Restoration plan for Korapuki Island (Mercury Islands), New Zealand

2004–2024

David R. Towns and Ian A.E. Atkinson

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ABSTRACT

Restoration of the terrestrial fauna of Korapuki Island (Mercury Islands, off northeastern New Zealand) began in 1988, following eradication of kiore (Pacific rat) in 1986 and rabbits in 1987. The present restoration plan uses nearby Middle Island as a reference site. Effects of introduced species on the terrestrial systems of Korapuki I. were modelled using interaction webs, and compared with those on Middle I. Predictive models for systems on Korapuki I. in 20 years were developed. Topographic and geological differences between Middle and Korapuki Is are likely to influence the final form of each system. Differences in vegetation composition may also result from variable effects of keystone species such as kereru. Following removal of rats and rabbits, many plant species have recolonised, and there were more species of indigenous ferns and woody plants on Korapuki I. than on Middle I. by 2002. The land snail fauna of the two islands is of equivalent size, but differing composition. The spider fauna of Korapuki I. contains at least twice the number of species as that for Middle I. There appear to be more burrowing seabird species on Korapuki than Middle I., but their density is far higher on Middle I. Translocation of forest trees to Korapuki I. is not currently recommended. One species of *Cambridgea* spider, the large darkling beetle, two species of weta and tuatara should be reintroduced by 2012. While interaction webs help to define measurable components of the developing Korapuki I. ecosystem, they should be viewed as models to be tested and refined over time.

Keywords: Korapuki Island, Middle Island, restoration, interaction webs, reintroduction, burrowing seabirds, Mercury Islands tusked weta, tuatara, kereru, New Zealand

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1. Introduction

The following plan for the future management of Korapuki Island (I.) (in the Mercury Islands (Is) group) reflects priority actions defined for islands in the Mercury Islands Ecological District in the Department of Conservation (DOC) Waikato Conservancy Conservation Management Strategy (Waikato CMS; Anon. 1996).

The Mercury Is lie about 6 km off the eastern Coromandel Peninsula of New Zealand (Fig. 1). All islands in the Mercury group were once linked to the mainland, but the most recent linkages (possibly until about 6000–7000

