebacks by eradicating introduced Norway rats (*Rattus norvegicus*). We modelled adult and juvenile survival using Program MARK, and modelled numbers of young fledged per pair using Proc Mixed in SAS with individual female as a random factor. Juvenile survival clearly declined as the population increased, and the decline was closely correlated with the number of breeding pairs. Reproduction also showed a clear decline that was explained by two factors: a difference in quality between territories occupied immediately after reintroduction and those occupied later, and an overall decline as the number of pairs increased. Reproduction was also strongly affected by age, and this needed to be accounted for when modelling density dependence. A stochastic simulation model incorporating these dynamics closely predicted the observed population growth. The equilibrium population size was insensitive to density dependence in reproduction, but highly sensitive to density dependence in juvenile survival. The model is being used to plan management strategies for potential reintroductions of saddlebacks to mainland areas with predator control. The species is currently confined to predator-free islands and one fenced mainland sanctuary.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, pest management, Norway rats, *Rattus norvegicus*

Armstrong, D.P.; Ewen, J.G. 2001: Testing for food limitation in reintroduced hihi populations: contrasting results for two islands. *Pacific Conservation Biology* 7: 87–92.

The Hihi *Notiomystis cincta*, a New Zealand honeyeater (Aves: Meliphagidae), became extinct everywhere except one offshore island following European colonization. Attempts to establish Hihi on additional islands in the 1980s had poor success, and this was attributed to food limitation. These islands had all been modified by human use, and had a lower diversity of natural carbohydrate (fruit and nectar) sources than the source island, particularly in winter. When Hihi were released on two additional islands, Mokoia and Tiritiri Matangi, we used supplementation experiments to test whether condition and survival of birds were limited by availability of carbohydrate food. Sugar water was provided on an on-off basis from autumn through spring in the year after the release. Birds were weighed at the beginning and end of fed periods, and survival for fed and unfed periods was estimated using mark-recapture analysis on sighting data. Armstrong and Perrott (2000) reported that supplementary feeding had no effect on condition or survival on Mokoia, and annual survival was about 40%, both in the year of the experiment and in subsequent years when food was supplied continuously. This paper reports contrasting results for Tiritiri Matangi. Supplementary feeding on Tiritiri Matangi increased both condition and survival, and overall survival was substantially higher than on Mokoia—66% in the year of the experiment and 76% the following year when food was supplied continuously. It therefore appears that supplementary feeding can be used to improve survival of Hihi on Tiritiri Matangi, whereas survival is constrained to a low level by other factors on Mokoia. These results emphasize the value of habitat manipulation experiments for developing appropriate management strategies for reintroduced populations.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong; D.P.; Lovegrove, T.G.; Allen, D.G.; Craig, J.L. 1994: Composition of founder groups for bird translocations: does familiarity matter? Pp. 105–111 in Serena, M. (Ed.): Reintroduction biology of Australian and New Zealand fauna. Surrey Beatty & Sons. Chipping Norton.

Several studies have shown that: (1) birds are much less aggressive to their neighbours than they are to unfamiliar birds; (2) birds with familiar neighbours have greater breeding success than those with new neighbours; and/or (3) established breeding pairs are more successful than newly-formed pairs. These results suggest that bird translocations are likely to be more successful if there is a high level of familiarity in a founder group. Here we summarize experiments designed to test for effects of familiarity in translocations of three species of New Zealand forest birds: Whiteheads, North Island Robins and North Island Saddlebacks. Our experiments compared (1) birds transferred in intact neighbourhood groups v. those transferred with unfamiliar birds, and (2) birds transferred with and without their mates or breeding groups. In all cases, our results suggest that familiarity had no effects on survival, dispersal, aggression, pair bonding or reproductive success of the translocated birds. Birds were effective at establishing new relationships and pair bonds with previously unfamiliar birds, and most existing breeding pairs and groups broke up after translocation. On the basis of our available evidence, we suggest that familiarity need not be an important consideration in developing translocation strategies, at least for forest birds.

[The paper notes the North Island saddleback translocation to Mokoia from Tiritiri Matangi, and states the survival, dispersal and conspecific attraction, pair bonding and breeding results obtained—BRC.]

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*

Armstrong, D.P.; Perrott, J.K. 1995: Testing for food limitation following translocation, New Zealand. *Re-introduction News 10*: 9.

[The report in full follows.]

People often try to enhance habitat at re-introduction sites by providing food, water, shelter, nest sites, etc. It is often difficult, however to test whether or not, or to what extent, the enhancement is needed. We are currently running an experiment to test whether individual hihi (*Notiomystis cincta*) an endangered New Zealand honeyeater, also known as stitchbird) are limited by natural food supplies on Mokoia Island, where they were re-introduced in September 1994. Mokoia is still regenerating following clearing, hence may not have the same variety of fruit and nectar sources that occurred historically. There are also abundant tui (parson bird, *Prosthemadera novaeseelandiae*), a larger honeyeater that could exclude the hihi from prime food sources.

The experiment involves providing sugar-water feeders at some times but not others. Out of every four weeks, birds are fed for 18 days and then not fed for ten days. We weigh the birds at the end of each period to compare their "fed" and "unfed" condition. This is done remotely using electronic scales set up at feeders. The experiments are accompanied by a sampling programme to measure:

1. energy availability from natural carbohydrate sources;
2. hihi time budgets when foraging on natural sources;
3. degree to which hihi are excluded from particular food sources by tui; and
4. tui abundance.

We can therefore determine whether food limitation (as measured by weight loss) can be attributed to shortage of carbohydrate food and/or competition from tui. After running the experiment for a complete annual cycle, we aim to determine;

1. what times, if any, do hihi need supplementary food;
2. what plant should be grown on Mokoia to enhance hihi food supply in the long term; and
3. what other islands are likely to have sufficient year-round food supply for hihi.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Perrott, J.K. 2000: An experiment testing whether condition and survival are limited by food supply in a reintroduced hihi population. *Conservation Biology 14*: 1171–1181.

The Hihi (stitchbird, *Notiomystis cincta*) is an endemic New Zealand honeyeater that after European colonization survived on only one offshore island. Attempts to reintroduce Hihi to other islands have been unsuccessful, with populations slowly declining. The main hypothesis for these declines was an inadequate year-round supply of carbohydrate food (nectar and fruit) due to human impacts on the forest habitat. When Hihi were reintroduced to Mokoia, another island with regenerating forest, we tested whether survival was limited by carbohydrate food in the year after release. We conducted an "on-off" experiment in which *ad libitum* sugar water was available to birds for 2 out of every 4 weeks. We compared the masses of individual birds at the end of on and off periods to identify times when birds lost condition with no supplementary food and would be likely to starve. We also used mark-recapture analysis of resighting data to test whether mortality rates were higher when supplementary food was unavailable. The only effect of the supplementary food was that Hihi spent less time foraging for nectar and fruit and more time foraging for invertebrates. There was no time of year when birds lost mass when the food was taken away, and survival rates were not significantly lower when supplementary food was absent. The low (38%) annual survival rate could not be accounted for by shortage of carbohydrate food, and population viability analysis suggests that the population is likely to slowly decline. Our experiment shows that declines of reintroduced Hihi populations may be unrelated to food supply and that alternative hypotheses should be developed and tested. Our results also show the importance of using experimental methods, when possible, to test hypotheses about factors thought to be limiting reintroduced populations.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Perrott, J.; Castro, I. 1997: The effect of food supply on the viability of hihi populations: an experimental study on Mokoia. Report to World Wide Fund for Nature. Massey University, Palmerston North (unpublished report). 89 p.

Following European colonisation, hihi (or stitchbirds) became extinct everywhere except Little Barrier Island. There were several translocations of hihi to Hen, Cuvier, and Kapiti Islands from 1980–92, but these failed to establish self-sustaining populations. The main hypothesis given to explain these failures was insufficient year-round supply of nectar and fruit, in conjunction with competition from other honeyeaters (bellbirds and tui). Hihi were translocated to Mokoia Island in September 1994, and this report covers research over the two years following the translocation. We tested the hypothesis that the viability of this new population was limited by food supply. We did this by: (1) quantifying availability of energy from fruit and nectar sources throughout the year; (2) quantifying foraging behaviour, and exclusion by tui at food sources (there are no bellbirds on Mokoia); (3) doing food supplementation experiments to determine whether condition, survival and/or reproduction were limited by food availability; and (4) doing population viability analysis using the data obtained. We also did intensive observations immediately after release to evaluate aspects of the translocation strategy.

The bands used in the translocation caused leg injuries and some mortality. However, if the effects of the bands is excluded the mortality rate immediately after release was no higher than the long-term mortality rate over the next two years. This suggests that there were no problems with the translocation strategy.

Hihi were seen taking nectar from 16 plant species and fruit from 12 species. There was generally a good variety of nectar or fruit sources available throughout the year, but August–September stood out as being a period with a low diversity of both nectar and fruit sources. We identified key plant species that hihi may depend on. We note that food supply will vary from year-to-year, and that crunch periods are most likely when hihi depend on few plant species. We discuss the effects that ecological succession will have on diversity of nectar and fruit sources in the future. We suggest species that could be planted on Mokoia.

Hihi foraging changed predictably with nectar and fruit availability, and they generally made extensive use of the highest-quality nectar or fruit sources. There was no evidence that hihi 'preferred' either nectar or fruit, or that their seasonal diet changes were more closely tied to fruiting or flowering phenologies. The degree to which they were excluded by tui varied according to the season and plant species, but hihi were never totally excluded from any nectar or fruit source.

We conclude that tui had little affect [*sic*] on access to food by hihi, and will not affect the viability of the hihi population. Feeder use varied seasonally, and hihi used feeders extensively at some times of year. However, our food supplementation did not show condition or survival of hihi to be affected by food availability. Feeders actually caused hihi to lose weight rather than gain weight. However, this weight loss was small and does not imply that feeders were harmful.

Hihi used the nestboxes provided, and had a high reproductive rate. It's unclear whether the number of fledglings hihi can produce is limited by food supply—females near feeders produced more fledglings in the first breeding season, but fewer in the second breeding season.

Hihi had a high mortality rate. The reproduction and mortality rates are close to balancing one another, and the long-term prospects of the population are uncertain. Surprisingly, female juveniles from nests near feeders were less likely to survive to the next breeding season than those from nests away from feeders. If this happened consistently, population viability would be higher if nests were away from feeders or if there were no feeders. However, this result is preliminary and more data are needed.

The population parameters we observed on Mokoia could explain the outcomes of previous hihi translocations. The high mortality rate on Mokoia was not due to an inadequate food supply. Therefore, the declines observed on other islands may also have been unrelated to food availability. We identified disease (especially Aspergillosis) as a key factor affecting the mortality rate, and nest mites as a key factor limiting the reproductive rate. We recommend further research on these factors.

We do not recommend translocating hihi to additional islands.

The current populations on Mokoia, Tiritiri Matangi, and Kapiti provide excellent opportunities for continuing research.

Keywords: fauna, ecology, conservation management, wildlife disease, translocations, hihi, stitchbird, *Notiomystis cincta*

Armstrong, D.P.; Perrott, J.K.; Castro, I. 2001: Estimating impacts of poison operations using mark-recapture analysis: hihi (*Notiomystis cincta*) on Mokoia Island. *New Zealand Journal of Ecology 25*: 49–54.

Hihi (*Notiomystis cincta*) were reintroduced to Mokoia Island, Lake Rotorua, New Zealand, in September 1994, and two years later there was an aerial drop of brodifacoum cereal pellets aimed to eradicate mice (*Mus musculus*). Using Program MARK, we analyzed data from resighting surveys to assess whether hihi had lower than normal survival in the 6-week interval following the drop. The resighting data were collected on a regular basis over a 3-year period, from 1994–97, allowing us to control for yearly and seasonal variation in resighting and survival probabilities. We initially established that the Cormack-Jolly-Seber model had a good fit to the data and could therefore be used as the global model for our analysis. We than compared a range of simpler candidate models, some of which included a poison effect (an unusual survival rate for the interval after the poison drop). Under the best model (that with the lowest AIC), the survival probability was constant over time and there was no poison effect. The estimated survival probability for the 6 weeks after the poison drop was 0.95, which is slightly higher than the value of 0.89 expected based on pre- and post-poison intervals. The approximate 95% confidence interval for the probability of a bird dying due to poison ranged from –0.17 (i.e., a decrease in mortality rate due to the poison) to +0.04. We therefore concluded that the poison caused at most a negligible increase in mortality, and that mark-recapture analysis on resighting data provided a powerful method for assessing the impact of the poison drop. We discuss the relative costs and benefits of radio tagging versus resighting surveys of banded birds for estimating impacts of poison operations. For species with relatively high resighting rates, such as hihi, analysis of resighting surveys is a much more reliable and cost-efficient methodology.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*, pest management, mice, *Mus musculus*

Avery, M. 1990: Colonisation of robin up to pupils. *The Daily Post*, 12 June 1990.

[This article on the proposed North Island robin transfer onto Mokoia focuses on the involvement of senior secondary school pupils in the translocation project.]

Keywords: conservation management

Axbey, B. 1994: The bird hunters. The Halcyon Press, Auckland. 146 p.

[This book is the author's perspective on waterfowl and gamebird hunting in New Zealand. The author, previously a ranger in the former New Zealand Wildlife Service, describes his experience trapping weka (*Gallirallus australis greyi*) around Gisborne and their subsequent liberation onto Mokoia. While there were many different liberation sites about the wider East Coast area, the Mokoia liberation formed the only new population.]

Keywords: fauna, translocations, weka, *Gallirallus australis greyi*

Beadel, S.M. 1989: Vascular plants of Mokoia Island. Department of Conservation, Rotorua (unpublished report). 8 p.

[A list of the vascular plants recorded by the author during May 1989, and records from B.R. Clarkson and C. Ecroyd during March 1982. It includes identification of planted species, as well as specimens deposited in the then New Zealand Forest Research Institute Herbarium, Rotorua. A full current species list is given in Appendix 2.]

Keywords: vegetation, plantings, flora

Beadel, S.M. 1990: Excursion to Mokoia Island. *Rotorua Botanical Society 20*: 15–16.

[Outlines a group botanical visit to Mokoia, with a description of vegetation types, e.g.] The vegetation is predominantly secondary, the dominant species being fivefinger (*Pseudopanax arboreus*), mahoe (*Melicytus ramiflorus*), kohuhu (*Pittosporum tenuifolium* ssp. *tenuifolium*) and Mamaku (*Cyathea medullaris*).

Keywords: vegetation, flora

Beadel, S.M. 1995: Vegetation and flora of lands administered by Bay of Plenty Conservancy. Wildlands Consultants Ltd. Contract report for Department of Conservation, Rotorua (unpublished report). 556 p.

[This is a compilation of vegetation descriptive information for the c. 1995 land parcels administered by the Bay of Plenty Conservancy, DOC. It contains information (where present) on the land parcel number, size (ha), ecological district, bioclimatic zone, vegetation types and habitat, vegetation map, flora, botanical conservation rank, date, reference and justification, notes, and references.]

Keywords: vegetation, flora

Beadel, S.M.; Ecroyd, C.E. 1990: Checklist of vascular plants of Mokoia Island. *Rotorua Botanical Society 20*: 18–24.

[This species list is based on visits by the authors in March 1982 (accompanied by B.R. Clarkson), May 1990, April 1990 and June 1990 (Rotorua Botanical Society field trip). A table summarising the plants is given below, and an updated current species list from subsequent surveys is provided in Appendix 2—BRC.]

GROUP	NATURAL	PLANTED
Gymnosperms	2	1 (also natural)
Monocot trees	1	1
Dicot trees	17	3
Dicot shrubs	12	2
Monocot lianes	1	
Dicot lianes	6	
Psilopsids and Lycopods	3	
Ferns	42	
Orchids	6	
Grasses	8	
Sedges	14	
Rushes	2	
Monocots (others)	6	
Composits	5	
Dicot herbs (others)	26	
Totals		
Adventive species	112	1
Indigenous species	157	

Keywords: vegetation, plantings, flora

Beveridge, A.E.; Daniel, M.J. 1965: Observations on a high population of brown rats (*Rattus norvegicus* Berkenhout 1767) on Mokoia Island, Lake Rotorua. *New Zealand Journal of Science 8*: 174–189.

[Summary reported in full follows.]

This paper reports the results of a fifteen-month study of a population of brown rats (*Rattus norvegicus*) in a forest habitat on Mokoia Island, Lake Rotorua, in the North Island. The vegetation and animal life of the island are described. Over much of the 334 acres there is second-growth forest, following fires and cultivation. The climate is frost-free and several coastal plants occur.

The results of systematic trapping on 553 trap nights and other evidence such as fresh burrows, droppings, and daylight feeding, indicate that there is a marked seasonal fluctuation in numbers. In the autumn and winter of 1963, the population was high with a correspondingly high proportion of cannibalism of trapped rats. This was followed by a sharp decline in numbers by the spring and early summer of 1964. After a summer breeding season, the numbers increased again by the autumn of 1964 until there were apparently as many as in the previous autumn.

Standard measurements were taken on 75 adult female, 66 adult male, and 12 juvenile brown rats. Both weights and head and body measurements of adult Mokoia Island rats were lower than those reported for British specimens. The only pregnant and lactating females were trapped in summer and autumn, suggesting that they do not breed the year round, in spite of the mild winters. The numbers of embryos ranged from five to ten, with an average of eight.

Food eaten by these rats included seeds, fruits, bark, insects, spiders, freshwater mussels, and crayfish. In the winter of 1963 a high proportion of several thousand tree seedlings planted on the island were destroyed by the rats biting through the stems. These seedlings included podocarp species, tawa, and kauri.

The harmful effects of rats on the bird fauna of the island are not known with certainty, but it appears that few ducks now breed there. Parasites identified from rats trapped on the island include the flea *Nosopsyllus fasciatus* and the nematode *Physaloplera getula*.

[The report contains a map of the island with an outline of the forest edge as of 1948 (no reference), and the location of former pheasantry—BRC.]

Keywords: pest management, Norway rats, *Rattus norvegicus*, ecology

Beveridge, A.E.; Daniel, M.J. 1966: A field trial of a new rat poison, compound S-6999, on brown rats. *Proceedings of the New Zealand Ecological Society 13*: 40–43.

[Introduction in full follows.]

The problem of introduced rats endangering the survival of rare birds is a very real one. This is shown by a recent depressingly long list of birds known to have become extinct since 1600, prepared by Vincent (1965) of the International Union for the Conservation of Nature and Natural Resources. Vincent shows that rats and other introduced predators have been directly responsible for the extinction of at least 30 species and subspecies of birds in that time, and probably of twice or three times that number. Several rare species and subspecies of birds surviving on New Zealand's off-shore islands are likewise in danger of extermination by rats.

A recent survey of Big South Cape Island off Southwest Cape, Stewart Island (Blackburn 1965) revealed that six species and subspecies of birds have either been exterminated or driven close to extermination on this island by rats during the past two years. Merton (1965) noted that the black rat (*Rattus rattus*) was responsible.

Following an ecological study of the brown rat (*Rattus norvegicus*) on Mokoia Island, Lake Rotorua (Beveridge and Daniel 1965), the opportunity arose, through the courtesy of the Australian manufacturers, to conduct acceptance trials of a unique new rat poison called "Raticate" which contains 1% of the organic compound S-6999 w/w in maize. Trials with compound S-6999 (also called norbormide) to control brown rats in the United States have been described by Crabtree et al (1964). The present paper describes two acceptance trials with brown rats carried out on Mokoia Island from November 1965 to January 1966.

The LD_{50} of compound S-6999 for *Rattus norvegicus* is 15 mg/kg, and at a concentration of 1% it is a highly specific poison for rats. The manufacturers claim that Raticate baits are harmless to other mammals, including mice and humans, and to birds. Raticate baits are normally distributed merely by placing on the ground the sealed Glassine envelopes, each containing 2 g of bait (Fig. 1); this quantity is said to be a lethal dose for four average-sized rats. The average-sized brown rat on Mokoia Island weighs 200 g, and the LD_{50} of Raticate bait for such specimens would thus be 3 g. Death is said to occur 15 minutes to 4 hours after a lethal dose has been eaten.

Keywords: pest management, Norway rats, *Rattus norvegicus*

Bowyer, R. 1993: Saddleback transfer from Tiritiri Matangi Island to Mokoia Island (1992). Rotorua (unpublished report).

Between 7–12 April 1992 36 North Island saddleback birds (*Philesturnus carunculatus*) were translocated from Tiritiri Matangi Island (38° 36', 174° 19'), an open reserve east of Whangaparoa, in the Hauraki Gulf, to Mokoia Island (28° 06', 176° 19'), Lake Rotorua. The Tiritiri Matangi population of saddlebacks originated from Cuvier Island and were introduced to Tiritiri Matangi six years ago. Although sexing was inconclusive at the time of translocation, it has been determined that 20 males and 16 females were transferred. During the first breeding season as of 23 Feb 1993, 37 juveniles were produced.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*

Boyd, S.; Castro, I. 2000: Translocation history of hihi (stitchbird), an endemic New Zealand honeyeater. *Re-introduction News 19*: 28–30.

In 1994 a translocation of 40 birds to Mokoia Island (135 ha) provided opportunities to investigate the effect of food supply and supplementation on the survival (Armstrong et al. 1999), breeding system and establishment of hihi.

[This report outlines the conservation management history, chiefly the translocation, of hihi. At present, hihi have been transferred only to Kapiti, Mokoia and Tiritiri Matangi Islands—BRC.]

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Buchanan, L. 1998: Two shining cuckoos (*Chalcites lucidus*) fed by one grey warbler (*Gerygone igata*). *Notornis 45*: 12 June.

[A short note on an observation of a grey warbler feeding two juvenile shining cuckoos.]

Keywords: fauna, ecology, shining cuckoo, *Chalcites lucidus*, grey warbler, *Gerygone igata*

Brunton, D.H.; Castro, I. 2003: Implications of differential sex allocation for endangered species management. New Zealand Ecological Society Annual Conference, Auckland, 2003 (unpublished report).

Supplemental feeding has become a method of increasing reproductive productivity for several of New Zealand's threatened species. However, recent studies have suggested that the provision of supplementary food may result in skewed sex ratios particularly for polygynous species. Current research has shown that females are able to alter primary sex ratios and potentially increase their individual fitness. Advances in molecular sexing techniques have seen a large number of observational studies examining female sex ratio manipulation and results have been variable. Very few studies have tested experimentally for facultative control of primary and fledging sex ratios in free-living populations. In this study we examine sex allocation in hihi (*Notiomystis cincta*) using empirical data from supplemental feeding experiments. We measured primary and fledgling sex ratios, and chick survivorship and growth rates in relation to the provision of food and maternal age. Support for two hypotheses that explain adaptive deviations from a 1 : 1 sex ratio are evaluated. Feeders were provided to breeding female hihi on selected territories on Mokoia Island, Lake Rotorua. Molecular techniques were used to determine the sex of eggs/chicks. Primary sex ratios tended to be male biased under poorer conditions. However, fledging sex ratios for both treatments tended to be male biased. This shift in sex ratio bias was the result of differential survival rates for males and females under the different treatments; in particular male offspring survived significantly better when raised on territories with supplemental food. Chick survival was also influenced by the sex composition of broods. Females in same sex broods had higher survivorship than females in mixed broods, whereas males in mixed sex broods had lower survivorship than males in same sex broods. Finally, while male and female offspring had different growth rates these were not influenced by food provisioning. Our results emphasise the importance of considering impacts of supplemental feeding on a variety of life history traits.

Keywords: fauna, ecology, conservation management, hihi, stitchbird, *Notiomystis cincta*

Cashmore, P. 2000: Mokoia Island, Lake Rotorua. *Rare Bits 38*: 5

[Report in full follows.]

Staff have just finished planting *Dactylanthus taylorii* seed on Mokoia Island. They planted an estimated 70,000+ seeds at six sites around the island mainly near mahoe and kohuhu host trees in a 2-day operation. This planting is a *Dactylanthus* Recovery Group priority and has been several years in the planning following consultation and approval from the Mokoia Island Trust Board last year. This is only the second predator-free island in the country where *Dactylanthus* has been introduced. Staff will monitor sites annually for any sign of germination or flowering, but it is likely to be many years before we know if this planting has been successful. With plenty of young host trees and no possums or rats Mokoia has long been considered an ideal habitat for establishment of *Dactylanthus*.

Staff spent another day on the island checking on the survival of two other threatened plant species introduced to the island late last year as part of the island's ongoing restoration. Mistletoe (*Tupeia antarctica* and *Ileostylus micranthus*) seed was planted on a range of host trees around the island but so far does not appear to have established. However the endangered native cress *Rorippa divaricata* has faired better with 50% of the original plantings having established and set seed, although half of these have died off over winter. The plentiful seed gives us hope that new plants will establish in the spring and viable populations result.

Keywords: flora, ecology, threatened plants

Cashmore, P. 2001: Mokoia Island field trip. *Rotorua Botanical Society 36*: 48–49.

[This article outlines a group botanical visit to Mokoia, with the intention to 're-examine the flora of the island, the ongoing vegetation changes and some of the recent threatened plant work undertaken'. The four threatened plant introductions to the island were: mistletoe (*Ileostylus micranthus* and *Tupeia antarctica*), *Rorippa divaricata* and *Dactylanthus taylorii*—BRC.]

Keywords: flora, ecology, threatened plants

Cashmore, P. 2004: Mokoia Island mistletoe seed translocation. *Rare Bits 38*: 5

[Full report follows.]

In September, several hundred more *Tupeia* seeds were planted along the sunny northern side of Mokoia Island on fivefinger trees, in the hope of establishing the species on the island.

A quick check on the *Ileostylus* seed planted in July revealed that some seed had disappeared from the branches, with a few seeds dry and most likely dead.

Keywords: flora, ecology, threatened plants

Castro, I.; Brejaart, R.; Owen, K. 2000: Status of weka (*Gallirallus australis greyi*) on Mokoia Island. *Conservation Advisory Science Notes No. 314*. Department of Conservation. Wellington. 25 p.

The status of weka on Mokoia Island was assessed in two ways: (1) by surveying the number of weka on the island using two methods: call broadcast and unsolicited call survey, and (2) by capturing weka.

Using our call broadcast technique we have estimated the population of weka on the island [to be] between 90 and 120 birds. However, several areas of the island were not surveyed. We caught 12 birds in 19 days (1420.5 cage/hrs). This catching success was low when compared to Owen 1998 (34 birds caught in 10 days). A possible explanation could be the availability of a great variety of foods at this time of the year compared with August, when Owen and collaborators were catching.

We recommend that a monitoring programme for weka is established on Mokoia well in advance of mice eradication (currently scheduled for 2001) to allow the Department of Conservation to effectively measure the effect of the poisoning on the birds. Removing some weka, as was done prior to the first attempt to eradicate mice, is also recommended.

Future studies of weka on Mokoia considered necessary include: feeding studies (food availability and use/preference), importance of habitat structure for weka and breeding dynamics.

Keywords: fauna, ecology, conservation management, weka, *Gallirallus australis greyi*

Castro, I.; Brunton, D.H.; Mason, K.M.; Ebert, B.; Griffiths, R. 2001: Effect of food supplementation, female age and clutch number on egg laying and incubation in a translocated population of hihi (Aves). New Zealand Ecological Society Jubilee Conference, 27–30 August 2001, University of Canterbury, Christchurch (unpublished report).

Food abundance, temperature, and day length in combination with life history traits such as age, and biotic factors like predation are known to affect the incubation behaviour of females. We studied the effect of food supplementation, age and clutch number on laying and incubation parameters of female hihi. The hihi is an endangered bird for which the main conservation action has been translocation. We found that food supplementation and female age were significant in shaping female laying and incubation behaviours. Food supplementation significantly increased clutch size from a mean of 3.8 to 4.1 eggs per nesting attempt. Females at fed sites had an 18% shorter clutch interval, and started a second clutch 72% sooner after fledging first clutch chicks, than unfed females. Females at fed nests had shorter incubation (–3.7 minutes) and foraging bouts (–2.2 minutes). Older females laid larger clutches (4.2 vs. 3.8 eggs), incubated for shorter lengths of time (15.6 vs. 16.4 days), had greater hatching success (77.0 vs. 66.5 %), and incubated for longer intervals (16%). The successful establishment of hihi populations on islands with poor natural food supplies, e.g. Mokoia Island, may be dependent on the provision of supplemental food at the nest site of each breeding female.

Keywords: fauna, conservation management, hihi, stitchbird, *Notiomystis cincta*

Castro, I.; Brunton, D.H.; Mason, K.M.; Ebert, B.; Griffiths, R. 2003: Life history traits and food supplementation affect productivity in a translocated population of the endangered hihi (stitchbird, *Notiomystis cincta*). *Biological Conservation 114*: 271–280.

We studied the effect of food supplementation, female age and clutch order on productivity in a translocated species. Food supplementation increased clutch size from 3.9 to 4.4 (average) eggs per nesting attempt, and more than doubled fledging and recruitment success. Supplemented females started a second clutch 9 days sooner after fledging first clutch chicks than unfed females. During second clutches, supplemented females incubated the eggs for a shorter period of time (15.2 v. 16.8 days). Older females laid larger clutches (4.6 v. 3.7 eggs) than yearlings and incubated second clutch eggs for a shorter period (15.4 v. 16.6 days). Females laid more eggs in first clutches (4.2 v. 3.8 eggs), and those eggs took approximately 30% longer to lay than eggs in second clutches. The successful maintenance of hihi populations on the available islands may be dependent on the permanent provision of supplemental food at nest sites.

Keywords: research—hihi, fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Castro, I.; Griffiths, R.; Stamp, R. 2001: Stitchbirds—a sweet management challenge. New Zealand Ecological Society Jubilee Conference, 27–30 August 2001, University of Canterbury, Christchurch (unpublished report).

The stitchbird (*Notiomystis cincta*) or hihi is an endemic honeyeater of New Zealand. Dominated by tui (*Anthornis melanura*) and bellbirds (*Prosthemadera novaezeelandiae*), they feed on nectar, fruit and insects. This cavity nesting species breeds between September and March and produces up to three clutches each consisting of between three and five eggs. Stitchbirds have monogamous and polygamous methods of mating and forced copulations have been observed. Once found throughout the North Island, stitchbirds were restricted to one population on Little Barrier Island. There are now three more translocated populations on Tiritiri Matangi, Kapiti and Mokoia Islands as well as a captive population at Mt Bruce. Techniques that have developed and behaviours that have been observed through the management of this species are described.

Keywords: fauna, conservation management, hihi, stitchbird, *Notiomystis cincta*

Castro, I.; Mason, K.M.; Armstrong, D.P.; Lambert, D.M. 2004: Effect of extra-pair paternity on effective population size in a reintroduced population of the endangered hihi, and potential for behavioural management. *Conservation Genetics 5*: 381–393.

We collected genetic and behavioural data on hihi (*Notiomysts* [*sic*] *cincta*, an endangered New Zealand bird) after reintroduction to Mokoia Island to assess the effect of extra pair copulation on effective population size (N_e), and investigate the potential for increasing N_e through behavioural management. DNA fingerprinting revealed that 46% of chicks (n = 188) resulted from extra-pair paternity, and 82% of broods (n = 56) had at least one extra-pair chick. Of the extra-pair young, 34% (n = 89) were from unpaired males, and the remainder were from paired males. Variance in reproductive success (VRS) among individuals changed between years, and the relative variance among males and females depended on the sex ratio. VRS increased when measured over longer time scales, the variance in recruits being three times higher than the variance in the number of hatchlings. Extra-pair copulation increased VRS by 150% in 1 year and decreased it by 30% in another year, but this only caused a 4% decrease and 8% increase, respectively, to N_e/N. Although there is potential to manage VRS in this species through behavioural management,

a more important factor is adult lifespan, which is the main correlate of lifetime reproductive success as well as the determinant of generation time. The high annual mortality rate in Mokoia hihi (females = 64%, males = 52%) has prevented the population from growing, so the key factors limiting N and N_e/N are the same.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Christensen, B.R. (Ed.) 2002: Monitoring, survey and inventory in the Rotorua Lakes Area, Bay of Plenty Conservancy. Department of Conservation, Rotorua (unpublished report). 194 p.

[This is an updated and expanded biodiversity information inventory (providing electronic access to inventory data, GIS data manipulation and analysis tools) for the Rotorua Lakes Area, Bay of Plenty Conservancy—see Hunt (2001).]

Keywords: biodiversity, inventory, conservation management, Mokoia Island Wildlife Refuge

Christensen, B.R. (Comp.) 2005: Mokoia stoat incursion incident action plans (I–IV). Department of Conservation, Rotorua (unpublished reports). I: 20 p., II: 20 p., III: 19 p., IV: 21 p.

[These are action plans (as incident operation progresses) for the management operation of a suspected stoat (*Mustela erminea*) incursion on Mokoia (23 Aug 2005). They contain the following sections: Situation Report, Incident Objectives, Organisation Plan, Communications Plan, Safety Plan, Division Assignment, Sector Assignment, Medical Plan, Weather Forecast and Map, Island Plan.]

Keywords: conservation management, pest management, stoat, *Mustela erminea*

Clarkson, B.D.; Smale, M.C.; Ecroyd, C.E. 1991: Botany of Rotorua. Forest Research Institute, Rotorua. 132 p.

[A book describing the botany around Rotorua. It includes a photograph of a kumara garden on Mokoia (circa late 1880s). It also notes Maori inland cultivation and use of coastal plants on Mokoia: chiefly pohutukawa (*Metrosideros excelsus*) and taupata (*Coprosma repens*), both of which can disperse and colonise inland areas; and whau (*Entelea arborescens*), which is likely to have been planted by Maori.]

Keywords: botany, biodiversity, vegetation, ecology, inventory, Maori—cultivation, kumara garden, coastal plants

Cleghorn, M.; Griffiths, R. 2002: Palatability and efficacy of Pestoff 20R bait on mice from Mokoia Island, Rotorua. *DOC Science Internal Series 25*. Department of Conservation, Wellington. 14 p.

Following an unsuccessful eradication attempt on mice (*Mus musculus*) on Mokoia Island, the palatability of the bait used and mouse tolerance to anticoagulants were raised as possible reasons for the operation's failure. To alleviate these concerns before another eradication attempt, a two-choice trial was carried out on 21 mice from Mokoia to compare the palatability of Pestoff 20R to a standard diet. A no-choice trial was also run to assess bait efficacy. A high degree of variability was recorded between individual mice, but in general, mice found Pestoff 20R significantly less palatable than the standard diet. No evidence for tolerance to brodifacoum could be found. The absence of information on dietary preferences and reasons that several mouse eradication attempts have failed are discussed and recommendations are made for the need to test the palatability of a range of bait types in a natural situation. Research on the impact of social interactions on the success of eradication attempts is also recommended.