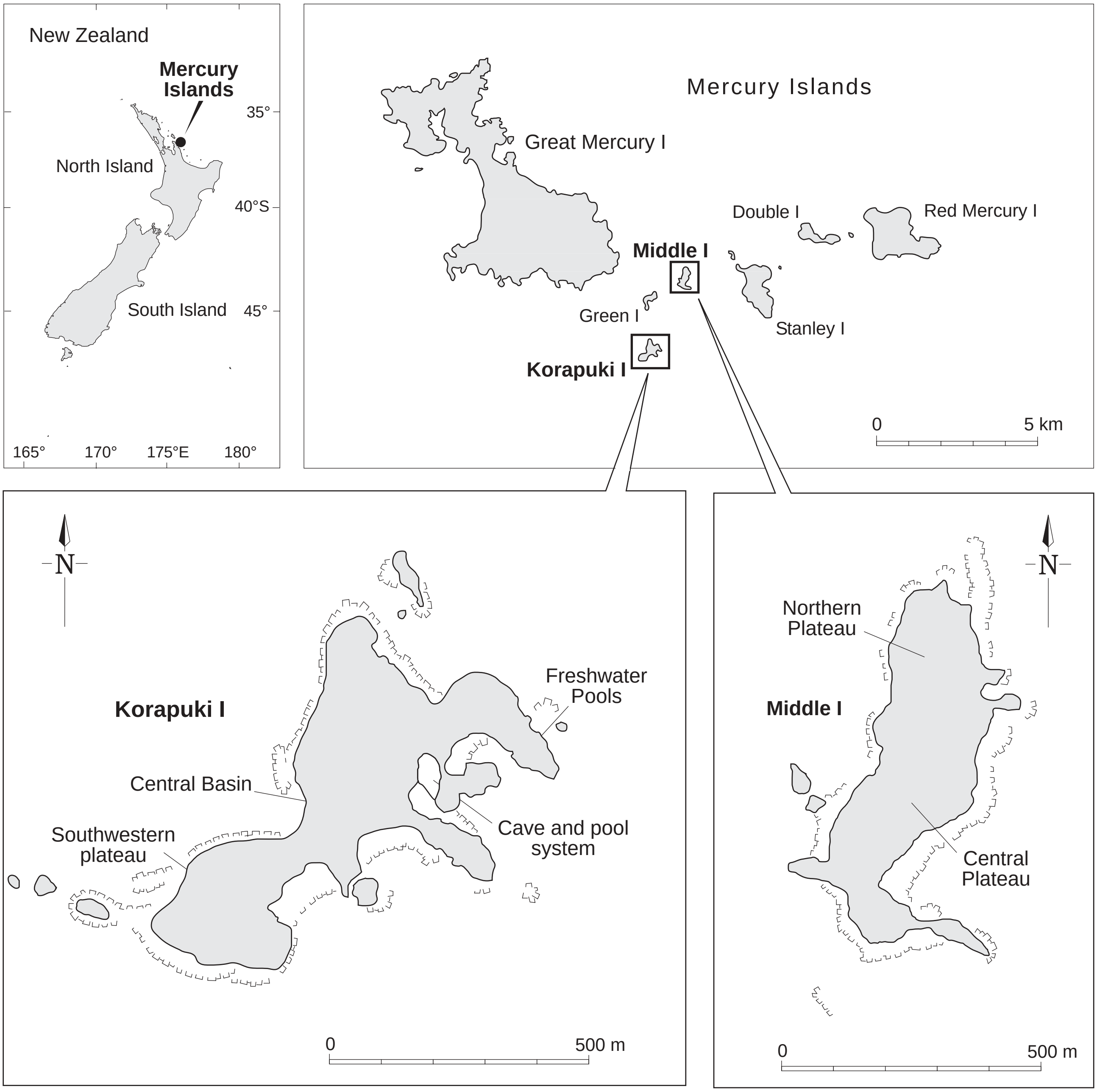


Figure 1. Map of the Mercury Islands with detail of Korapuki and Middle Is.

years ago) were between Korapuki, Green, and Middle Is (Towns 1994). Whereas Middle I. (13 ha) and Green I. (3 ha) have remained free of introduced mammals, Korapuki I. was, until recently, occupied by kiore and rabbits (Appendix 1). The kiore were removed in 1986 (McFadden & Towns 1991) and the rabbits in 1987 (I. McFadden pers. comm.). Unlike Middle and Green Is, Korapuki I. was highly modified by recent fires. Based on old photographs, there was still very little forest vegetation in the 1940s.

Towns et al. (1990) proposed that Korapuki I. was suitable for restoration, and identified possible early phase restorative actions. The proposal was subsequently incorporated into an Action Plan for the Mercury Is Ecological District by Thomson et al. (1992). The present plan supersedes an earlier draft detailing 5-year actions from 1997 (Towns & Green 1997).

The present plan is for 20 years from 2004–2024, at which point the success with restoration activities should be reviewed. We recommend a range of restoration actions which should be completed in the first 10 years, and optional actions for the second 10 years. We also recommend that at 5-year intervals criteria for success should be summarised, and the outcomes and priorities reassessed. Other components of the plan, such as the priority order of key tasks, addition of new tasks and the range of research needs, can be revised at any time. The plan refers to many species of plants and animals by their common names, with corresponding scientific names given in Appendix 1.

2. Mandate and vision

2.1 MANDATE

Korapuki I. (36°39.5′ S, 175°51′ E) is an 18-ha Scenic Reserve with secondary use as Wildlife Sanctuary, administered by DOC. The island is classified as Class A ‘Inviolable Reserve’ as part of the Hauraki Gulf Maritime Park, with strict restrictions on access (Mossman & Miller 1986).

The Waikato CMS (Anon. 1996) states that the management objective for Korapuki I., along with other Mercury Is, the Aldermen and Cuvier I. is:

> ‘To preserve and enhance the outstanding ecological values of the islands.’

This is to be implemented by:

- Maintaining ‘in their natural state islands which have suffered minimal impact from human colonisation’ and prohibiting access ‘to these islands except by permit for scientific, cultural or management purposes…’ (Anon. 1996: Vol. 1: 50–51).
- Restoring indigenous biotic communities on islands which have lost their original communities (Korapuki, Double, Middle Chain, Stanley, and Cuvier Is) and prohibiting access to these islands except under strictly supervised and controlled conditions.

- Undertaking management in accordance with the recommendations contained in the draft Conservation Action Plan for the Mercury Is Ecological District and with reference to species recovery plans.

The Waikato CMS also states that Korapuki I. is valuable as ‘a vanguard for successful island restoration …’ maintained by fostering ‘knowledge and support for the island by interpretation, education and involvement’ (Anon. 1996: vol. 2: 68) and allowing scientific investigation on a controlled basis. Additional specific implementation steps identified included:

- Restoring natural lizard, plant and invertebrate communities.
- Taking visitor parties to the island on a controlled basis for specific advocacy purposes in order to demonstrate island restoration measures.
- Seeking involvement of tangata whenua and the Mercury Bay community in management.

Korapuki I. has, therefore, been identified explicitly as a showcase for restoration of the natural communities of an island ecosystem. This plan outlines ways that the restoration goal can be achieved. The goals of advocacy and community involvement will need to be addressed in a separate strategy.

2.2 VISION

The biological diversity of Korapuki I. will be restored to form diverse communities of indigenous plants, animals, and micro-organisms representative of Mercury Is ecosystems. Indigenous species will interact within natural pathways as far as possible unmodified by the detrimental effects of introduced organisms.

3. Principles, goals, and outcomes

3.1 DEFINITIONS AND PRINCIPLES

This plan defines ecological restoration as active intervention to restore species or physical conditions lost due to human-induced disturbance in order to recreate a biological community that previously existed (Atkinson 1988). The plan uses the following guiding principles to achieve maximum benefit and cost-effectiveness.