Keywords: research—mice, conservation management, pest management, mice, *Mus musculus*

Colbourne, R. 2005: Kiwi (*Apteryx* spp.) on offshore New Zealand islands: populations, translocations and identification of potential release sites. *DOC Research & Development Series 208*. Department of Conservation. Wellington. 24 p.

At least five species and six taxa of kiwi (*Apteryx* spp.) are recognised at present. All taxa are currently listed as threatened. Since the 1890s, translocation of kiwi populations to the offshore islands of New Zealand has been used in the conservation of the genus. This report identifies and reviews offshore (and lake-bound) islands where kiwi occur naturally, together with islands to which kiwi have been translocated. Brief, descriptive histories of populations and translocations are provided. At least 28 offshore islands (excluding Stewart Island) currently support populations of kiwi. A number of islands, nominated by DOC conservancies, which might be suitable for future translocations, are also listed. The criteria for this list of potential islands include: lack of predators; sufficient size (at least 100 ha); presence of suitable habitat; legal protection; and absence of conflicting conservation values. Before recommendations as to which species should be translocated (and to which islands) can be made, consultation with other interested parties and detailed investigations of the islands' suitability will be required.

[The author noted in the Mokoia section (p. 17) that 'Mokoia I. (38°04'S, 176°17'E) has an area of 120 ha and lies in the middle of Lake Rotorua. Four North island brown kiwi from the Bay of Plenty area were released onto the island in 2004. These three male and one female kiwi were hatched and raised at Rainbow Springs Kiwi Centre as part of the ONE programme (B. Evans, DOC, pers. comm. 2004)'. There are some details that are to be corrected. Mokoia is approximately 134 ha in size, not 120 ha or 143 ha as the author reported in the text and associated table; additionally, the four kiwi were released onto the island in 2003 (refer to Owen 2003a, b)—BRC.]

Keywords: conservation management, North Island brown kiwi, *Apteryx australis*, translocations

Davidson, R.S. 1999: Population dynamics of the saddleback population on Mokoia Island and implications for reintroduction to the mainland. Unpublished MSc thesis, Ecology Department, Massey University, Palmerston North. 143 p.

The saddleback (*Philesturnus carunculatus*) is an endemic New Zealand forest bird that no longer occurs on the mainland. It is thought that predation from introduced species (especially rodents) led to its extinction except on offshore islands. In April 1992, 36 saddlebacks were released onto Mokoia Island, a 135 ha island in Lake Rotorua. Using data collected from this population over the following five and a half years, I estimated parameters to describe the population's demography.

Survival was modelled by mark-recapture analysis, using re-sighting data for banded birds. Survival was found to be age dependent, with two classes, adult and juvenile. The juvenile age class consisted of birds in their first nine months. All other ages were treated as adult. Adult survival was density independent, while juvenile survival was density dependent. The juvenile survival rate was initially close to the adult rate, but declined as the number of pairs on the island increased. There was a male bias in the sex ratio of birds surviving their first nine months, but the cause for this was not ascertained.

Reproductive success was related to the age of the parents, with two classes for both males and females. For both sexes, first year breeders produced fewer fledglings than older birds. A density dependent decline in the population's reproductive success was also found.

Using parameter estimates that took these factors into account, I created a model to simulate the Mokoia Island saddleback population. My model predicted a mean population growth trajectory that closely matched the observed population growth on the island. After the establishment phase (a period of rapid growth) the simulated population reached a mean density of 103 pairs, with 44 unpaired males, around which the population fluctuated.

Once the basic model structure had been established, I added a routine to simulate the poison drop that occurred on the island in September 1996. Using mark-recapture analysis, I estimated that the poison drop killed 27% of the birds. However, the simulations model predicted that this mortality would not affect the population's viability.

I altered the model structure so that effects of predation could be included, to simulate a reintroduction onto the mainland. I also added annual and biennial poisoning regimes to see if these could be used to counteract the effects of predation, and at what predation levels they would prove beneficial to the saddleback population. To do this I assumed that a poison drop would result in no predation for six months, then predation would return to normal levels. Annual poisoning was better at increasing the population's viability than biennial poisoning, but neither allowed the population's persistence at predation levels that would probably occur on the mainland.

I also looked at the effects of harvesting the island population, to see what the maximum sustainable rates were. The results from this indicated that the [*sic*] up to 139 birds could be harvested from the population at a single occasion without affecting the population's viability, if the population was left to recover afterwards.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, pest management

Davidson, R.S.; Armstrong, D.P. 2001: A saddleback population model with implications for reintroduction to the mainland. New Zealand Ecological Society Jubilee Conference, 27–30 August 2001, University of Canterbury, Christchurch (unpublished report).

The saddleback is an endangered endemic forest bird that only occurs on islands. In 1992 the saddleback was released on Mokoia Island to produce the only mainland population. We used the data collected from this population over its first five and a half years to construct a simulation model. We were able to estimate the population's vital rates at different densities, and the impact of an aerial brodifacoum poison drop on the population was observed. A sensitivity analysis of the population model indicated that the population was most susceptible to changes in juvenile survival.

We used the model to assess the viability of releasing saddleback onto the mainland. A mainland population of saddleback would have lower levels of survival and reproductive success than an island population as mainland reserves have not completely eradicated pest species. We looked at the effect that reducing these parameters had on the population. The population was less sensitive to reduced reproductive success than to reduced survival. We looked at whether a saddleback population could survive an annual poisoning program where the baits were aerially distributed. This suggested that a saddleback population would not survive repeated poison drops.

Keywords: fauna, conservation management, North Island saddleback, *Philesturnus carunculatus rufusater*

Davidson, R.S.; Armstrong, D.P. 2002: Estimating impacts of poison operations on non-target species using mark-recapture analysis and simulation modelling: an example with saddlebacks. *Biological Conservation 105*: 375–381.

Poison operations to control or eradicate exotic mammals are a key component of conservation management in the South Pacific. They also result in by-kill of native species. It is therefore important to develop reliable methods for estimating by-kill and assessing its impact. The North Island saddleback (*Philesturnus carunculatus rufusater*), a rare New Zealand forest bird, was reintroduced to Mokoia Island in 1992, and 4 years later there was an aerial drop of cereal pellets containing Brodifacoum aimed at eradicating mice. We used mark-recapture analysis on resighting data collected from

1992 to 1997 to estimate the by-kill of saddlebacks attributable to this poison drop. We nominated a set of candidate models to explain the data, and compared these using Akaike's Information Criterion. The analysis showed that saddleback survival was substantially lower than expected in the 6-week interval after the poison drop, taking age, density dependence, season and random variation into account. Taking expected survival rates into account, the probability of an adult being killed was estimated to be 0.45 (95% CI = 0.34–0.56), and the probability of a juvenile being killed was estimated to be 0.35 (95% CI = 0.05–0.75). We then used a simulation model developed for the population to assess the longer-term impact of this mortality. While the mortality set back the expansion of the population by 1–2 years, we predicted that the population would have recovered fairly quickly and ultimately reach the same carrying capacity. Mark-recapture analysis permits precise estimates of background survival rates unconfounded by seasonal or random variation.

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, pest management, mice, *Mus musculus*, Norway rats, *Rattus norvegicus*

Dumbell, G.S. 1998: (Draft) Mokoia island ecological management strategy. Applied Ecology Ltd. Contract report for Department of Conservation, Auckland (unpublished report). 73 p.

[A very comprehensive summary of information pertaining to Mokoia—written under a strategic planning format, with the following sections: The Vision, The Values, Introduction, Mokoia Island Trust Board, Department of Conservation, Ecological Management, Ecological Objectives, Acknowledgements, References, and Appendices. It contains some key information on the when and where of historical conservation management, which is listed in the island chronology (Appendix 1). This is an informal (i.e. unpublished) document that is still referred to by researchers and managers. The primary reason for this work was to integrate the two partners' (iwi and the Crown, i.e. DOC) visions and management of the island. It outlines and links the Mokoia Island Trust Board's Strategic Plan (c. 1997) and DOC's Bay of Plenty Conservation Management Strategy (1997–2007)—BRC.]

Keywords: biodiversity, inventory, history, conservation management, Mokoia Island Trust Board, Mokoia Island Wildlife Refuge

Field, D. 1989: Notes on the restoration of Mokoia Island. Department of Conservation, Rotorua (unpublished report). 2 p.

Mokoia Island is described as a dome of Haparangi rhyolite. It is roughly circular in outline, is approximately 1200 m across and has an area of 136.7 hectares. The highest point is 180 metres above lake level and 490 metres above sea level. The shortest distance to the mainland is 1750 m. On the western side of the island, steep slopes descend to a rocky shoreline, while on the eastern side there is a strip of low-lying land along the shore.

According to Maori legend, Mokoia Island was occupied for at least 500 years. The most recent inhabitants were members of the Arawa tribe, the last of who left the island in 1950. Few people have lived on the island in the last 70 years. Kumara and potatoes were cultivated on the flatter parts. The island is a Wildlife Refuge and was used by the Department of Internal Affairs for rearing pheasants from 1952 to 1961.

About 90% of the island is covered by dense second-growth with some more mature forest adjacent to the flat. The vegetative cover of the island has been modified by fires and cultivation over centuries. Since the last residents left the island the frequency of the fires has diminished and little damage has been done to the vegetation in the last 40 years. The plant species present are now diverse aided by planting by the [Rotorua] Botanical Society and associates.

The terrestrial animal communities on Mokoia are not vast and are restricted to introduced species and the more mobile passerine birds. It is not known what species naturally occurred on the island but it is reasonable to assume that all flighted species of bird, an assortment of reptiles and invertebrate species from the mainland were present. Rats, mice and goats are the only pests on the island and all these species are currently receiving treatments to eradicate them. It is not known when rats reached Mokoia Island but they were well established at the time of the Internal Affairs pheasantry in 1951. It is most likely that rats were brought to the island by vessels bringing stores to the island during the island's occupation. Mice are a very recent arrival not being recorded prior to 1989. [Previous work on the rodents on Mokoia Island did not record the presence of mice (Daniels & Beverage 1965)—BRC.]

Keywords: fauna, conservation management, history

Field, K. 1995: Hanky-panky among the hihi. *The New Zealand Herald*, 1 November 1995.

[This popular magazine-type article outlines the Massey University Ecology Department's bird research (mainly hihi *Notiomystis cincta*, and also morepork *Ninox novaeseelandiae*) on Mokoia island—BRC.]

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*, morepork, *Ninox novaeseelandiae*

Forrester, R. 1989: Good old-days recalled with trout lineup. *The Daily Post*, 8 December 1989.

[An opinion article, reproduced in part here, recalling a personal experience of the fire on Mokoia.]

I'm digressing, but a similar situation arose with the rats on Mokoia. I recall when the Department of Internal Affairs decided to make a pheasant farm out of Mokoia Island because there would be no need for fences and the pheasants could not fly off the Island. The flats were ploughed up by landrover so that clover seed could be planted, the scrub hillsides were burnt off and tons of pollard and fowl food was carted across to feed the pheasants. The pollard encouraged the rats and caused the rat plague which DOC have ironically been cleaning up over the past months. I am sure this would make a good yarn for Ripley's Believe If Or Not, as it gets better. You see I was the fellow instructed to take a landrover to Mokoia Island and plough up all the flats and plant clover seed. A mate of mine was the feller instructed by the then Conservator of Wildlife to take a flame thrower and burn all the scrub on the hillsides. Well, he burnt it all right and it's a wonder the island didn't become devastated. The flames could be seen for miles and during the night the Conservator of Wildlife organised fire fighting teams to go by boat in relays to extinguish the blaze. The next day in the local paper, the Conservator of Wildlife was highly commended for putting out the fire, but he never told anyone he had caused it.

[Article and reference information courtesy of Craig Cooper, Editor of *The Daily Post*—BRC.]

Keywords: history, pheasant management, fire

Grange, L.I. 1937: The geology of the Rotorua–Taupo subdivision, Rotorua and Kaimanawa divisions. *Geological Survey Branch Bulletin No. 37*. Department of Scientific and Industrial Research, Wellington. 138 p.

[From the letter of transmittal:]

... The Bulletin contains 138 pages of letterpress, including an index, together with thirteen geological maps, several locality maps, numerous plates of photographs and line drawings, and two block diagrams. It describes the physiography and areal geology of 2,090 square miles of the active volcanic region of the North Island. The district, on account of its innumerable hot springs and other thermal phenomena, is an increasingly popular tourist and health resort. The principal industries are sawmilling and farming. The native forests yield much valuable timber, and exotic trees, now planted over millions of acres, will make the region one of the chief sources of forest products in New Zealand. Agriculture and grazing, long retarded by poor access and the prevalent deficiency diseases of stock, are likely to develop greatly. The mining industry so far has contributed little except a few hundred tons of sulphur, bat there are large resources of diatomite, pumice, and pozzolana at present quite unutilized.

The report is based on fieldwork carried out by Dr Grange, or under his direct supervision, between October 1926, and May 1930. Before Dr Grange was able to complete his report, he was transferred to other work, which fully occupied him for a number of years. In order to assist Dr Grange, Dr Marwick and Mr Fyfe spent three weeks in the area, and, with the aid of the field-sheets, prepared the account of the physiography and structure ...

[Mokoia is described as a dome of Haparangi rhyolite, with a photographic plate on page 72. In the 'Physiography & Structure' section, the history of eruptions within the lake are noted, with the 'most important one' (assuming size) building Mokoia. From the 'Hot Springs & Fumaroles' section: 'Close to the eastern and southern shore of Mokoia Island are clear alkaline warm pools. Hinemoa's Bath (analysed), a spring about 35 ft. by 15 ft. and 4 ft.

deep, has a temperature of 38°C at the north-eastern end, but is cold at the opposite end. On the floor is a growth of green algae. The springs on the eastern shore resemble Hinemoa's bath except that they are smaller'.]

Keywords: geology

Griffiths, R. 1998: Proposal for implementing a long-term invertebrate monitoring programme on Mokoia Island. Department of Conservation, Rotorua (unpublished report). 7 p.

[From the Introduction:]

The justification for this project is based on the present lack of knowledge about the Mokoia invertebrate population. I have summarised this lack of information into three main areas. There is currently no information on the composition of the Mokoia Island invertebrate population. This is despite several intensive studies carried out by Massey and Auckland Universities on Mokoia's recently established North Island saddleback, stitchbird and North Island robin populations. No formal investigation, with the exception of John Perrott's current study on cicadas, has been attempted. The only positive identification of a resident insect species is *Hexatricha pulverulenta*: Cerambycidae (Hutcheson 1993, in Dumbell 1998). The impact of mice on the Mokoia Island invertebrate population is unknown. Mokoia Island has a long history of habitat modification and rodent infestation and it is likely that many larger invertebrates, particularly those that are ground dwelling will have either been reduced to very low numbers, or have been driven to local extinction (Green 1996, in Dumbell 1998). Rats were eradicated from Mokoia Island in 1989 but it is likely that mice are continuing to place pressure on remaining invertebrate populations. However, the scale of this impact is unknown. There is little information on the response of island invertebrate populations to mice eradication. Only one other study has been attempted in New Zealand to quantify these effects (Fitzgerald et al. 1999, in prep). Prior to the September 1996 attempt to eradicate mice, students from Rotorua Lakes High School undertook monthly insect activity sampling using the protocol set out in Appendix 1. This sampling was designed to track changes in insect activity once mice had been eliminated. However, the eradication attempt failed and the objective of this research was not achieved. Consequently, it is proposed to implement a long-term invertebrate monitoring programme on Mokoia Island. This would provide information on the composition of the invertebrate population. It would also provide information on the impacts of mice on the Mokoia invertebrate population if another mice eradication attempt was carried out in the future.

Keywords: conservation management, invertebrates

Griffiths, R. 2001: Operation prescription for the eradication of mice from Mokoia Island. Department of Conservation, Rotorua (unpublished report). 14 p.

Conservation goal:

From the Mokoia Island Ecological Management Strategy (Dumbell, 1998) the goal for Mokoia is: 1. To restore the ecology of Mokoia, using the best available knowledge and expertise so it is: a) The most intact and functional island habitat in New Zealand; b) able to provide a secure home for populations of threatened plants and animals; c) recognised as the best example of partnership conservation in New Zealand where people and conservation are an integrated part of the island and its future.

Operational objectives: 1. Mice are eradicated from Mokoia. 2. The operation is conducted without accident or incident. 3. The operation is completed on time and within budget. 4. The pest-free status of the island is maintained, once the operation has been completed.

Keywords: conservation management, pest management, mice, *Mus musculus*

Griffiths, R.; Lander, R. 2005: Mokoia Island pest quarantine and contingency plan. Department of Conservation, Rotorua (unpublished report). 26 p.

[A report describing the quarantine and contingency planning surrounding a potential 'pest' animal (rodent, mustelid, cat and/or dog) incursion onto Mokoia. This report details the protocols for responding to each species and/or group.]

Keywords: conservation management, island biosecurity

Gummer, H. 2002: Report on *Salmonella* alert in hihi transferred from Mokoia Island to Kapiti Island on 16/08/02. Department of Conservation, Wellington (unpublished report).

[From the Introduction:]

The translocation of hihi from Mokoia Island (Bay of Plenty CO) to Kapiti Island (Wellington CO) was implemented in August 2002 in an attempt to remove this species from an area where a population is not considered to be self-sustainable without on-going management. The BOP Conservancy had limited funds and staff availability to commit to hihi management on Mokoia, influencing this decision. Kapiti Island was chosen as the destination site because there is currently a hihi population in the early stages of establishment; this struggling population was predicted to benefit from a boost in numbers, in particular males.

Keywords: conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Healy, J. 1962: Geology of the Rotorua District. Vulcanicity and vegetation in the Rotorua District: a symposium. Pp. 53–58 in: Proceedings of the New Zealand Ecological Society, Rotorua, 20–22 October 1992.

[The Introduction in full follows.]

The Rotorua district is 3500 square miles in area, extending north from Maroa and Murupara to the Bay of Plenty coast between Matata and Tauranga. The Taupo Volcanic Zone, which lies as a belt north-east from Ruapehu to White Island, passes through the centre of the area. In this account the rocks have been divided into a number of groups on a lithologic basis, and their distribution and approximate age range are shown in Figure 1. These groups do not include late Quaternary volcanic ash, which mantles the entire area superficially and in places is more than 40 ft thick.

[The author notes that Mokoia is the result of an extrusion/eruption, although it is much younger than the other extrusions of rhyolite, e.g. Ngongotaha, within the Rotorua Caldera—BRC.]

Keywords: geology, Taupo Volcanic Zone, volcanicity

Heaphy, J. 2003: Transfer of NI robin from Mokoia to Tuhua in May 2003. Unpublished report, held at Tauranga Area Office, Department of Conservation, Tauranga (file NHE-03-51-01). 21 p.

[From the report Summary:]

Operational targets:

- Successful capture, translocation and release of up to 40 NI robins from Mokoia to Tuhua with less than 15% mortality.
- Complete ongoing incidental monitoring for the three years following release to determine whether successful breeding is occurring on Tuhua and that robin are gradually extending their distribution range on the island.
- If successful breeding has not been identified after the first breeding season e.g. through sighting of unbanded birds, then investigate a dedicated monitoring programme for the second season to determine reasons why successful breeding is not occurring.

Result:

- 42 NI robins successfully transferred from Mokoia to Tuhua on Saturday 17 May 2003 with no injury or mortality of birds and no personnel accidents during the entire capture-release operation. All birds released in good health on Tuhua within 70 minutes of departing Mokoia with involvement of Tangata Whenua from both islands in release. Media releases made.
- First fledglings sighted 11 November 2003.
- A specific robin monitoring survey on 5-8 April 2004 following the first breeding season found 23 of the 42 original banded birds, 55 unbanded (bred on Tuhua) birds, and 3 unknown birds for a total of 81 robin. These were distributed over the entire island.
- All actual translocation targets met or exceeded.

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Holland, D. 1997: Observations on Mokoia Island (Lake Rotorua): August 18–28 1997. Unpublished report held on file at Bay of Plenty Conservancy, Department of Conservation, Rotorua.

[This report details the author's inventory of biological factors on the island. It contains eight sections, including a pest plant list, with plant control priorities and recommended actions.]

Keywords: biodiversity, inventory, conservation management, pest plants, weed management

Hooson, S.; Jamieson, I.G. 2003: The distribution and current status of New Zealand saddleback *Philesturnus carunculatus*. *Bird Conservation International 13*: 79–95.

[The Summary states the following:]

This paper reviews and updates the distribution and status of two geographically distinct subspecies of New Zealand Saddleback *Philesturnus carunculatus*, a New Zealand forest passerine that is highly susceptible to predation by introduced mammals such as stoats and rats. The recovery of the North Island and South Island saddleback populations has been rapid since translocations to offshore islands free of exotic predators began in 1964, when both subspecies were on the brink of extinction. South Island saddlebacks have gone from a remnant population of 36 birds on one island to over 1,200 birds spread among 15 island populations, with the present capacity to increase to a maximum of 2,500 birds. We recommend that South Island saddleback be listed under the IUCN category of Near Threatened, although vigilance on islands for invading predators and their subsequent rapid eradication is still required. North Island saddlebacks have gone from a remnant population of 500 birds on one island to over 6,000 on 12 islands with the capacity to increase to over 19,000 individuals. We recommend that this subspecies be downgraded to the IUCN category of Least Concern. The factors that limited the early recovery of saddlebacks are now of less significance with recent advances in predator eradication techniques allowing translocations to large islands that were formerly unsuitable. The only two predators that still cohabit some islands with saddleback are Pacific rats or kiore *Rattus exulans* and Weka *Gallirallus australis*, a flightless native rail. Although North Island saddlebacks coexist with kiore, South Island saddlebacks do less well in their presence, possibly because the relict population had no previous history with this species of rat. The impact of Weka as predators of saddlebacks is less clear, but population growth rates appear to be slowed in their presence. It is recommended that while current recovery strategies involving island habitat restoration and translocations be maintained, management effort should also be directed towards returning saddlebacks to selected, "mainland island" sites, where introduced pests are either excluded by predator-proof fences or controlled at very low levels by intensive pest management.

[The author notes the translocation of saddleback onto Mokoia—BRC.]

Keywords: research—North Island saddleback, fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*

Howard, M.; Christensen, B.R. 2005: Report on Mokoia and Ngongotaha invertebrate samples ID and analysis. Department of Conservation, Rotorua (unpublished report). 3 p.

[The Background and Discussion are reported in full.]

Mokoia (island) is the largest island within the Rotorua Lakes Area, containing a population of the threatened North Island saddleback. Mokoia is an important icon not only for the Rotorua area, but also for the wider Bay of Plenty region. It is a focus of key relationships for the Department of Conservation with local iwi, and the national captive (animal) management group (CMaG) including a potential increasing involvement with the Operation Nest Egg (ONE) work.

Mokoia is currently predator-, and pest animal- (i.e. mammalian-pest) free. An increased level of kiwi management will occur over the next ten years, and Mokoia offers the chance to act as a protective site for kiwi (rearing) within the mainland. Knowledge on the composition and abundance of ground invertebrates on Mokoia would be vital to the likely carrying capacity for kiwi on the island. This would additionally add to the knowledge base for the management of the broader ecosystem health by providing a dataset of pre- and post-management (removal of mammalian pests) invertebrate assemblage information.

While only a small sample of the total collection (145 samples equates to approx. 4% of total collection), it covered the complete time range of the sampling project, from the earliest (30/10/1999) to the most recent (9/09/2003). The samples currently stored are therefore from one and half years to over five years old from when they where removed from the pitfall traps.

A review of the 145 samples ... including the 100 prescribed to this project identified 19,195 individual invertebrate specimens. Two of the 145 samples were either degraded or partially decomposed, although the contents of the samples still could be identified. A few soft-bodied invertebrates e.g. Pulmonata (snails, and slugs), etc. were degraded, although could be identified to the level requested; i.e. identified to order, e.g.

2003	Oct	10/10/2003	Mokoia	1	7	B	Lepidoptera	0.5–1.0	1	soft body mass only

Generally the samples are in very good condition, with 1.4% (2 of 145) of the samples processed showing some degradation although not enough to discard the samples. Even the dried-out samples could be re-constituted by soaking in 70% ethyl alcohol and their contents sufficiently identified. The contents of the samples could be easily identified to the level requested; i.e. order. The (19,195) individual invertebrates looked at and processed still had good structural integrity even though the curation of the stored samples is currently somewhat left to be desired.

Keywords: invertebrates, conservation management, Mt Ngongotaha

Hunt, K. 2001: (Draft) Survey and monitoring in the Rotorua Lakes Area, Bay of Plenty Conservancy: Volume II Appendices. Department of Conservation, Rotorua (unpublished report). 194 p.

[This is a compilation of biodiversity information on land parcels administered by DOC within the Rotorua Lakes Area, including Mokoia Island. It includes botanical and fauna conservation rank (measures for conservation management prioritisation), flora and fauna lists, information on threatened species, references to vegetation maps, and threats to protected areas, including introduced pest plant and animal species. Volume II provides the inventory on each land parcel, excluding topographical maps. While Volume II was completed in draft form, Volume I (the Summary) of this set was not completed by 2001, although it is now in draft form—BRC.]

Keywords: biodiversity, inventory, conservation management, Mokoia Island Wildlife Refuge

Ihaka, J. 2004: Island no haven for stitchbird. *The Daily Post*, 22 September 2004.

[This article outlines Dr John Perrott's experiences and research findings on hihi (*Notiomystis cincta*), and why hihi were unsuccessful in establishing a growing population at Mokoia.]

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Jakob-Hoff, R. 2005: Report on disease screening of North Island robins, (*Petroica australis longipes*), on Mokoia Island, Rotorua. New Zealand Centre for Conservation Medicine, Auckland (unpublished report).

[From the Discussion and Conclusion (as no Summary was given):]

Mokoia island has the highest concentrations of robins anywhere in New Zealand (David Pattemore, pers. comm.). Given this population density, combined with the territorial nature of these birds, one might expect stress levels to be relatively high and this could provide a suitable environment for parasitism and disease to flourish. Although, due to our small sample size, this survey must be viewed with caution as being representative of the entire island population, it does suggest that, at least in the collection area, there is a robust and healthy population of robins. This part of the island (the southwest corner between Hinemoa's pool and IR gully) contains dense stands of native bush and, as noted, an abundant supply of invertebrate food, both features that are clearly providing adequately for the birds' needs.

Another species, the hihi or stitchbird, had to be removed from this island as a result of high mortality rate due to the fungal disease, aspergillosis. This was related to the species' susceptibility and the high fungal spore counts encountered in the ecologically disturbed habitats on the island (Perrot, J.K. 2001, The Ecology of *Aspergillus fumigatus* and Implications for Wildlife Conservation in Modified Environments, PhD Thesis in Wildlife Ecology, Massey University). No direct evidence of this disease was found in the robins examined.

Conclusions:

1. No significant disease problems were detected in the 13 North Island robins examined on Mokoia Island during this survey.
2. While this limited survey cannot exclude the possible presence of disease in the robin population, it provides a useful initial baseline on which to evaluate the risk of disease transfer nom Mokoia Island to the Ark in the Park site in the Waitakere Ranges.
3. The results of this survey in combination with the current low passerine density at the translocation release site would suggest that the risk of disease transfer is moderately low.
4. No disease surveillance data on passerines in the Waitakere Ranges has been conducted [*sic*] so the disease risk to the translocated robins at the release site is unknown. However, Mokoia Island clearly has a thriving population of robins which the Department of Conservation considers will be relatively unaffected by the loss of the birds to be removed.
5. To improve understanding of disease prevalence and risks every future opportunity should be taken to collect more disease surveillance data (including virology) on robins and other passerines on Mokoia Island and the Ark in the Park release site.

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*, wildlife disease

Jane, G.; Ecroyd, C.E. 2001: Additions to the checklist of vascular plants of Mokoia Island (Beadel & Ecroyd 1990). *Rotorua Botanical Society 36*: 50.

[The article lists 20 species (mostly exotic) that were added to the Beadel & Ecroyd (1990) checklist. Refer to full current list in Appendix 2—BRC.]

Keywords: flora, ecology

Jansen, W.P. 1989: Mokoia rat eradication project plan. Department of Conservation, Rotorua (unpublished report). 45 p. including appendices.

[Objectives and Summary are reported in full.]

The aim of this project is to eradicate *Rattus norvegicus* from Mokoia Island in Lake Rotorua without endangering existing conservation values or public safety. It is planned to achieve eradication through saturation poisoning with "Talon 20p" (brodifacoum) poison. Lines will have to be cut where necessary to provide access to all parts of the island. All poison baits will be laid in bird-proof bait stations. These stations will be placed at intervals along the cut lines and be loaded daily with bait over a 15 week period from 22 May to 31 August. The success of the campaign will be checked daily during May–August period and during follow-up trips where index and attractant baits will be used to assess the rodent population. Prior to any poisoning taking place an index line will be run for 1000 nights. This will be our base line and will be repeated at the completion of the operation and at suitable intervals there after to check for possible reinvasion or build up in rats which have escaped the poison campaign.

[The report contains a location diagram of robin observations—BRC.]

Keywords: fauna, ecology, conservation management, pest management, Norway rats, *Rattus norvegicus*

Jansen, W.P. 1992: Introduction and subsequent observations of a population of North Island robin (*Petroica australis longipes*) to Mokoia Island, Lake Rotorua. Department of Conservation, Rotorua (unpublished report). 10 p.

Seventeen North Island robin (*Petroica australis longipes*) were released in June 1991 onto Mokoia Island, Lake Rotorua. Thirteen birds were caught from the wild some 20 km due west of the release site. A further four birds came from captivity, three of these being offspring raised in captivity by the fourth. All birds originated from the Mamaku Plateau. Sexing of the individuals was not conclusive; however it is believed that 10 female and male robins were released. Birds were monitored randomly after release. Casual observations were combined with data from specific surveys to assess survivorship of the released birds and juvenile production. A minimum of fifteen robin contributed to the 1991/92 breeding season producing at least sixteen juveniles.

[The report contains a location diagram of robin observations—BRC.]

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Jansen, W.P. 1993: Introduction of North Island robins to Mokoia Island, Lake Rotorua, and public involvement. *Ecological Management 1*: 39–43.

Seventeen North Island robins (*Petroica australis longipes*) were released in June 1991 onto Mokoia Island, Lake Rotorua. Of these, 13 birds were caught from the wild and four from captivity. All birds originated from the Mamaku Plateau. A minimum of 13 robins survived the release and produced at least 16 juveniles in 1991/92.

[The paper contains a location diagram of robin observations—BRC.]

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Jansen, W.P. 1994: Report to Mokoia Island Trust Board on wildlife liberations, monitoring and management on Mokoia Island, Lake Rotorua. Department of Conservation, Rotorua (unpublished report). 2 p.

[This article provides a background history of protected bird species liberations onto Mokoia Island.]

Keywords: fauna, ecology, conservation management, translocations

Kelly, D.; Ladley, J.; Robertson, A.; Peterson, P.; Merrett, M. 1999: Pollen and dispersal limitation in *Fuchsia excorticata* on the New Zealand mainland. P. 30 in Rose, A.B. (Ed.): Proceedings of the New Zealand Ecological Society Annual Conference, 29 June–2 July 1999, Blenheim. Landcare Research.

Conservation of ecosystems requires that interactions such as mutualisms are maintained. Recent work suggests that reduced densities of bird pollinators and dispersers may be negatively affecting reproduction in some native plants. Here we describe pollination experiments on *Fuchsia excorticata*, tree fuchsia, in 1998/99 at 6 mainland sites. *Fuchsia* is gynodioecious and self-compatible, and pollinated by bellbirds and tui when these birds are present. Female flowers bagged to exclude all pollinators never produced fruits. Bagged hermaphrodite flowers gave low fruit set (0–32%). Hand pollination with cross or self pollen gave high to very high fruit set (56–96%) except at Ruahine (31%). The difference in fruit set between hand pollinated flowers and naturally pollinated flowers accessible to birds gives an index of the adequacy of the pollination mutualism. Natural pollination varied from excellent (Mokoia Island, Nelson Lakes, Opepe), through moderately reduced (Banks Peninsula, Ohakune) to poor (Ruahine). Female plants were much more susceptible to failure of natural pollination than hermaphrodites, which may self-pollinate. Dispersal was also only partly effective. Overall, low bird densities on the mainland are limiting reproduction in fuchsia in some areas, as has been previously shown for *Peraxilla*.

Keywords: flora, fauna, ecology, conservation management, tree fuchsia, *Fuchsia excorticata*

Lambert, D.M.; King, T.; Shepherd, L.D.; Livingston, A.; Anderson, S.; Craig, J.L. 2005: Serial population bottlenecks and genetic variation: translocated populations of the New Zealand saddleback (*Philesturnus carunculatus rufusater*). *Conservation Genetics* 6: 1–14.

The genetic effects of population bottlenecks have been well studied theoretically, in laboratory studies, and to some extent, in natural situations. The effects of serial population bottlenecks (SPBs), however, are less well understood. This is significant because recurrent population bottlenecks are likely to be a common feature of the life history of many species. The lack of understanding of SPBs in natural populations has certainly been hampered by a lack of good examples where it can be studied. We report the results of a study into island populations of North Island Saddleback (*Philesturnus carunculatus rufusater*) that have undergone 13 translocations since 1964, all but one of these has been deliberate and for which detailed records are available. We have examined nine island populations of this passerine bird, from the source population, three first-order bottlenecked and five second-order bottlenecked populations. We examine variation in these nine populations using multilocus minisatellite DNA markers, together with Mendelian loci comprising six microsatellite DNA loci and a variable isozyme locus. Despite the generally low level of genetic variation in the Saddleback source population, we were able to detect a pattern of significant changes in both the mean number of minisatellite DNA bands per individual and the frequency of alleles at the Mendelian loci, with increasing population bottlenecks. This study generally shows that in a natural population, SPBs result in more pronounced genetic changes than do single population bottlenecks by themselves, thereby highlighting their importance for the conservation of rare and endangered species.

[The authors note the successful translocation of saddlebacks to Mokoia, and also outline the population stability—BRC.]

Keywords: fauna, ecology, conservation management, translocations, population bottlenecks, North Island saddleback, *Philesturnus carunculatus rufusater*

Lettink, M.; Armstrong, D.P. 2003: An introduction to using mark-recapture analysis for monitoring threatened species. *Department of Conservation Technical Series 28*. Department of Conservation, Wellington. 63 p.