- The short-term financial cost of restoration comprises removal of pest species, reintroduction of species determined from historic data and restoration models, monitoring of the effectiveness of reintroductions and natural recovery of resident species, and technical developments (research) required to support these.
- All species reintroduced to the island should eventually form self-sustaining populations that do not require further management.
- Wherever possible the natural processes of dispersal, colonisation and succession would be allowed to operate. Reintroductions would only be undertaken for species clearly unable to recolonise by other means.
- The species composition finally achieved would be based on local island models and historic data, but the structure and dynamics of the biotic communities that form will be determined by prevailing ecological factors on the restored island.
- The long-term financial cost of maintaining the restored island system would be restricted to the cost of protection from invasion by pests and problem weeds.

The plan is also based on the following assumptions:

- Access to the island will continue to be restricted to categories of visitors defined in the Waikato CMS (Anon. 1996).
- Pests that could materially affect the restoration goals will not disperse to Korapuki I. either directly or from other islands in the group.
- Activities undertaken on the island will minimise impacts on the biological communities. Most importantly, the landing and unloading of all stores on the island will follow risk mitigation procedures established to maintain its present rodent-free status and to protect against the introduction of pathogens, weeds and invertebrate pests. The necessary procedures are defined as part of a biosecurity plan for islands in Waikato Conservancy.

3.2 GOAL, TARGET, AND OUTCOMES

3.2.1 Goal

Statements in the Waikato CMS (Anon. 1996) identify the goal of Korapuki I. as ecological restoration of indigenous flora and fauna. However, the statements do not identify a restoration target, without which criteria for success cannot easily be defined (Towns 2002b).

3.2.2 Target

A restoration target proposed for Korapuki I. by Towns et al. (1990) was for a seabird-reptile-invertebrate-plant system similar to that of Middle and Green Is. One unusual feature of the biota of Middle and Green Is is co-existence of very dense populations of small seabirds (particularly diving petrels) with a high diversity of reptiles and many invertebrate species not present elsewhere in the Mercury Is group. These form two distinctive communities:

- Milktree forest/bird burrowed friable clay—at present restricted to the plateaux on Middle I. and part of Green I.
- Wharangi-mahoe forest/bird-burrowed friable clay—present on the gentle slopes of Middle and Green Is.

Although conditions on Korapuki I. should enable restoration of the above two communities, unique site conditions might also lead to the development of biotic communities on Korapuki I. no longer represented anywhere in the Mercury Is group (Towns et al. 1990).

3.2.3 Outcomes

In the short term (< 10 years), realising the following achievements will ensure significant gains to the biodiversity of Korapuki I. (Table 1):

- At least 10 species of plants and animals resident on Korapuki I., but rare or absent on the mainland, will continue to benefit from the absence of rats and rabbits.
- At least nine additional species (including up to six species of reptiles and three of insects) will have been reintroduced to Korapuki I.
- Most of the known threatened species of invertebrates and reptiles on Middle I. should be established on Korapuki I. in an increasingly diverse forest system.

In the longer term (> 10 years), the Korapuki I. seabird-reptile-invertebrate-plant system may show increasing similarity with that on Middle I. However, there are likely to be distinctive elements, some of which will remain for decades.

- Pohutukawa is likely to continue to influence litter composition, canopy structure and invertebrate distribution at some sites for decades to centuries.
- A patotara, orchid, and herbaceous plant community on shallow naturally phosphorus-deficient soils, although absent from Middle I., may persist for many decades on Korapuki I.
- At least 12 species of plants present on Korapuki I. are absent or very rare on Middle I. (Table 2). Rangiora, coastal *Astelia*, rengarenga, tree ferns, and widespread tawapou are likely to contribute to distinctive features of the biota of Korapuki I.

- Two species of lizards, copper skinks and moko skinks, are likely to remain much more common on Korapuki I. than on Middle I. because of the greater range of suitable habitats available on Korapuki I. However, some of the more open areas occupied by both species on Korapuki I. may disappear through natural succession (Towns et al. 1990).

Despite the distinctive features of Korapuki I. communities, their increasing similarity with those on Middle (and Green) Is should:

- Reduce the level of threat to the unique seabird-reptile-invertebrate-plant system of these islands.
- Provide extensive new habitat for threatened species from Middle I.
- Provide a testing ground for new methods and a natural laboratory for understanding the principles of ecological restoration.

TABLE 1. LIST OF SPECIES TO BENEFIT FROM RESTORATION ON KORAPUKI ISLAND.
Species as listed in New Zealand threat classification system (Hitchmough 2002); those listed by IUCN (1996) are identified by superscript letters.