Accurate and reliable monitoring is necessary for effective management of threatened species in New Zealand. Mark-recapture studies are a powerful tool for conservation managers, and can be used in any situation where animals can be marked (or otherwise identified) and detected later by capture or sighting. In addition to estimating population size and survival rates, mark-recapture methods can be used to evaluate impacts of threats on survival, record population trends, collect information for population viability analyses, set performance targets against which responses to management can be measured, and highlight areas where further research is necessary. This report has three main sections. The first section introduces the basic principles of mark-recapture methodology that conservation managers need to understand to design effective mark-recapture studies. In the second section, specific guidelines for estimating abundance, survival and population growth rates are provided. We show which methods are appropriate for different situations, how field studies should be designed to avoid violating assumptions of mark-recapture methods, and how to get started on analysing the data. In the final section, we review a case study involving long-tailed bats (*Chalinolobus tuberculatus*), and use this to illustrate some problems that may be encountered in mark-recapture studies.

[The report cites Davidson & Armstrong's (2002) '45% population death' estimation of saddlebacks 'following a poison drop on Mokoia Island, setting the population growth back by one or two years but having no long-term impact on the population'—BRC.]

Keywords: fauna, ecology, conservation management, North Island saddleback, *Philesturnus carunculatus rufusater*, mark-recapture

Lovegrove, T.G. 1996: Island releases of saddlebacks *Philesturnus carunculatus* in New Zealand. *Biological Conservation* 77: 151–157.

The success of 45 releases of saddlebacks *Philesturnus carunculatus* between islands in New Zealand is compared. Forty-three releases were 'immediate' (birds released immediately on arrival at site), and two were 'delayed' (birds released after 12 days' conditioning in an aviary on site). Most releases with a balanced sex ratio on predator-free islands were successful. Others failed because (1) predators were still present, or arrived after release, or (2) too few birds were released. The success of releases may have been enhanced by the birds' limited dispersal, small territories, flocking behaviour, high reproductive rate and broad habitat requirements. Before one release, prior conditioning of the birds in an aviary on site did not improve their subsequent survival. Immediate releases should be used for wild caught birds, and the captive period minimised. Conditioning may be appropriate for captive-reared birds to adjust to the wild.

[The author summarises saddleback translocations within a table, with the following entry for Mokoia:

DATE OF RELEASE	SOURCE ISLAND	RELEASE ISLAND	POSSIBLE PREDATORS	AREA (ha)	NO. RELEASED	RESULT	NOTES, POPULATION SIZE	REFERENCES
12 Apr 1992	Tiritiri	Mokoia	M, W	135	36	s	c. 140 by Sep 1994	P. Jansen, pers. comm.

M—mice; W—weka; s—successful translocation.]

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*

McEwan, W.M. (Ed.) 1987: Ecological regions and districts of New Zealand. Sheet 2: Central North Island from Meremere to Eastern Hawkes Bay. *New Zealand Biological Resources Centre Publication No. 5.* Department of Conservation, Wellington. 125 p.

[A descriptive account of the central North Island covering the Rotorua ecological plateau. It contains short sections on topography, geology, climate, soils, vegetation, development and mammals.]

Keywords: topography, geology, climate, soils, vegetation, development, mammals

Meads, M.J.; Fitzgerald, B.M. 1993: List of invertebrates on Mokoia Island, Lake Rotorua. *Conservation Advisory Science Notes 343*. Department of Conservation, Wellington. 9 p.

A survey of invertebrates was undertaken on Mokoia Island, Lake Rotorua, for three days in February 2000, with the emphasis on larger ground-dwelling species that might be important in the diet of house mice, or which might recover in numbers when mice are eradicated. A few additional species taken in pitfall traps by R.W. Griffiths in 1999 and 2000 have been included in the list. The species list comprises 124 taxa, including 51 species of spiders in 23 families, 18 species of beetles in 11 families, and 14 species of Lepidoptera in 9 families. Species typical of the forest floor were poorly represented, and this may reflect the long history of modification and clearing of the forest, and of the presence of mice and Norway rats on the island. Also, rare species on the forest floor may be missed during a brief survey such as this, but may be recorded during the current programme of pitfall trapping. A list of indicator species that could be important in the diet of mice, or which may increase significantly in numbers if mice are eradicated from the island, is included.

Keywords: invertebrates, ecology, conservation management, pest management, mice, *Mus musculus*, Norway rats, *Rattus norvegicus*

Moorcroft, G. 2003: Transfer report: Mokoia hihi translocation. Department of Conservation, Wellington (unpublished report).

[From the report Summary:]

Operational targets:

1. To transfer all hihi from Mokoia Island to Kapiti Island.
2. To complete the capture and transfer of hihi during the week of 12–16 August 2002.
3. The key criteria in determining if the transfer is a success is the presence of all released hihi 3 months after the release (December 2002).

N.B: As not all hihi were transferred by 16 August 2002 a second transfer was approved and carried out in November 2002, under the same Transfer Proposal: BOPCO-22187.

Justification:

In December 2001 Chris Jenkins, Conservator, Bay of Plenty Conservancy decided, supported by Peter Lawless, Regional General Manager Northern, to transfer all hihi on Mokoia Island to Kapiti Island. This decision was based on the inability of the Bay of Plenty Conservancy to continue supporting the management programme on Mokoia. This was mainly due to the lack of resources, particularly staff capacity and funding needed to sustain the population to the required level. A key factor of this was the Department's inability to increase the population due to factors such as disease issues and nest mites.

At its May 2001 meeting the Hihi Recovery Group recommended that if the option of continuing management of hihi on Mokoia Island was not available then Kapiti Island was the most suitable transfer site. The latter proposal was fully supported by Chris Jenkins and Wellington Conservancy and Authorities 9/376 ROA and 9/376A ROA issued by Wellington Conservancy approved the transfers with a number of conditions.

Result:

1. All hihi have been removed from Mokoia
2. A second transfer had to be undertaken in November 2002

<u>Transfer one:</u>

Twelve hihi were transferred to Kapiti.

Six hihi are reported to be alive and well as at 12 December 2002. Four are known to have died (three from morepork predation and one from unknown causes) and the wereabouts [*sic*] of the other two is unknown.

<u>Transfer two:</u>

Three hihi and three eggs were transferred to Mt Bruce. One bird was later transferred to Kapiti Island.

The birds are doing well, the eggs were infertile.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Nicholas, J. 1995: Royal wave for Rotorua. *The Daily Post*, 22 November 1995.

[This report on HRH Prince Phillip's visit to Rotorua mentions an hour-long visit to Mokoia to view the stitchbird conservation programme.]

Keywords: conservation management

Owen, K. 1997: Transformation of an inland island (Mokoia Island) now home to endangered species. Pp. 74–87 in Johnson, T.; Boyes, P. (Eds): New Zealand Conservation Management Group Annual Conference Proceedings, 1997, Rotorua.

[An outline of conservation management that has occurred on Mokoia. Updated in 2002—BRC.]

Keywords: conservation management

Owen, K. 2002a: Hihi transfer Mokoia Island to National Wildlife Centre: report to Wellington Conservancy. Department of Conservation, Rotorua (unpublished report).

[This report outlines the hihi transfer to the National Wildlife Centre at Mount Bruce. Three female hihi and three eggs were transferred from Mokoia.]

Keywords: conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Owen, K. 2002b: Hihi transfer Mokoia to Kapiti: report to Wellington Conservancy. Department of Conservation, Rotorua (unpublished report).

[This reports on the hihi transfer to Kapiti Island. Twelve hihi (eight males and four females) were transferred from Mokoia.]

Keywords: conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Owen, K. 2002c: Transformation of an inland island (Mokoia Island) now home to endangered species. Department of Conservation, Rotorua (unpublished report). 14 p.

[An outline of conservation management that has occurred on Mokoia. This is updated from Owen's (1997) report—BRC.]

Keywords: conservation management

Owen, K. 2003a: Mokoia Island. *Rare Bits 49*: 23.

[The report in full follows.]

A North Island brown kiwi translocation proposal for Operation Nest Egg (ONE) and wild birds onto Mokoia Island has been prepared by the Mokoia Island Trust Board. Moana, a juvenile male (ex Whirinaki Forest) raised from an egg at Rainbow Springs in Rotorua, was the first of the founder population to be released on to the island on Waitangi Day. On the release day the Trust Board members, Minister of Conservation, the South African deputy Chief Justice, other special guests and a large number of Te Arawa attended the release ceremony. Another ONE juvenile kiwi will be released onto Mokoia over the next few months.

Keywords: fauna, translocations, North Island brown kiwi, *Apteryx australis*

Owen, K. 2003b: North Island brown kiwi releases: Mokoia. *Rare Bits 50*: 7.

[The report in full follows.]

A further release of three sub-adult North Island brown kiwi (Tutanekai, Hinemoa and Tiki) took place on Mokoia Island on 22 July 2003. The three birds (raised under the Operation Nest Egg programme at Rainbow Springs) were from Whirinaki Forest Park, and join Moana nui a kiwa, a wild-hatched male from Ohope Scenic Reserve. A very enthusiastic party made up of Te Arawa, Mokoia Island Trust Board members, Ngati Whare, Bank of New Zealand Kiwi Recovery Trust and DOC staff was in attendance. There are now three males and one female (Hinemoa) on Mokoia.

Keywords: fauna, translocations, North Island brown kiwi, *Apteryx australis*

Owen, K. 2005: Kiwi management plan: Bay of Plenty Conservancy 2005–2010. Department of Conservation, Rotorua. 23 p.

[This plan outlines the kiwi management on Mokoia.]

Keywords: conservation management, North Island brown kiwi, *Apteryx australis*, translocations

Owen, K.; Asquith, P. 2000: Transfer of toutouwai (*Petroica australis longipes*) from Mokoia Island to Moturoa Island. New Zealand. *Ecological Management 8*: 61–64.

The toutouwai, or North Island robin (*Petroica australis longipes*), is an endemic passerine found in central North Island forest and on Hauturu (Little Barrier), Tiritiri Matangi, Mokoia, Kapiti, and Mana Islands. Nineteen toutouwai were captured on Mokoia Island, and transferred to Moturoa Island, Northland, on 2 June 1999. This is the third population of toutouwai currently in Northland.

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Perrott, J.K. 1997: Effects of food supply and competition on the outcome of the hihi (*Notiomystis cincta*) translocation to Mokoia Island. Unpublished MSc thesis, Ecology Department, Massey University, Palmerston North.

The hihi or stitchbird (*Notiomystis cincta*) is a cavity-nesting honeyeater (family Meliphagidae) indigenous to New Zealand. Hihi were originally widespread but following European colonisation became confined to Little Barrier Island. Attempts to establish hihi on other islands appear to have been unsuccessful. The main reasons suggested for these failures are: (1) insufficient year-round supply of nectar and fruit, (2) competition from the other more dominant honeyeaters (bellbirds *Anthornis melanura*, and tui *Prosthemadera novaeseelandiae*), and (3) lack of nesting cavities.

This study was conducted on Mokoia Island, situated in Lake Rotorua. 40 hihi were translocated to Mokoia in September 1994 from Little Barrier Island. Two field-trips, lasting three to four days, were made to the island every month from August 1994 through October 1995.

The primary aim of this study is to assess whether hihi suffer increased mortality, or lose weight due to seasonal shortages in their food supply, and therefore whether artificial food supplementation would be needed to sustain a population. The methods for testing this aim involved: (1) doing food supplementation experiments throughout the year (20% sugar solution), (2) measuring changes in birds' weights and mortality throughout the year, when supplementary food was available vs. unavailable, (3) measuring nectar and fruit availability throughout the year as energy per unit area (e.g. kJ/ha), and (4) observing hihi to determine the amounts of time spent feeding on nectar, fruit and invertebrates, and any interference from tui whilst feeding at those sources.

These data allowed me to identify periods when hihi were most limited by the naturally occurring nectar/fruit supply on Mokoia. This 'limitation' is measured in terms of changes in birds' body mass, survival, reproduction, and foraging effort in response to food supplementation. These data allow me to make recommendations concerning further supplementary feeding, and planting programs on Mokoia to make the habitat more suitable to hihi.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*

Perrott, J.K. 2001: The ecology of *Aspergillus fumigatus* and implications for wildlife conservation in modified environments. Unpublished PhD thesis, Ecology Department, Massey University, Palmerston North. 114 p.

This thesis outlines my research since 1998 into inter-trophic interactions between pathogenic fungi, insects, birds, and the environment. Chapter One is a stand-alone investigation into fungal diseases associated with native cicadas on Mokoia Island (Lake Rotorua) and the Eastwoodhill Arboretum (Gisborne). Chapters Two through Four are specifically concerned with the natural occurrence of the pathogenic fungus *Aspergillus fumigatus* and its connection to hihi (or stitchbird) on Little Barrier Island (northern Hauraki Gulf), Mokoia Island, Tiritiri Matangi Island (Hauraki Gulf), and the Mt Bruce Wildlife Centre (near Masterton).

The hihi (*Notiomystis cincta*) is a small (i.e., starling sized) cavity-nesting honeyeater endemic to New Zealand. Following European colonisation, hihi became extinct everywhere except on Little Barrier Island, making the future of this species very uncertain. In response to this situation there have been several translocations of hihi to Hen, Cuvier, Kapiti, Mokoia and Tiritiri Matangi Islands from 1980 to 1996. While hihi on Tiritiri Matangi seem to be progressing well with intensive management, all previous translocations to other islands have failed to establish, self-sustaining populations. The main hypotheses given to explain these failures are insufficient year-round supply of nectar and fruit, and lack of suitable nesting cavities.

Hihi were translocated to Mokoia Island in September 1994 with nest boxes provided. However, like past translocations, hihi have continued to decline on the island with high annual mortality rates above 50%. It is not clear what factors are contributing to this high mortality rate. My MSc studies carried out on Mokoia Island during 1994–1997 demonstrated that hihi had a good year-round supply of food, and were not dying as a result of starvation. Subsequent post-mortem examinations by Professor Alley of sick and dead hihi from Mokoia from 1995–1997 has revealed that the fungal disease aspergillosis, caused by *Aspergillus fumigatus*, is the most common cause of death among those birds. In addition, captive hihi at the Mt Bruce Wildlife Centre also suffer high rates of aspergillosis, and there is presently concern regarding the susceptibility of hihi to this fungal disease. This study suggests also that past hihi translocations have failed due, in part, to birds being exposed to elevated levels of disease-causing microorganisms.

Aspergillus fumigatus is an ubiquitous fungus, and common aspergillosis-causing pathogen in birds and mammals. Infection takes place following the aspiration of fungal spores, and is primarily a respiratory disease. *Aspergillus* infections are usually considered to be opportunist following other primary infections, immunosuppression or stressful environmental conditions. Small numbers of spores can usually be tolerated by the immune system, but large numbers can cause disease and death. At present, prevention is the only effective method of controlling aspergillosis in wild bird populations.

This project is concerned with studying the ecology of *A. fumigatus,* and identifying the most likely source/s of infection in hihi. Therefore, this project is directed towards identifying the most likely source/s of *A. fumigatus* rather than the most likely causes of aspergillosis in hihi. In doing so, the primary aim of this project is to investigate whether previous hihi translocations from Little Barrier Island to young growth forests and forest edge habitats have been exposing birds to elevated levels of *A. fumigatus,* and therefore, whether *A. fumigatus* preventative management should be considered when planning future hihi translocations.

This project aimed to, A) determine whether habitat disturbance encourages the establishment of *A. fumigatus* in the environment; B) measure and compare *A. fumigatus* densities from early growth regenerating forests (i.e. Mokoia and Tiritiri Matangi Islands), a pristine mature forest (i.e. Little Barrier Island), and two mainland forest locations (i.e. Mt Bruce Wildlife Centre, and the Massey University Campus); C) measure and compare *A. fumigatus* densities in forest edge habitats and inner forest locations; D) investigate whether hihi nest boxes on Mokoia Island and natural tree cavity-nests on Little Barrier Island are promoting the growth of *A. fumigatus* and; E) investigate various types of forest disturbance events that could account for the differences in *A. fumigatus* densities found between study sites.

Results from Chapter One describe a unique and previously unreported cicada disease caused by a *Conidioblus* fungus on Mokoia Island. Results from Chapters Two and Three report elevated levels of *A. fumigatus* on Mokoia Island and at the Mt Bruce Wildlife Center [*sic*]. Low levels of *A. fumigatus* were recorded on Little Barrier Island, and moderate levels recorded for Tiritiri Matangi Island. Results indicate that forest disturbance promotes the abundance of *A. fumigatus* in the environment, and that forest edge habitats have significantly higher levels of *A. fumigatus* compared to inner forest locations. This suggests that forest disturbance alters natural disease dynamics, and increases birds' exposure to opportunistic disease-causing agents such as *A. fumigatus*. These results, in part, illustrate the functional significance of old growth forests in keeping weedy pest species like *A. fumigatus* in check. Results from Chapter Four report that hihi are exposed to elevated levels of airborne *A. fumigatus* spores while in the nest box. Additionally, results indicate that hihi re-using old nest sites would further suffer increased exposure to *A. fumigatus* spores.

Because hihi are a vulnerable species, and seem to be particularly susceptible to aspergillosis, the conservation value of this work is high. This study was made possible by grants from the J. S. Watson Conservation Trust, Massey University Graduate Research Fund, and the World Wide Fund for Nature, and furthers our understanding of mortality factors affecting free-living birds, and provides new information on the ecology of this common wildlife disease. The broader implications of this work for managing wildlife, particularly birds in New Zealand forests are also explored. The relationship between clear-felling forest regrowth, and the incidence of aspergillosis may be the key to understanding the fate of bird populations reintroduced into forests, and determine the viability of "mainland islands".

Keywords: fauna, ecology, conservation management, wildlife disease, hihi, stitchbird, *Notiomystis cincta*, research—hihi

Perrott, J.K.; Armstrong, D.P. 2000: Vegetation composition and phenology of Mokoia Island, and implications for the reintroduced hihi population. *New Zealand Journal of Ecology 24*: 19–30.

Hihi (or stitchbird, *Notiomystis cincta*) is a rare honeyeater endemic to the North Island of New Zealand. Hihi were translocated from Little Barrier Island to Mokoia Island, Lake Rotorua, in 1994. Mokoia is a small (135 ha) island with secondary vegetation, so there was some doubt as to whether the island had sufficient diversity of fruit and nectar sources to support a hihi population. This paper reports data collected in the year after the translocation on the density, distribution and phenology of plants likely to be used by hihi. We address the following questions. (1) How many hihi food plant species are on Mokoia? (2) How are the food plant species distributed over the island? (3) Are there periods when flower and fruit sources are scarce and/or spatially confined? (4) How might the availability of fruit and nectar change with succession or additional planting? There was always a minimum of 2–3 species providing nectar or fruit used by hihi. Most (16/21) of the species providing nectar flowered during the hihi breeding period, from October–February, and most (9/16) of these were canopy tree species. The greatest diversity of fruit sources was from March–May. August–September stood out as the period with the lowest diversity of fruit and flower sources, followed by June–July. While there was no time of year when hihi clearly suffered from shortage of fruit and nectar, we suggest that they may be susceptible to shortages in future years at times when diversity of food sources is low. We recommend further planting that could make the island more suitable for hihi in the long term.

Keywords: fauna, ecology, conservation management, translocations, hihi, stitchbird, *Notiomystis cincta*, flora, phenology, vegetation, research—vegetation, research—phenology

Simberloff, D. 2002: Today Tiritiri Matangi, tomorrow the world! Are we aiming too low in invasives control? Pp. 4–12 in Veitch, C.R.; Clout, M.N. (Eds): Turning the tide: the eradication of invasive species. Proceeding of the International Conference on eradication of island invasives. Occasional paper of the IUCN Species Survival Commission No. 27. IUCN.

[Under the heading of 'Possibility of Restoration': '... Our knowledge of community structure and function is inadequate to predict with assurance the impacts of removing a prominent member of an ecological community ... Mouse densities increased greatly following eradication of Norway rats from Mokoia Island'.]

Keywords: conservation management, Norway rats, *Rattus norvegicus*

Stephenson, B.M. 1998: The ecology and breeding biology of morepork, *Ninox novaeseelandiae*, and their risk from secondary poisoning, in New Zealand. Unpublished MSc thesis, Massey University, Palmerston North. 219 p.

I studied morepork, *Ninox novaeseelandiae*, on Mokoia Island from November 1995 through to March 1997. Radio telemetry was a technique essential for the study of this species. Methods for the capture of morepork and attachment of radio transmitters were developed during this study. A population estimate of 25 breeding pairs was made for Mokoia.

Thirty-one morepork were captured and transmitters were fitted to 21 of these birds. Both adults and juveniles were radio-tagged successfully. Morphological measurements, a blood sample and plumage descriptions were made at the time of capture. Using the morphological measurements and plumage characteristics the sex of the bird was, in most cases, unable to be determined. However, using the blood sample collected and a DNA-based technique, sex could be resolved in all cases.

Before this study, little was known about the ecology and breeding biology of morepork. This thesis reveals that morepork are primarily nocturnal, strictly territorial, and roost during the day amongst foliage. It has also confirmed that morepork are primarily insectivorous, but do prey on mice, *Mus musculus*, and birds. Breeding occurs from September through to January, and nests were located in a variety of locations.

Secondary poisoning has received relatively little investigation, both in New Zealand and world-wide. The growing use of second-generation anticoagulant poisons in New Zealand conservation means that more information is needed. Seventeen radio-tagged morepork were monitored following a poison drop in September 1996, to eradicate mice from Mokoia. I followed 14 birds successfully, and of these, one died due to secondary poisoning, and a further two birds died, probably also as a result of poisoning.

This thesis, therefore, provides information not only on the ecology and breeding biology of a little known species, but also information of use to conservation managers planning future poisoning operations.

[The data are published in Stephenson et al. (1999)—BRC.]

Keywords: fauna, ecology, conservation management, morepork, *Ninox novaeseelandiae*, pest management, mice, *Mus musculus*

Stephenson, B.M.; Minot, E.O.; Armstrong, D.P. 1999: Fate of moreporks (*Ninox novaeseelandiae*) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. *New Zealand Journal of Ecology 23*: 233–240.

We monitored 16 radio-tagged moreporks (*Ninox novaeseelandiae*) on Mokoia Island after a brodifacoum poison drop to eradicate mice (*Mus musculus*), normally included in the owls' diet. All 16 moreporks were alive after 13 days. One bird was found dead on day 22, and corpses of two radio-tagged birds were located on day 51. The bird found on day 22 contained 0.97 $mg\,kg^{-1}$ of brodifacoum in its liver. The other two carcasses were not analysed, but they probably died as a result of brodifacoum poisoning. Thus, three out of 14 birds died (21% mortality). A further eight banded and six non-banded birds were also monitored. Of these, 50% were not seen following the drop. Secondary poisoning is implicated in the disappearance of these birds. Sub-lethal effects such as lowered breeding success and stress may have affected morepork over a prolonged period following the poisoning operation. Further studies are needed to investigate the exact pathway of this poison, especially the potential for invertebrates to carry poison.

Keywords: fauna, ecology, conservation management, morepork, *Ninox novaeseelandiae*, pest management, mice, *Mus musculus*

Sumich, J. 2005: Report on transfer of North Island robin from Mokoia Island, Rotorua, to the Ark in the Park sanctuary, Waitakere Ranges, West Auckland. Ark in the Park Sanctuary, Auckland (unpublished report).

[From the report Summary:]

Operational targets:

- To successfully capture, translocation [*sic*] and release toutouwai from Mokoia Island to the Ark in Park site, Waitakere Ranges with less than 10% mortality.
- To monitor for successful breeding by the sighting of unbanded birds and for dispersal within the Ark site or beyond.
- To investigate possible reasons if breeding is not shown to have occurred after the first breeding season.

Result:

- 51 N.I. robins were successfully transferred from Mokoia Island to the Waitakere ranges site of the Ark in the Park; 22 on Friday 15 April; the remaining 31 on Saturday 16 April. Media releases were made. There were no accidents suffered by personnel but one robin was killed outright when it collided with the descending arm of the clap-trap.

Keywords: fauna, ecology, conservation management, translocations, toutouwai, North Island robin, *Petroica australis longipes*

Taylor, S.S.; Castro, I.; Griffiths, R. 2005: Hihi/stitchbird (*Notiomystis cincta*) recovery plan. *Threatened Species Recovery Plan 54*. Department of Conservation, Wellington. 31 p.

The hihi/stitchbird (*Notiomystis cincta*) is a medium-sized forest-dwelling passerine that once occurred throughout the North Island of New Zealand. European colonisation, introduced predators, habitat loss and, possibly, disease reduced the distribution of hihi to Hauturu/Little Barrier Island in the Hauraki Gulf, where they have persisted to the present day. Recovery efforts first initiated in the 1980s have, to date, failed to establish further self-sustaining populations, although small populations remain at two of the translocation sites in the presence of supportive management. With the Hauturu population being the only population of reasonable size, hihi are currently still vulnerable to extinction. For this reason, establishing additional populations remains a core focus for hihi recovery. The likelihood of success of future translocations, however, cannot presently be fully evaluated because information on the factors limiting establishment is incomplete. Consequently, research into the requirements for establishing hihi populations is considered one of the highest priorities for hihi recovery. Future translocations of hihi will remain a central activity of the recovery programme but success of these cannot be guaranteed until such questions have been answered.

[The authors note that 'a high level of aspergillosis was a key factor in the decline of hihi on Mokoia, or at least the population's failure to expand (Alley et al. 1999). The Mokoia population was found to be food limited during the breeding season, but this could be redressed by management'.]

Keywords: fauna, birds, hihi, stitchbird, *Notiomystis cincta*, wildlife disease, threatened species, recovery plan

Taylor, S.S.; Jamieson, I.G.; Armstrong, D.P. 2005: Successful island reintroductions of New Zealand robins and saddlebacks with small numbers of founders. *Animal Conservation 8*: 415–420.

Populations established with a small number of founders are thought to have a high risk of extinction due to Allee effects, demographic stochasticity, inbreeding and reduced genetic variation. We tested whether the initial number of birds released was related to persistence in reintroductions of saddlebacks (*Philesturnus carunculatus*) and robins (*Petroica australis*) to New Zealand offshore islands. Data were analysed for 31 populations that had been observed for at least 3 years since reintroductions. The numbers released ranged from 5–188. Most of the populations (26) survived and grew, including five from less than 15 founders, and four out of the five extinctions were attributable to introduced mammalian predators. The number of individuals released did not significantly affect extinction probability. The ability of these small releases to establish populations can be attributed to the closed nature of the islands (allowing birds to find mates), low mortality rates following release and high growth rates at low density. Stochastic simulation models based on data from two reintroduced populations suggested that populations with four founders (two male, two female) would have a negligible chance of extinction through demographic stochasticity and would be able to grow even if there were high rates of egg failure through inbreeding.

[The authors note that the simulation models of population growth (numbers of females) 'could experience high levels of egg failure and still grow. Doubling or tripling the egg failure of the Mokoia saddleback population slowed the growth rates of simulated populations, but produced negligible extinction risk'.]

Keywords: fauna, ecology, conservation management, translocations, North Island saddleback, *Philesturnus carunculatus rufusater*, toutouwai, North Island robin, *Petroica australis longipes*

Thomas, B.W.; Taylor, R.H. 2002: A history of ground-based rodent eradication techniques developed in New Zealand, 1959–1993. Pp. 301–310 in Veitch, C.R.; Clout, M.N. (Eds): Turning the tide: the eradication of invasive species. Proceeding of the International Conference on eradication of island invasives. Occasional paper of the IUCN Species Survival Commission No. 27. IUCN.

[Under the heading of '1989 to 1993: The rolling front' and other campaigns: '… Concurrent with eradication operations on Hawea, Breaksea and Ulva Islands, important development work was also being undertaken in other areas by DOC workers. In 1989, Paul Jansen adapted the Breaksea Island work plan to eradicate Norway rats from Mokoia Island (135 ha) in Lake Rotorua (Veitch & Bell 1990)'.]

Keywords: conservation management, Norway rats, *Rattus norvegicus*

Wallace, S.W. 1992: Proposal to establish permanent vegetation plots on Mokoia Island. Department of Conservation, Rotorua (unpublished report). 4 p.

[From the Introduction and the section 'Establishment of permanent vegetation plots':]

The vegetation of Mokoia Island is predominantly secondary following a long history of burning and cultivation by the Maori. In more recent times introduced animals, particularly goats, have had an impact on the vegetation by retarding succession and reducing the abundance of palatable species. The present vegetation pattern comprises a mosaic of fernland, scrub and forest reflecting the long history of disturbance. Along the eastern side of the island an area of grassland is maintained by grazing and mowing. Areas of bracken fern occur on the high points and several northern slopes. Previously more widespread, these fernlands are now being replaced by scrub dominated by kohuhu, fivefinger and mahoe over much of the island. Mamaku is common in the shaded gullies and on the southern slopes along with kohekohe. Cabbage tree is abundant in the northeast, with local emergent karaka (Beadel 1990). Large pohutukawa and occasional northern rata are present around most of the island margins.

The recent eradication of goats from Mokoia Island provides an opportunity to establish a baseline to monitor vegetation changes without the influence of browsing animals. Rats have also been removed; their influence on the vegetation has been less obvious probably affecting flower and fruit production. Permanent vegetation plots will provide data on the recovery of the vegetation, the re-establishment of palatable species, and, in the long term, record the succession from fernland and scrub to forest on the island.

The data obtained from these plots can be integrated with and enhanced by that from other studies currently in progress or proposed. A phenology study to assess the availability of suitable and sufficient food supplies for stitchbirds to be transferred to the island, has been proposed by Rotorua Lakes High School in conjunction with the Department of Conservation. Sampling for this study could include tagged trees from the permanent plots. Plot data could also be integrated into an overall assessment of the island's vegetation to determine the distribution and abundance of food species and habitat for other wildlife, including the recently transferred saddlebacks.

Keywords: monitoring, flora, vegetation

Wallace, S.W. 1993: Establishment of four permanent vegetation plots on Mokoia Island. Department of Conservation, Rotorua (unpublished report). 39 p.

[From the Introduction and Methods:]

Establishment of permanent vegetation plots

The eradication of goats from Mokoia provided an opportunity to establish a baseline to monitor vegetation changes without the influence of browsing animals. Change has been very evident in the last three years. Forest and scrub understoreys have quickly re-established and become particularly dense in places; temporary tracks cut for poison lines are no longer evident; and previously open areas have become overgrown with bracken, blackberry, sweet brier, and other weeds. Unfortunately, permanent vegetation plots were not established soon enough following eradication to record these initial changes. Long-term change, the succession from fernland and scrub to forest, will however be recorded.

Method

Four 20 metre × 20 metre permanent vegetation plots were established in February, March and April 1993. The plots were subjectively located, following an inspection of aerial photographs and a reconnaisssance [*sic*] of the island, in order to include the most common vegetation types and a range of environmental conditions. The plots also had to be reasonably accessible.

Keywords: monitoring, flora, vegetation

Watson, C. 1992: Transfer of birds. *Rotorua Review*, 22 October 1992.

[A short article on DOC running a public open day including a guided walk outlining the Department's bird conservation programmes on the island.]

Keywords: conservation management

West, M. 1997: Ecosystems and environments. *New Zealand Science Monthly* March: 12.

[An opinion article in the view-point column on environmental education and its importance to developing well-rounded, capable and informed students. The author's premise is that such work on Mokoia involving high school students is key to fostering such values within students, in essence 'to see the connection between the classroom and the real world'. It outlines involvement of Rotorua high schools (as well as the Mokoia Island Trust, the Department of Conservation and Massey University) in the conservation and restoration work occurring on Mokoia, such as the removal of pest species and introduction of protected species. The author states that these learning opportunities clearly bring into focus for students the 'real world' value judgements that emerge in managing natural ecosystems; e.g. with each stitchbird transfer costing $1000 per bird.]

Keywords: environmental education, high schools

Whiteford, P.C. 1992: Heat flow in the sediments of Lake Rotorua. *Geothermics 21*: 75–88.

A total of 48 heat flow measurements were made in the sediments at the bottom of Lake Rotorua during June 1990. High heat flows (greater than 0.25 W/m^2) were measured in the south-eastern part of the lake, and the total natural heat output for this area is estimated to be 20 MW. Within this area there are two regions with heat flow greater than 2 W/m^2; one immediately north of Rotorua, and the other located between Mokoia Island and Rotokawa. The former marks the northward extension of the Rotorua geothermal field beneath the lake. The latter probably represents a separate small geothermal field although it may be the effect of an outflow from Rotorua geothermal field.

Keywords: Lake Rotorua, geothermal activity, Rotorua Geothermal Field

Wilcox, M.D. 1990: History of plantings on Mokoia Island. *Rotorua Botanical Society 20*: 24–25.

[This table lists the species planted on Mokoia, with approximate source locations and the date planted. The species planted are given in chronological order within Appendix 3, which is updated to include more recent plantings, translocations, and the lead planter's name.]

Keywords: flora, plantings

Wilson, L.R. 1997: The ecology and management of honeyeaters in northern New Zealand. Unpublished MSc thesis, University of Auckland, Auckland.

The ecology of New Zealand's three endemic species of honeyeater, the tui (*Prosthemadera novaezeelandiae*), bellbird (*Anthornis melanura*) and stitchbird (*Notiomystis cincta*), was studied on Tiritiri Matangi Island (Tiri), with the aim of providing recommendations for the management of the bellbird and stitchbird, which are rare in northern New Zealand.

It was found that the dominance hierarchy recorded by previous researchers was in place on Tiri, with tui dominating bellbirds which in turn dominated stitchbirds, with males dominating females in all species.

The distribution of each honeyeater species was related to food supply, to show whether species of higher status were found in areas with more food, and especially whether stitchbirds were being excluded from areas with a greater food supply. Stitchbirds were always found in the areas with the highest food availability; however they suffered much aggression in these habitats, predominantly from male bellbirds. They also decreased in number in some areas when the number of male bellbirds increased.

The diet of each honeyeater species was examined, to show whether more dominant species were making greater use of higher quality plant species. Some resource partitioning occurred, with stitchbirds making greater use of fruit than the other species. Stitchbirds were excluded from high quality species that were present at low densities, but were able to gain access to highly concentrated food sources.

The use of planted vegetation by bellbirds, and plant species preferred by bellbirds and stitchbirds were also investigated, in order to recommend species to be planted to provide food and enhance the habitat for these species. Bellbirds made extensive use of the planted and regenerating vegetation and preferred the nectar of these species to that of forest species.

It is recommended that future translocations of stitchbirds should preferentially be to islands lacking bellbirds. If this is not possible, understorey species used primarily by stitchbirds should be planted to provide an escape from the more dominant species.