RESIDENT SPECIES NOW RARE OR ABSENT ON THE MAINLAND	THREAT CLASSIFICATION	QUALIFIERS*	COMMENTS
Mawhai (native cucumber)	Nationally critical	CD, TO	Rapidly spreading at several sites
Milktree	Sparse		New seedlings spread by birds
Giant centipede	n.t.		Present throughout the island.
Duvaucel's gecko^{LR}	Sparse	HI	Widespread through all habitats
Moko skink	Sparse	HI	Common throughout island
Grey-faced petrel	n.t.		Throughout island
Pycroft's petrel	Range restricted	RC, HI	Breeding in scattered localities
Fluttering shearwater	n.t.		Locally common
Southern diving petrel	n.t.		Expanding around coast
Little shearwater	n.t.		Scattered localities
Flesh-footed shearwater	Gradual decline	SO	Scattered localities
REINTRODUCED SPECIES			**STATUS**
Large darkling beetle	n.t.		Translocations under way
Auckland tree weta	n.t.		Spreading through central basin
Suter's skink	n.t.		Spreading on western coast
Marbled skink	Range restricted	ST	Breeding, but status unclear
Robust skink^{VU}	Range restricted	ST, HI	Breeding but status unclear
Whitaker's skink^{VU}	Range restricted	CD, RC, HI	Spreading to southwestern plateau and central basin
SPECIES PROPOSED FOR REINTRODUCTION			**SOURCE**
Rhytida snail	n.t.		Green I. or Matapaua Bay
Cambridgea spider	n.t.		Green or Middle Is
Ground weta	n.t.		Middle I. (or Green I., if present)
Mercury Is tusked weta	Nationally critical	EF, OL	Middle I. (captive reared), depends on success of releases elsewhere
Pacific gecko	Gradual decline	HI	Middle or Green Is
Tuatara^{LR}	Sparse	ST, HI	Green Is

* CD = Conservation dependant; DP =Data poor; EF = Extreme fluctuations; EW = Extinct in the wild; HI = Human induced; OL = One locations; RC = Recovering; RF = Recruitment failure; SO = Secure overseas; ST = Stable; TO = Threatened overseas.
^{VU} Vulnerable; ^{LR} Low risk. n.t. = not threatened.

- Eventually provide a source of plants and animals for study and for reintroductions to other islands, thereby reducing human disturbance to the Middle and Green I. systems.

Given its roughly equivalent area and topography to Korapuki I., Middle I. is used here as a reference site against which targets and outcomes are defined. The tasks required to meet these targets depend on an understanding of the characteristics of each island system and the capacity for these systems to change.

TABLE 2. COMPARISONS BETWEEN THE RESIDENT INDIGENOUS FLORA AND FAUNA OF MIDDLE AND KORAPUKI ISLANDS UNTIL 1986.

With data from Hicks et al. (1975), Cameron (1990), and I.A.E. Atkinson (unpubl. data).

	MIDDLE ISLAND	KORAPUKI ISLAND
Vegetation	Coastal broadleaved forest	Scrub and forest of manuka, pohutukawa, mahoe; distinctive ratstail–patotara grasslands
Flora	Native monocotyledons and dicotyledons total 62 species; includes kohekohe and scurvy grass	Native monocotyledons and dicotyledons total 42 species; lacks kohekohe and scurvy grass, but includes the following absent from Middle I.: Akepiro, hangehange, kanuka, *Astelia banksii*, koromiko, mamaku (tree ferns), manuka, mingimingi, rangiora, rengarenga, tauhinu, and possibly tutu
Invertebrates	Includes large-bodied flightless species, e.g. two species of large darkling beetle, Mercury Island tusked weta, ground weta, giant centipede	Excludes large-bodied invertebrates; no known weta or centipedes
Tuatara	Abundant	Represented only as subfossil remains
Seabirds	Five species, with diving petrels and flesh-footed shearwaters very abundant	Up to 8 species, scattered, with penguins most abundant

4. Characteristics of the Middle Island system

4.1 PHYSIOGRAPHY, GEOLOGY AND SOILS

Middle I. (36°38′ S, 174°52′ E) is oriented approximately north–south. The summit of the island forms two small plateaux connected by a narrow saddle (see Fig. 1). Steep slopes border the plateau on the north-eastern portion of the island, but the southeast and much of the western side are bordered by vertical cliffs of massive andesite, up to 70 m high (Atkinson 1964).

The main rocks are andesite (some with platy cleavage), greyish breccias, and hard yellowish-brown tuffs. The soils are heavily burrowed clay loam—loose when dry and forming a red-weathered, cheesy clay when wet (Atkinson 1964).

4.2 VEGETATION AND FLORA

The flora and vegetation of Middle I. were described by Atkinson (1964) and Cameron (1990). In addition to cliff vegetation on shallow rocky soils, Atkinson (1964) described three forest types during his visit in 1962. Cameron (1990) confirmed these forest types following his two visits in 1983 as did Towns et al. (1997). Atkinson has subsequently reconfirmed the forest types, with the most recent visit being in 2002 (I.A.E. Atkinson unpubl. data). The vegetation types were:

- Karo-taupata scrub on burrowed very friable clay loam—this fringes the entire island, with karo often emergent through the taupata. There are occasional ngaio, coastal mahoe and poroporo.
- Wharangi-mahoe forest on burrowed, very friable clay loam—this occurs on steep slopes and forms the transition between karo-taupata scrub and milktree forest on the plateaux.
- Milktree forest on burrowed, very friable clay—this is confined to the plateaux and associated with mahoe, wharangi, and localised karaka.

Cameron (1990) considered the flora of Middle I. to be rather depauperate for an island of its size. He listed 96 vascular plants, 74% of which were native (Table 3).

4.3 FAUNA

The indigenous fauna of Middle I. is distinctive, and it includes:

- The only natural population of the Mercury Island tusked weta (Sherley 1998)
- A particularly diverse land snail fauna for an island of its size, with 22 species recorded (R. Parrish and D.R. Towns unpubl. data)

TABLE 3. COMPONENTS OF THE FLORA OF MIDDLE AND KORAPUKI ISLANDS.

With data from Cameron (1990) and I.A.E. Atkinson (unpubl. data), comparing data from the same observers on Korapuki Island before removal of kiore and rabbits (1962–1970), after removal of kiore and rabbits (completed in 1987), and up to 17 years after removal of kiore and rabbits (2004).

	MIDDLE ISLAND 1962–1985	KORAPUKI ISLAND 1962–1970[1]	KORAPUKI ISLAND 1987–88	KORAPUKI ISLAND 1997–2002
Native ferns and allies	9	12	17	18
Native dicotyledons	45	33	57	64
Native monocotyledons	17	9	17	21
Introduced dicotyledons	20	10	17	18
Introduced monocotyledons	5	1	7	7
Total	96	65	115	128
% native	74	83	79	81

[1] Numbers of species in 1962–1970 may reflect relatively limited search time.

- The largest number of reptile species for any island of equivalent size in New Zealand, comprising tuatara and 10 species of lizards (Cameron 1990)
- The only remaining location in New Zealand where four species of *Cyclodina* skinks naturally co-exist (Cameron 1990; Towns 1999)
- Extremely dense populations of burrowing seabirds, predominantly diving petrels and flesh-footed shearwaters, but also including little shearwaters, grey-faced petrels, fluttering shearwaters and penguins (Southey 1985)

There is a small terrestrial avifauna that includes bellbirds, red-crowned kakariki, grey warblers, fantails, silvereyes, and, occasionally, kereru. Predatory species include harriers (these commute around the islands), small numbers of resident moreporks and kingfishers.

5. The Korapuki Island system to 1986

5.1 PHYSIOGRAPHY, GEOLOGY, AND SOILS

Korapuki I. is the southern most of the Mercury Is, and is irregular in shape with the long axis oriented northeast–southwest (see Fig. 1). The island is formed into two portions separated by a central basin. The southern portion is comprised of a plateau at about 30 m a.s.l that rises to a small rocky peak (45 m a.s.l). The northern portion is comprised of a ridge and valley system that rises to 81 m. The northeastern and southwestern ends of the island are bounded by steep cliffs which, on the northern faces, reach 75 m. There are three embayments on the southeast coast that form rocky beaches, and boulder or rocky strands fringe almost the entire western coast.

There is no running fresh water, although temporary streams do develop in a western valley after heavy rain. There is also a small complex of rainwater-filled pools at the north-eastern extremity of the island. The water in these pools is sufficiently fresh to support a small community of freshwater invertebrates (Hicks et al. 1975).

The rocks of Korapuki I. are Mercury basalts of Pleistocene age, including extrusive lava flows, breccias, ash and scoria, and intrusive dikes. Eruptive centres can be recognised on the southeast coast at a cave-and-pool complex, with reddish coloured lapilli, ash, and scoria. There are extensive areas of exposed basalt and breccia in cliffs, but also at the surface on ridges inland. Basalt areas have eroded to form extensive boulder tumbles on the southeastern-most promontory, from an exposed dike on the north-eastern end of the island, and they form the summit of the southwestern plateau.

Most soils on Korapuki I. are reddish-brown clay loams weathered from basalt. The exception is on the ridge leading to the summit, where soils are shallow, dusky red clay loams overlying weakly weathered breccia (I.A.E. Atkinson unpubl. data).

5.2 FLORA

The vegetation of Korapuki I. was described by Atkinson in 1962 (unpubl. data), mapped by Hicks et al. (1975) from observations in 1974 and remapped by Atkinson (unpubl. data) between 1987 and 1989.

In 1962 Atkinson found the following vegetation types:

- Pohutukawa forest, especially on the top and north facing slopes of the southwestern plateau. A canopy gap on these slopes contained stands of mahoe and ngaio
- Pohutukawa forest and manuka scrub on other slopes

- Extensive flaxland, especially on southeast slopes, seaward slopes and in the central basin
- Ratstail grassland, patotara, manuka scrub, flaxland and pohutukawa scrub that formed mosaics along the main ridge and slopes of the eastern block of the island

Essentially similar vegetation types were identified by Atkinson in 1970 and Hicks et al. (1975), except that the latter noted the presence of mahoe, a mapou understorey under the pohutukawa on the southwestern plateau, and dense patches of manuka on the southern part of this plateau. The vegetation was consistent with the presence of rabbits since late in the 19th Century, and repeated firing of parts of the island in the early 20th Century (I.A.E Atkinson unpubl. data).

Further changes included by 1986:

- Grassland on the southern part of the main ridge had been over-topped by pohutukawa, although other areas remained
- Manuka scrub on southern end of the southwestern plateau, in parts of the central basin an on the north western slopes of the main ridge had been over-topped by pohutukawa and was lying dead on the forest floor
- Most of the flax in the central basin had been over-topped by the expanding crowns of pohutukawa (I.A.E. Atkinson unpubl. data)

The flora recorded to 1970 was very depauperate, comprising about 65 species, although over 80% of these were native. By 1987–88, the plants known from the island comprised 115 species, including 17 species of ferns and 57 species of native higher plants (dicotyledons) (see Table 3).