[The thesis contains some information pertinent to Mokoia. The author notes the translocation of stitchbirds to Mokoia (which lacked bellbirds), and the mortality of stitchbirds caused by aspergillosis. He also notes tui aggression towards hihi (Perrot unpubl. data).]

Keywords: fauna, ecology, conservation management, translocations, honeyeaters, tui, *Prosthemadera novaezeelandiae*, bellbird, *Anthornis melanura*, hihi, stitchbird, *Notiomystis cincta*, wildlife disease

Withers, S.; Brunton, D.H.; Castro, I. 2003: Composition and function of hihi (*Notiomystis cincta*) song in relation to social behaviour and resources. P. 22 in: Proceedings of the New Zealand Ecological Society Annual Conference, 2003, Auckland. School of Biological Sciences, University of Auckland, Auckland.

Research on bird song has tended to focus on the Northern Hemisphere and work on the function of male song has predominated. New Zealand represents a particularly interesting location for bird song analysis, with several species in which both males and females sing. The proposed research aims to analyse the function of song in an endemic New Zealand species, the hihi or stitchbird (*Notiomystis cincta*). The proposed research will determine the structure of both male and female song, using sonogram analysis of recorded vocalisations. Recordings from Tiritiri Matangi Island, Mokoia Island and Little Barrier Island will be compared for inter-population differentiation in song types, song structure and song context. Fine scale analysis of bird song within the Tiritiri Matangi population will focus on a comparison of male and female song structure, repertoires, calls and song types, to determine the function and context of hihi song. Research on avian vocalisation has consistently found that different song types function for territorial display or for mate attraction and retention. An analysis of both the social and non-social context of song will be focussed on, in order to determine the function of particular song types in hihi. Variation in song will be tracked temporally and related to temporal changes in resources, using measurements of resource quality and quantity within territories. This research will represent the first in depth song analysis on hihi, and will be one of few studies that focus on the function of song in both males and females.

Keywords: fauna, ecology, conservation management, hihi, stitchbird, *Notiomystis cincta*, bird song

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Appendix 1

CHRONOLOGY OF MOKOIA ISLAND

Management, monitoring, research and key events on Mokoia Island. Information taken from articles.

YEAR	EVENT
Prehistory	150 000 years BP: volcanic eruption forms Mamaku plateau, and resulting caldera (collapse) forms the physical environment for Lake Rotorua. Mokoia and other key domes are formed from subsequent smaller extrusions of lava. Refer to Andrews (1992).
c. 1450	Inhabitation of Mokoia, with burning and associated cultivation, including translocation and use of coastal plants (Clarkson et al. 1991).
1830–1900+	Number of humans inhabiting island steadily declines.
1839	Norway rats (*Rattus norvegicus*) recorded on island.
1841	Botanist Ernst Dieffenbach visits the island and comments on the shrubs and grasses.
1842	Botanist William Colenso visits the island searching for a rare tree.
1926–1930	Dr L. Grange visits the island to record and describe the geology of Mokoia. Refer to Grange (1937).
1950	Cultivation of kumara and other plants ceases (Dumbell 1998). Subsequent island-wide natural regeneration.
1950s	Approximately 60 acres (24 ha) of vegetation are burnt, almost 20% of the island. Refer to Andrews (1992) and Forrester (1989).
1952	Establishment of Mokoia Island Wildlife Refuge Status: • Government involvement in Mokoia, Department of Internal Affairs 6-year lease over half of island for rearing of ring-necked pheasant. Caretaker lives on island during summer and autumn months. • Five North Island weka (*Gallirallus australis greyi*) (from Gisborne) are released onto island.
1956	Ring-necked pheasant rearing operation moves to Ngongotaha. 12 North Island weka released onto island.
1963/4	Earliest record of mice (*Mus musculus*) on Mokoia, with one trapped (Beveridge & Daniel 1965, 1966).
1970s	Release of two injured North Island brown kiwi (*Apteryx mantelli*) onto island.
1985	Approximately 20 goats are taken to island to suppress weeds on the flats.
1988	Mokoia Island Trust Board decides to seek eradication of rats from the island.
1989	Department of Conservation starts programme to remove exotic mammals from the island (Jansen 1993): • Large reduction of mouse numbers occurs, although not eradication. • Eradication of goats off the island. • Pig escapes from pens on the island.

Continued on next page

YEAR	EVENT
1992	Transfer of North Island robins (*Petroica australis longipes*) onto Mokoia (Jansen 1992, 1993; Lovegrove 1996). North Island saddlebacks (*Philesturnus carcunculatus*) are released onto the island (Armstrong & Craig 1995). 1 April: A rat is sighted on the island by Dave Wilks, Royal Forest and Bird Protection Society, Te Puke Branch, near the toilet behind Hinemoa's Pool. Refer to Owen (2002c). 31 May: A Reporoa couple are found walking their dog on Mokoia.
1993	Speckled skinks (*Oligosoma infrapunctatum*) are discovered on the island.
1994	Hihi/stitchbird (*Notiomystis cincta*) translocation. Extensive rat trapping regime.
1994/95	Hihi breeding season is monitored. Refer to Castro et al. (2004).
1995	A rat is sighted on the island. Extensive rat trapping and poisoning regime. Visit by HRH Prince Phillip. Refer to Nicholas (1995).
1995/96	Hihi breeding season is monitored. Refer to Castro et al. (2004).
1996	Last two horses are air-lifted off the island. Aerial distribution of poison. Large reduction of mouse numbers, although not eradication. A rat is sighted on the island (Owen 2002c). A mouse is sighted on the island.
1996/97	Hihi breeding season is monitored. Refer to Castro et al. (2004).
1997	Weed survey (Holland 1997). A rat is sighted on the island.
1997/98	Hihi breeding season is monitored. Refer to Castro et al. (2004).
1998/99	Research on tree fuchsia (*Fuchsia excorticata*) pollen dispersal (Kelly et al. 1999).
1999	Transfer of North Island robins to Moturoa (Armstrong 2000; Owen & Asquith 2000). Invertebrate monitoring efforts start. Refer to Howard & Christensen (2005).
2000	Threatened plant plantings and transfers. Refer to Cashmore (2000, 2001). Rotorua Botanical Society trip. Refer to Cashmore (2001) and Jane & Ecroyd (2001).
2002	Hihi are removed from the island to Mount Bruce and Kapiti Island (Owen 2002a, b).
2003	Waitangi Day: North Island brown kiwi Moana is released onto the island (Owen 2003a). July: Three North Island brown kiwi, named 'Tutanekai', 'Hinemoa' and 'Tiki' are released onto the island (Owen 2003b). Blood sampling of and ectoparasite collection from saddlebacks, blackbirds and North Island robins.
2003/4?	Transfer of North Island robins to Tuhua (Mayor Island).
2004	Threatened plant plantings and transfers. Refer to Cashmore (2004).
2005	Doug Armstrong carries out research on saddleback density dependence. 23 August: Stoat (*Mustela erminea*) possibly sighted on island. Mokoia stoat incident action plans (Christensen 2005). Eight or nine weka are transferred from Mokoia to Whirinaki Forest Park (Owen 1997).

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Appendix 2

VASCULAR PLANT SPECIES LIST

Compiled from Beadel (1989), Beadel & Ecroyd (1990), Jane & Ecroyd (2001), and Perrott & Armstrong (2000).

This species list is based on visits by B.R. Clarkson and C. Ecroyd in March 1982; S.M. Beadel in May 1989; S.M. Beadel and C. Ecroyd in May 1990, April 1990 and June 1990 (Rotorua Botanical Society Field Trip); G. Jane and C. Ecroyd in August 2000; D.P. Armstrong, J.K. Perrott and others in 1995; and D. Holland in 1997. It also incorporates a current revision of the list by J. Hobbs, and includes common names where found.

Key: * = adventive species, CE = recorded by B.R. Clarkson and C. Ecroyd in March 1982, B = Beadel May 1989, P = planted, NZFRI = Forest Research Institute Herbarium, Rotorua, JE = G. Jane & C. Ecroyd August 2000, PA = J.K. Perrott and D.P. Armstrong in 1995. Includes subsequent identifications by P. Cashmore (Cashmore 2000, 2001), and John Hobbs (JH).

SPECIFIC NAME	COMMON NAME	NOTES
INDIGENOUS PLANTS		
Gymnosperms		
Dacrycarpus dacrydioides (P, CE)	Kahikatea	
Podocarpus totara (natural and planted)	Totara	
Monocot trees		
Cordyline australis	Ti or cabbage tree	
Rhopalostylis sapida (P)	Nikau	
Dicot trees		
Alectryon excelsus (P, CE)	Titoki	
Aristotelia serrata	Makomako or wineberry	
Beilschmiedia tawa	Tawa	W.P. Jansen NW1U (18451)
Corynocarpus laevigatus	Karaka	
Dysoxylum spectabile	Kohekohe	
Entelea arborescens	Whau	Although now naturalised on the island, the parent(s) may have been planted
Fuchsia excorticata	Kotukutuku or tree fuchsia	
Griselinia littoralis (PA)	Broadleaf	
Knightia excelsa (B)	Rewarewa or New Zealand honeysuckle	
Kunzea ericoides var. *ericoides* (B)	Kanuka	
Litsea calicaris	Mangeao	W.P. Jansen, pers. comm.
Melicytus ramiflorus ssp. *ramiflorus*	Mahoe or whiteywood	
Metrosideros excelsa	Pohutukawa	
Metrosideros robusta (B)	Northern rata	
Metrosideros excelsa × *M. robusta* (B)	Pohutukawa–northern rata hybrid	
Myrsine australis	Mapou	
Nothofagus menziesii	Silver beech	
Pittosporum tenuifolium ssp. *tenuifolium*	Kohuhu	

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Pseudopanax arboreus	Fivefinger	
Schefflera digitata	Pate or seven finger	
Sophora microphylla (P, CE)	Kowhai	
Sophora tetraptera (P, CE)	Kowhai	
Weinmannia racemosa	Kamahi	
Dicot shrubs		
Brachyglottis repanda var. *fragrans* (P, CE)	Rangiora	
Brachyglottis repanda var. *repanda*	Rangiora	
Coprosma grandifolia	Kanono	
Coprosma repens	Taupata	M.D. Wilcox, pers. comm.; probably planted
Coprosma robusta	Karamu or glossy karamu	
Coriaria arborea var. *arborea*	Tutu	
Dodonaea viscosa	Akeake	
Gaultheria antipoda (B)	Bush snowberry	
Gaultheria oppositifolia (B)	Niniwa or snowberry	
Geniostoma rupestre var. *ligustrifolium*	Hangehange	
Hebe stricta var. *stricta*	Koromiko	
Ileostylus micranthus (P, Cashmore 2001)	Small-flowered mistletoe	
Leptospermum scoparium	Manuka	
Leucopogon fasciculatus (B)	Mingimingi	
Macropiper excelsum var. *excelsum*	Kawakawa	
Tupeia antarctica (P, Cashmore 2001)	White mistletoe	
Urtica ferox	Ongaonga or stinging nettle	NZFRI MW911
Monocot lianes		
Ripogonum scandens	Supplejack	W.P. Jansen, NZFR118450
Dicot lianes		
Clematis cunninghamii		
Clematis sp. (possibly *C. paniculata*)	White clematis	
Metrosideros diffusa (CE)	Rata	
Metrosideros fulgens	Scarlet rata or rata	
Metrosideros perforata	Akatea	
Muehlenbeckia australis	Puka or large-leaved *Muehlenbeckia*	
Rubus cissoides	Tataramoa or bush lawyer	
Psilopsids and Lycopods		
Lycopodium varium (B)	Iwituna or hanging clubmoss	
Lycopodium volubile (B)	Climbing clubmoss	
Tmesipteris elongata	Fork fern	
Tmesipteris tannensis (JE)	Fork fern	
Ferns		
Adiantum cunninghamii	Maidenhair	
Anarthropteris lanceolata (B)	Lance fern	
Asplenium bulbiferum ssp. *bulbiferum*	Hen and chickens fern	
Asplenium flaccidum ssp. *flaccidum*	Hanging spleenwort	
Asplenium gracillimum (B)		
Asplenium oblongifolium	Shining spleenwort	
Asplenium polyodon	Sickle spleenwort	
Blechnum sp. "black spot"		

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Blechnum chambersii	Nini or lance fern	
Blechnum discolor	Crown fern	Small plant established from earlier plantings
Blechnum filiforme	Thread fern	
Blechnum novae-zelandiae	Kiokio	
Blechnum vulcanicum (JE)	Korokio	
Cyathea cunninghamii (CE)	Gully tree fern	
Cyathea dealbata	Silver fern	
Cyathea medullaris	Mamaku	
Dicksonia fibrosa	Wheki-ponga	
Dicksonia squarrosa	Wheki	
Diplazium australe		
Doodia media ssp. *australis*	Rasp fern	
Histiopteris incisa (B)	Water fern	
Hymenophyllum demissum	Irirangi	
Hymenophyllum dilatatum (B)	Filmy fern	
Hymenophyllum flabellatum	Filmy fern	
Hymenophyllum flexuosum (CE)	Filmy fern	
Hymenophyllum multifidum (CE)	Filmy fern	
Hymenophyllum rarum (B)	Filmy fern	
Hymenophyllum sanguinolentum	Piripiri	
Hymenophyllum scabrum (CE)	Filmy fern	
Hypolepis ambigua	Pig fern	
Hypolepis dicksonioides	Giant hypolepis	
Lastreopsis glabella	Smooth shield fern	
Leptolepia hymenophylloides	Heruheru	
Microsorum pustulatum	Hound's tongue	
Microsorum scandens	Fragrant fern	
Paesia scaberula	Lace fern	
Pellaea rotundifolia	Tarawera	
Pneumatopteris pennigera	Gully fern	
Polystichum richardii	Common shield fern	
Polystichum richardii × *P. vestitum* (CE)		NZFRI19057
Polystichum vestitum (JE)	Prickly shield fern	
Pteridium esculentum	Bracken	
Pteris macilenta	Sweet fern	
Pteris tremula	Taraera or Australian bracken	
Pyrrosia eleagnifolia	Leather-leaf fern	
Rumohra adiantiformis (JE)	Leathery shield fern	
Trichomanes venosum	Veined filmy fern	
Orchids		
Corybas micranthus	Spider orchid	M.D. Wilcox, pers. comm.
Drymoanthus adversus (CE)	Green fleshy orchid	
Earina autumnalis (B)	Raupeka	
Earina mucronata	Weka-a-waka or New Zealand bamboo orchid	
Ichthyostomum pygmaeum	Piripiri or bulb-leaf orchid	
Microtis unifolia	Maikaika or onion orchid	
Nematoceras macranthum		M.D. Wilcox, pers. comm.

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Pterostylis sp.		Probably *P. graminea*; *P. cardiostigma* does not flower until October (JE)
Winika cunninghamii	Winika	
Grasses		
Cortaderia fulvida	Toetoe	
Deyeuxia avenoides	Mountain oat grass	
Dichelachne crinita (CE)	Patiti or plume grass	
Isachne globosa	Swamp millet	
Lachnagrostis sp. *(L. filiformis)* (CE)	New Zealand wind grass	
Microlaena stipoides (B)	Meadow rice grass	
Rytidosperma gracile (B)		
Sedges		
Carex breviculmis (B)	Grassland sedge	
Carex dissita	Flat-leaved sedge	
Carex maorica	Cyperus sedge	
Carex secta		
Carex solandri	Solander's sedge	
Carex testacea (CE)	Speckled sedge	
Carex virgata	Swamp sedge	
Carex sp. (*C. geminata* agg.)	Rautahi	
Cyperus ustulatus	Toetoe or coastal cutty grass	
Eleocharis acuta	Sharp spike sedge or club rush	
Isolepis nodosa	Wiwi or knobby clubrush	
Schoenoplectus validus	Lake clubrush	
Uncinia uncinata	Kamu or hook grass	
Rushes		
Juncus gregiflorus	Wiwi or leafless rush	
Juncus planifolius	Flat-leaved rush	
Luzula picta var. *limosa*	Woodrush	
Monocots (other than orchids, grasses, sedges and rushes)		
Astelia solandri	Kahakaha, kowharawhara	
Collospermum hastatum	Kahakaha	
Cordyline pumilio (JE)	Ti rauriki or dwarf cabbage tree	
Dianella nigra	Turutu or inkberry	
Lemna minor	Karearea or common duckweed	
Phormium tenax	Harakeke or flax	
Typha orientalis	Raupo or bulrush	
Composits		
Anaphalioides trinervis (JE)		On rock at shore
Gnaphalium gymnocephalum	Creeping cudweed	
Leptinella dispersa		
Pseudognaphalium sp. (*P. luteoalbum*)	Pukatea or jersey cudweed	
Senecio glomeratus	Pukatea or Australian fireweed	
Senecio minimus	Australian burnweed	
Dicot herbs (other than composits)		
Acaena novae-zelandiae (JE)	Bidibid	
Cardamine sp. (*C. debilis* agg.)	Panapana or New Zealand bitter cress	