5.3 FAUNA

Surveys of the fauna until 1974 included two surveys for lizards (Whitaker 1973; Hicks et al. 1975), and in addition, accounts of invertebrates, seabirds, landbirds and introduced mammals (Hicks et al. 1975). The fauna comprised:

- A depleted terrestrial invertebrate fauna that had few large flying insects, few large species of beetles or moths, and no species of weta
- Litter fauna that tended to be sparse under pohutukawa and contained few large invertebrates
- A lizard fauna comprising five species. Three species, common gecko, Duvaucel's gecko and copper skink, were regarded as very rare. Two small diurnal skinks (moko skink and shore skink) were common, with moko skink present in grassland and flax and shore skink along boulder beaches
- Tuatara were absent, but subfossil remains indicated previous presence
- A small fauna of forest birds, of which red-crowned kakariki, fantails, grey warblers and silvereyes were particularly abundant
- Eight species of burrowing seabirds, the most numerous of which were blue penguins. Other species were at scattered locations and included

small areas burrowed by fluttering shearwaters and diving petrels. Some of these species may have been harvested in the past, with burning the forest to facilitate access. However, we have found no oral history in support of this, or to indicate any other motive for regularly burning the island.

Introduced mammals (kiore and rabbits) were present. Rabbits were present in low numbers (encountered at 0.04 individuals/person-hour) and kiore abundance varied seasonally. Assuming the same observer effort as for rabbits, encounter rates for kiore were higher in winter (6.9 individuals/person-hour) than in spring (0.3 individuals/person-hour) (Hicks et al. 1975).

6. Comparison between Korapuki Island and Middle Island to 1986

The most distinctive differences between Korapuki I. and Middle I. are listed below (and summarised in Tables 2 and 3).

The vegetation on Korapuki I. has undergone extensive successional change. In 1925 the island was largely under grass and manuka, which by 1962 had changed to manuka, flaxland, pohutukawa forest, and scrub, and residual areas of ratstail grassland (Hicks et al. 1975). By 1986, pohutukawa dominated over much of the island, grassland areas had declined, and substantial areas of manuka were over-topped by pohutukawa.

The vegetation of Middle I. has apparently retained the present distribution of vegetation types for many decades. Coastal broadleaved species with milktree predominated in 1962; with the latter species regenerating under its own cover after wind-throw following storms. This vegetation type has not changed to the present day. Although there is evidence of prehistoric firing (Cameron 1990), the current vegetation shows little evidence of succession to include additional hardwood species present elsewhere on larger islands in the group. This present vegetation structure appears to reflect the dry soil conditions and disturbance effects of seabirds and storms.

The floristic diversity within vegetation types on Korapuki I. was very limited up to 1986. With 42 recorded native monocotyledons and dicotyledons, this was even smaller than the depauperate list of 62 species listed for the same groups on Middle I. by Cameron (1990).

Invertebrate density and diversity on Korapuki I. were considered by Hicks et al. (1975) to be low. Litter invertebrate samples were not obtained on Middle I. However, species not found on Korapuki I. before 1986, but present on Middle I., included two species of darkling beetles, coastal earwigs, three species of weta, large isopods, and giant centipedes (Green, cited in Towns et al. 1997).

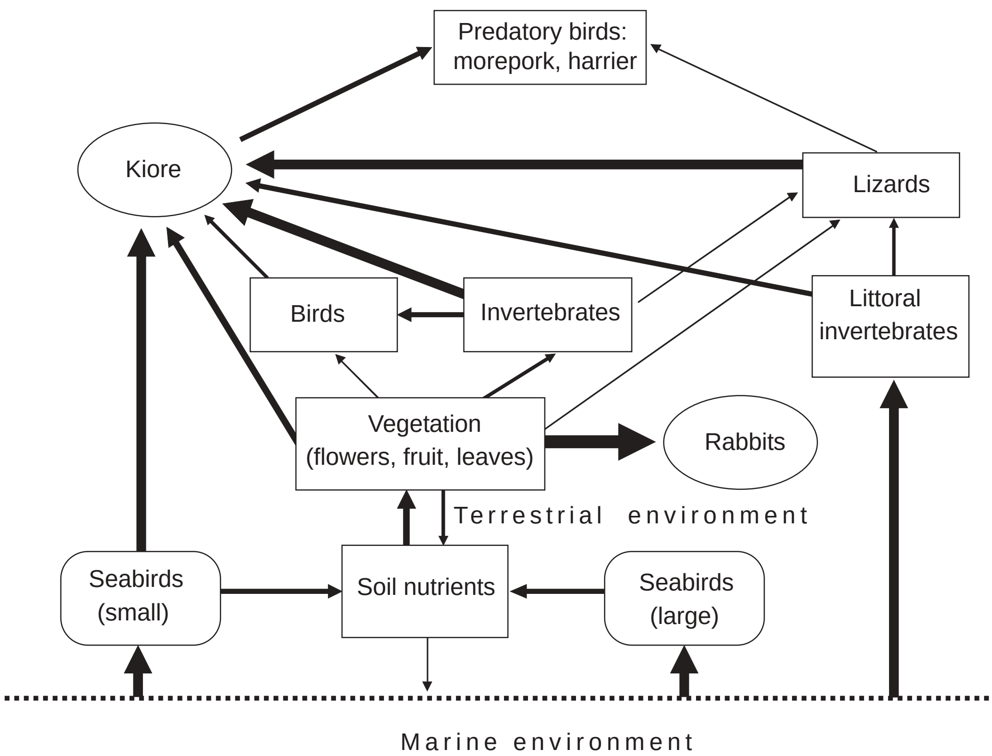
The reptile fauna of the two islands differed in density and species diversity. Although absent from Korapuki, tuatara numbers were estimated to be in the 'low thousands' on Middle I. (Gaze 2001: 32). The small lizard fauna of Korapuki I. included five species present on Middle I. One of these, moko skink, was rarely encountered on Middle I., but was widespread and common on Korapuki I.; apparently in response to the favourable open areas resulting from rabbits suppressing regeneration (Towns et al. 1990).

Unlike other components of the biota, the avifauna of Korapuki I. was either similar to or larger than that of Middle I. In part this probably reflected the ability of birds to commute between islands in the group. However, although the seabird diversity of Korapuki I. was higher than recorded on Middle I., densities of the component species were lower. For example, diving petrels intensively burrow every available area on Middle I. Based on estimates from nearby Green I., Middle I. diving petrels probably reach densities of 1000 birds/ha (Thoresen 1967). Diving petrels were rare on Korapuki I., where the most common procelariiform seabird was the grey-faced petrel, estimated as a total of 600–700 pairs over the entire island (Hicks et al. 1975).

In addition to differences in fire regimes, only Korapuki I. has been influenced by introduced mammals. The likely effects of kiore were discussed by Whitaker (1973), Hicks et al. (1975), Towns (1991, 1996, 2002b), and the effects of rabbits, or rabbits and kiore combined, by Towns et al. (1990, 1997). The effects of kiore and rabbits on the Korapuki I. ecosystem can be summarised in an interaction web (Fig. 2) characterised by:

- Low levels of input into soils by seabirds due to low seabird densities
- High use of littoral invertebrates as food by lizards, most of which were confined to coastal refuge habitats. By comparison, terrestrial sources provided weak contributions (Whitaker 1973; Towns 1991)
- Very high interaction effects of kiore on lizards, invertebrates, vegetation (especially fruit) and small seabirds summarised by Atkinson & Towns (2001)
- Very high interaction effects of rabbits on vegetation, especially foliage (I.A.E. Atkinson unpubl. data)
- Low potential for dispersal of seed by birds, since the vegetation was predominantly of species dispersed by wind (e.g. manuka, pohutukawa)
- Rare kingfishers and occasional, probably non-resident moreporks
- A small number of links between each component group, forming a relatively simple system

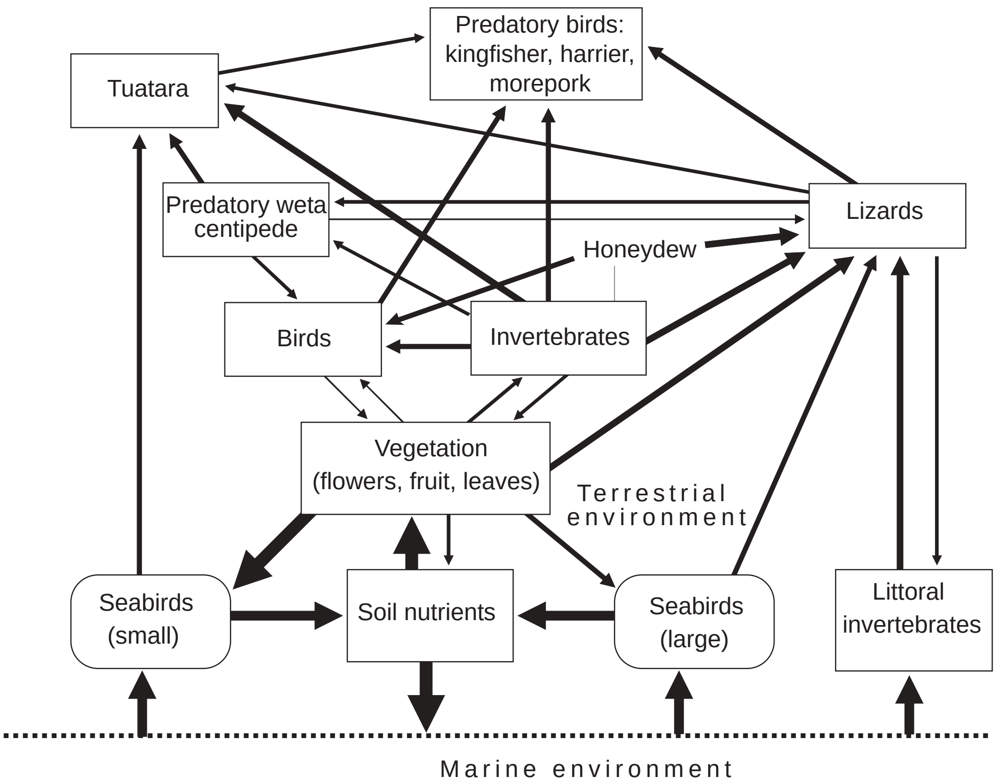
Figure 2. Simplified interaction web for Korapuki Island in 1986 before the eradication of introduced mammals (oval shapes); line width is proportional to interaction strength.