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Epilobium alsinoides		
Epilobium nerteroides		
Epilobium nummulariifolium	Creeping willowherb	
Epilobium pedunculare	Long-stalked willowherb	
Galium propinquum	Mawe	
Geranium potentilloides ssp. *potentilloides*		
Geranium solanderi "coarse hairs"	Matua-kumara or turnip-rooted geranium	
Glossostigma elatinoides		
Haloragis erecta ssp. *erecta*		
Hydrocotyle heteromeria	Waxweed	
Hydrocotyle hydrophila		
Hydrocotyle moschata	Hairy pennywort	
Hydrocotyle novae-zeelandiae agg.		
Lilaeopsis sp. (*L ruthiana*?)		
Limosella lineata	Mudwort	
Myriophyllum propinquum	Common water milfoil	
Pelargonium inodorum	Pukupuku	
Polygonum salicifolia		
Pratia angulata	Panakenake	
Ranunculus reflexus	Kopukapuka or hairy buttercup	
Rorippa divaricata (P)	Matangoa (Cashmore 2001)	
Rorippa palustris	Hanea, marsh yellow cress	
Stellaria parviflora (incl. *S. decipiens* and *S. minuta)*	New Zealand chickweed	
Wahlenbergia sp.		
NON-INDIGENOUS PLANTS OR ADVENTIVE SPECIES		
Gymnosperms		
Pinus pinaster	Maritime pine	
Dicot trees		
Alnus glutinosa	Alder	
Eucalyptus sp. (JH)	Gum tree	
Ficus carica (CE)	Fig	
Fraxinus excelsior (CE)	European ash	
Paraserianthes lophantha (PA)	Brush wattle	
Populus nigra 'Italica' (P)	Lombardy poplar	
Prunus domestica (CE)	European plum	
Prunus persica (CE)	Peach	
Quercus robur	English oak	
Robinia pseudoacacia (CE)	False acacia	
Salix cinerea	Grey willow	
Salix fragilis	Crack willow	
Dicot shrubs		
Artemisia absinthium	Wormwood	
Buddleja davidii	Buddleia	
Buxus sempervirens	Common boxthorn	
Crataegus monogynya (JH)	Hawthorn	
Crocosmia × *crocosmiiflora*	Montbretia	
Cyphomandra betacea (JH)	Tamarillo	

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Cytisus scoparius	Broom	4 April 2004: all plants found were removed.
Ligustrum sinense	Chinese privet	All located plants were removed.
Lupinus luteus (PA), or *Lupinus arboreus* (JH)	Tree lupin	
Ricinus communis (JE)	Caster oil plant	
Rosa rubiginosa	Sweet brier	
Teline monspessulana	Montpellier broom	
Ulex europaeus	Gorse	
Dicot lianes		
Clematis vitalba (PA)	Old man's beard	
Hedera helix	Ivy	
Humulus lupulus (CE)	Bine or hop	
Lonicera japonica	Japanese honeysuckle	
Rubus sp. (*R. fruticosus)*	Blackberry	
Vinca major	Periwinkle	
Grasses		
Agrostis capillaris	Browntop bent, browntop, bent grass	
Agrostis stolonifera	Creeping bent	
Anthoxanthum odoratum (JE)	Sweet vernalgrass	
Arundo donax	Giant reed	
Bromus catharticus (CE)	Rescuegrass	
Bromus willdenowii (JE)	Rescuegrass	
Cynodon dactylon	Couch or bermuda grass	
Dactylis glomerata	Cocksfoot	
Digitaria sanguinalis	Dummer grass	
Festuca arundinacea	Tall fescue	
Glyceria maxima (B)	Reed meadow grass	
Holcus lanatus	Yorkshire fog	
Lolium perenne	Perennial ryegrass	
Oplismenus imbecillis	Creeping beard grass	
Paspalum dilatatum	Paspalum	
Paspalum distichum	Paspalum or mercer grass	
Pennisetum clandestinum (JE)	Kikuyu grass	
Pennisetum macrourum	African feather grass	
Sporobolus africanus (CE)	Ratstail	
Unknown sp.	Bamboo	
Vulpia bromioides (JE)	Vulpia hair grass	
Sedges		
Cyperus eragrostis (CE)	Puketangata or umbrella sedge	
Rushes		
Juncus acuminatus	Sharp-fruited rush	
Juncus effusus (B)	Common rush	
Juncus tenuis	Track rush	
Monocots (other than orchids, grasses, sedges and rushes)		
Kniphofia sp.	Red hot poker	
Dicot herbs (other than composits)		
Amaranthus powellii (CE)	Redroot, Powell's amaranth	
Anagallis arvensis	Scarlet pimpernel	

Continued on next page

SPECIFIC NAME	COMMON NAME	NOTES
Aster subulatus	Saltmarsh aster	
Barbarea intermedia	Early wintercress	
Bidens frondosa	Devil's beggartick	
Cardamine hirsuta	Hairy bittercress	
Carduus nutans	Nodding plumeless thistle	
Centaurium erythraea (B)	Centaury	
Cerastium glomeratum	Sticky chickweed	
Chenopodium album (CE)	Hua inanga or fat-hen, lamb's quarters	
Cirsium arvense	Californian thistle	
Cirsium vulgare	Pungitangita or Scotch thistle	
Conyza albida (JH)	Broad-leaved fleabane	
Coronopus didymus	Lesser swinecress	
Cucurbita sp.		
Datura stramonium	Jimsons weed or thornapple	
Digitalis purpurea (JE)	Foxglove	
Elodea canadensis (CE)	Oxygen weed	
Epilobium cinereum	Willowherb	
Euphorbia peplus	Kaikaiatua or milkweed	
Galium aparine	Cleavers	
Galium palustre	Marsh bedstraw	
Geranium molle	Dove's foot	
Geranium robertianum	Herb Robert	
Gnaphalium spicatum	Purple cudweed	
Hypochoeris radicata	Spotted cat's ear	
Lactuca virosa	Acrid lettuce	
Lapsana communis (JE)	Nipplewort	
Leontodon taraxacoides	Hawkbit	
Lepidium africanum	Peppercress	
Lotus pedunculatus	Lotus	
Ludwigia palustris (CE)	Water purslane	
Lycium barbarum	Chinese boxthorn (vine)	
Lythrum hyssopifolia	Hyssop loosetrife	
Malva parvifolia		
Mentha × piperita	Peppermint	
Microtis uniflora (JE)		
Mimulus guttatus	Monkey musk	
Modiola caroliniana		
Mycelis muralis	Wall lettuce	
Myosotis scorpioides	Water forget-me-not	
Myosotis sylvatica	Forget-me-not	
Oenothera glazioviana (CE)		
Orobanche minor (JE)	Broomrape	
Oxalis sp.	Wood sorrel	
Physalis peruviana (CE)	Cape gooseberry	
Phytolacca octandra	Dyeberry	
Plantago australis	Swamp plantain	
Plantago lanceolata	English plantain	
Plantago major	Broad-leaved plantain	
Poa annua	Annual poa	
Polygonum hydropiper	Water pepper	

Continued on next page

Appendix 2—continued

SPECIFIC NAME	COMMON NAME	NOTES
Polygonum persicaria (CE)	Willow weed	
Prunella vulgaris	Self-heal	
Ranunculus repens	Creeping buttercup	
Rorippa nasturtium-aquaticum		
Rumex acetosella	Sheep's sorrel	
Rumex obtusifolius	Paewhenua or broad-leaved dock	
Rumex pulcher	Fiddle dock	
Sagina procumbens	Spreading pearlwort	
Senecio bipinnatisectus	Australian fireweed	
Senecio jacobaea	Ragwort	
Sigesbeckia orientalis	Punawaru or Indian weed	
Silene gallica	Catchfly	
Sisymbrium officinale	Hedge mustard	
Solanum americanum (JE), (JH)	Raupeti or small flowered nightshade	
Solanum nigrum	Raupeti or black nightshade	
Solvia sessilis	Onehunga weed	
Sonchus asper	Kautara or prickly sow thistle	
Sonchus oleraceus	Puha or common sow thistle	
Stellaria media	Kohukohu or chickweed	
Taraxacum officinale (CE)	Tawao or dandelion	
Tradescantia fluminensis	Wandering willie	
Trifolium campestre	Hop trefoil	
Trifolium dubium	Suckling clover	
Trifolium pratense	Red clover	
Trifolium repens	White clover	
Urtica dioica ssp. *gracilis* (CE)	Nettle	NZFRI12446
Verbascum virgatum	Moth mullein	
Veronica persica (CE)	Speedwell	
Vicia sativa (CE)	Vetch	
Wahlenbergia marginata	Harebell	
Wahlenbergia sp.	Harebell	
Zantedeschia aethiopica (JE)	Arum lily	In flower when washed up on the shore

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Appendix 3

PLANTINGS ON MOKOIA ISLAND

Repeated in full from Wilcox (1990). Additional species planted are noted from Beveridge & Daniel (1965). Includes subsequent plantings and translocations led by P. Cashmore.

SPECIES	SOURCE	PLANTER	DATE PLANTED
Agathis australis			Early 1960s
Alectryon excelsus	Commercial stock		14 July 1968
Aleusomia macrophylla			
Asplenium polyodon	Local		14 July 1968
Beilschmiedia tawa			Early 1960s
Blechnum 'black spot'	Pukapuka Rd, Kaingaroa.		11 Jan 1969
Blechnum chambersii	Whakarewarewa Forest		21 Dec 1968
Blechnum colensoi	Mt Tauhara		Aug 1968
Blechnum discolor	Pukapuka Rd, Kaingaroa		11 Jan 1969
	Whakarewarewa Forest		21 Dec 1968
Blechnum fluviatile	Pukapuka Rd, Kaingaroa		11 Jan 1969
Blechnum fraseri	Te Hapi Stream, Tairua		11 Jan 1969
	Waipoua Forest, Northland		Sept 1968
Blechnum minus	Mt Tauhara		Aug 1986
	Pukapuka Rd, Kaingaroa		11 Jan 1969
Blechnum penna-marina	Kaingaroa		21 Dec 1968
Blechnum vulcanicum	Mt Tauhara		Aug 1968
	Pukapuka Rd, Kaingaroa		11 Jan 1969
Cardiomanes reniforme	Pillar of Hercules		Aug 1968
Chiloglottis cornuta	Kaingaroa		21 Dec 1968
Cyathea smithii	Mt Pihanga		Aug 1968
Dactylanthus taylorii		P. Cashmore	2000
Histiopteris incisa	Auckland		30 June 1968
	FRI grounds, Rotorua		11 Jan 1969
	Pukapuka Rd, Kaingaroa		11 Jan 1969
Hymenophyllum scabrum	Local		14 July 1968
Hypolepis ambigua	FRI grounds, Rotorua		11 Jan 1969
Hypolepis rufobarbata	Pukapuka Rd, Kaingaroa		11 Jan 1969
Ileostylus micranthus		P. Cashmore	2000
Lastreopsis hispida	Te Whetu, Mamaku		14 July 1968
	Te Hapi Stream, Tairua		11 Jan 1969
Lastreopsis microsora	Coromandel coast		11 Jan 1969
Leptopteris hymenophylloides	Pukapuka Rd, Kaingaroa		11 Jan 1969
	Whakarewarewa Forest		21 Dec 1968
Leptopteris superba	South Rd, Mamaku		18 Jan 1969
Libocedrus plumosa	Peter Wakefield		30 June 1968
Loxsoma cunninghamii	Waipoua Forest, Northland		Sept 1968
Lygodium articulatum	Te Hapi Stream, Tairua		11 Jan 1969
Paesia scaberula	Pukapuka Rd, Kaingaroa		11 Jan 1969

Continued on next page

SPECIES	SOURCE	PLANTER	DATE PLANTED
Nothofagus menziesii			Early 1960s
Pellaea rotundifolia	Local		14 July 1968
Polystichum vestitum	Kaingaroa		30 June 1968
	Pukapuka Rd, Kaingaroa		11 Jan 1969
Pseudopanax ferox	Commercial stock		5 April 1970
Pteris comans	Coromandel coast		11 Jan 1969
Pteris tremula	Mokoia Island		18 Jan 1969
Rorippa divaricata		P. Cashmore	2000
Sticherus cunninghamii	Tarawera		Aug 1968
	Pillar of Hercules		Aug 1968
Sticherus flabellatus	Waitakere Range		18 Jan 1969
	Waitangi, Northland		Sept 1968
Tupeia antarctica		P. Cashmore	2000

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Appendix 4

VERTEBRATE FAUNA SPECIES LIST

Species name and removal/transfer details. Species marked with an asterisk are generally considered not to be present. Information has been taken from Andrews (1992), Holland (1997), Owen (1997) and other sources. List follows Turbott (1990) and King (2005).

A4.1 Indigenous and coloniser species

Birds

North Island brown kiwi *Apteryx australis mantelli*

- Since 2003, North Island brown kiwi have been released onto the island from Whirinaki Forest and Ohope Scenic Reserve (Owen 2003a, b).

Black shag *Phalacrocorax carbo novaehollandiae* kawau

Little black shag *Phalacrocorax sulcirostris*

Little shag *Phalacrocorax melanoleucos brevirostris* kawaupaka

Black swan *Cygnus atratus*

Grey duck *Anas superciliosa* parera

New Zealand scaup *Aythya novaeseelandiae* papango

Australasian harrier *Circus approximans* kahu

Southern black-backed gull *Larus dominicanus dominicanus* karoro

Red-billed gull *Larus novaehollandiae scopulinus* tarapunga

Black-billed gull *Larus bulleri*

New Zealand pigeon *Hemiphaga novaeseelandiae novaeseelandiae* kereru

Shining cuckoo *Chrysococcyx lucidus lucidus* pipiwharauroa

Morepork *Ninox novaeseelandiae* ruru

New Zealand kingfisher *Halcyon sancta vagans* kotare

Welcome swallow *Hirundo tahitica neoxena*

Grey warbler *Gerygone igata* riroriro

North Island fantail *Rhipidura fuliginosa placabilis* piwakawaka

Silvereye *Zosterops lateralis* tauhou

Bellbird* *Anthornis melanura melanura* korimako

Tui *Prosthemadera novaeseelandiae novaeseelandiae*

North Island tomtit *Petroica macrocephala toitoi* miromiro

North Island rifleman* *Acanthisitta chloris granti* titipounamu

North Island weka *Gallirallus australis greyi*

- In the 1950s (1952, 1956), weka were transferred onto Mokoia (Axbey 1994).
- In 2005, weka were released from Mokoia into the Whirinaki Forest (Owen 1997, 2002).

North Island robin *Petroica australis longipes* toutouwai

- 1991: Robins were released onto the island (Jansen 1992, 1993; Lovegrove 1996).
- 1999: Robins were transferred from Mokoia to Moturoa Island, Northland (Owen & Asquith 2000).
- 2003: Robins were transferred to Tuhua (Mayor Island) (Heaphy 2003).
- 2005: Robins were transferred to the Waitakere Ranges (the Ark in Park project).

North Island saddleback *Philesturnus carcunculatus* tieke

- 1992: North Island saddleback from Tiritiri Matangi were released onto the island (Armstrong & Craig 1995).

Stitchbird *Notiomystis cincta* hihi

- 1994: Hihi from the one wild population on Hauturu/Little Barrier Island were released onto the island (Owen 1997; Armstrong et al. 1999).
- 2002: The hihi population was removed to Kapiti (Island) and Mount Bruce (Owen 1997, 2002).

Australian magpie *Gymnorhina tibicen*

Lizards

Speckled skink *Oligosoma infrapunctatum*

A4.2 Introduced species

Birds

Mallard *Anas platyrhynchos platyrhynchos*

Ring-necked pheasant* *Phasianus colchicus*

- 1952: Ring-necked pheasants were raised on Mokoia until 1956 when the programme (with birds) was moved to Ngongotaha (Perrot & Armstrong 2000).

Skylark *Alauda arvensis*

Hedge sparrow *Prunella modularis*

Song thrush *Turdus philomelos*

Yellowhammer *Emberiza citrinella*

Redpoll *Carduelis flammea*

Blackbird *Turdus merula*

Chaffinch *Fringilla coelebs gengleri*

Greenfinch *Carduelis chloris chloris*

Goldfinch *Carduelis carduelis britannica*

House sparrow *Passer domesticus domesticus*

Starling *Sturnus vulgaris*

Indian myna *Acridotheres tristis*

White backed magpie *Gymnorhina hypoleuca*

Mammals

Norway rat *Rattus norvegicus*

- 1839: Norway rats were first recorded on the island.
- 1990s: Rats were eradicated, although incursions occurred in 1996 and again in 2001 (Owen 1997, 2002).

Mouse *Mus musculus* or *M. domesticus*

- Mid-1960s: Mice were recorded on the island with one mouse caught in a trap (Beveridge & Daniel 1965).

Stoat *Mustela erminea*

- 2005: A possible incursion of a stoat on the island (Christensen 2005).

Cat *Felis catus*

- Mid-1960s: Cats were recorded on the island (Beveridge & Daniel 1965).

Horse *Equus caballus*

- Mid-1960s: Horses were recorded on the island (Beveridge & Daniel 1965).
- 1996: The last two horses were removed to the mainland (Owen 1997).

Feral pig *Sus scrofa*

- Mid-1960s: A few pigs were recorded on the island (Beveridge & Daniel 1965).

Feral cattle *Bos taurus*

- Mid-1960s: Cattle were recorded on the island (Beveridge & Daniel 1965). Cattle were found to have roamed over the island, judging from a skeleton found away from the flat southeastern part of the island (Wallace 1993).

Feral goat *Capra hircus*

- Mid-1960s: Two tethered goats were recorded on the island (Beveridge & Daniel 1965). Goats were brought to the island to control blackberry (Owen 1997) on the eastern flats of the island in 1985; however, they escaped into the surrounding bush (Perrot & Armstrong 2000).
- Goats were culled from in the island in 1989 (Owen 1997).

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