By comparison, a web constructed for Middle I. (Fig. 3) was characterised by:

- Very strong effects of seabirds on soil nutrient levels, structure and mobility, and negative effects of some seabirds (especially flesh-footed shearwaters) on seedling density (Mulder & Keall 2001). These species therefore modify the entire system.
- High use of terrestrial invertebrates by lizards, but also of fruit, flowers and honeydew (mainly on karo); use of seabird burrows by lizards and probably scavenging of spilled regurgitations. Very high lizard densities in suitable coastal sites, but probably some predation by *Leptograpsus* crabs on species that are nocturnal.
- Diverse invertebrates, including a large fauna of native wasps that feed on flowers and parasitize caterpillars, plus numerous fruit eating dipterans and high numbers of carrion-feeding blow flies (D.R. Towns unpubl. data).
- A distinctive fauna of large predatory invertebrates, including giant centipedes, tusked weta and ground weta.
- Dense populations of tuatara (at least 500 individuals/ha) feeding on invertebrates (largely), but also small seabird chicks. Seabird burrows are also used as shelter.
- Dispersal of numerous fleshy-fruited plant species by birds and lizards, although most of these produce small fruit. The exception is karaka, which, however, is not widely distributed.
- Predatory birds including kingfishers and a small and probably resident population of moreporks.
- Large numbers of links between the component groups, forming a relatively complex system.

Figure 3. Simplified interaction web for Middle Island as of 2002, with keystone species identified as rounded boxes; line width is proportional to interaction strength.



7. Changes on Korapuki Island since 1986

7.1 ECOLOGICAL PROTECTION THROUGH PLANT AND ANIMAL PEST CONTROL

There are a few perennial weeds on Korapuki I. which may have detrimental effects on the system. These include:

- Boxthorn—now under a control programme
- Occasional pampas—also being controlled, but some plants in deeper forest have died when over-topped by native tree species
- Occasional Mexican devil—pulled, bagged, and removed whenever it has been found

Following the removal of kiore in 1986 and rabbits in 1987, follow-up invasion prevention included bait stations using bromadiolone or brodifacoum-based baits. These were placed at or near likely landing sites. Index trapping using snap traps was also conducted in the first two years after the campaign against kiore. There has been no sign of interference with bait stations (Towns 1988). However, an unmated female ship rat was caught in a snap trap in August 1988, providing rare evidence of an intercepted invasion (I. McFadden pers. comm.).

7.2 NATURAL REGENERATION THROUGH SUCCESSION

The natural recovery of the biota on Korapuki I. since 1986 has included the following developments (I.A.E. Atkinson unpubl. data):

- Substantial declines in the area under grassland which halved between 1960 and 2000, from 0.42 ha to 0.22 ha
- Development of a more continuous pohutukawa canopy through extension of the crowns of individual trees, but reduction of the number of stems/ha through self-shading
- Development of an understorey of mahoe, karo, coastal karamu and (in places) houpara and mapou beneath tall pohutukawa forest
- Increases in the cover of taupata, karo, ngaio, and coastal karamu around shorelines
- Establishment of mahoe within flaxland, which over-tops the flax in many places
- Continued reduction in the areas occupied by manuka which is being over-topped by pohutukawa and invaded by karo, coastal karamu, and mapou
- Collapse of a grove of large ngaio trees

- Discovery of forest species not previously recorded (including New Zealand broom, ponga ferns, and kaihua). These, and colonisation by kaihua, have increased the flora to 128 species, almost double the number of species recorded to 1970 (Table 3)
- Spread of understorey and coastal species previously confined to a few plants (often in inaccessible places such as cliffs). These include rengarenga lily kawakawa, wharangi, and rangiora
- The appearance of young milktrees, under tall forest at several sites on the island
- Considerable increases in the numbers of tawapou, which has now spread over much of the island, despite the population having been reduced to two adult trees in 1986

In addition to changes in the vegetation and flora, the following changes of terrestrial invertebrates and reptiles have been recorded:

- Natural reappearance of many flightless invertebrate species previously unrecorded on the island (apparently suppressed by predation). These include three species of native cockroaches, one darkling beetle (*Mimopeus elongates*), a carabid beetle (*Ctenognathus novaeze-landiae*), the coastal earwig, a species of rhaphidophorid weta, large isopods and giant centipedes (Green, cited in Towns et al. 1997)
- Spread of honeydew scale from the few remaining ngaio trees to young ngaio and many karo (Towns 2002a)
- Rapid recovery of the diurnal shore skink, which at some coastal sites has shown capture rates that increased 5000% over 9 years (Towns 1996)
- Redistribution and recovery of two gecko species previously very rare on the island. Duvaucel's gecko is now found throughout the forest and in coastal areas; and the common gecko is now frequently seen feeding on ngaio trunks, flax flowers and pohutukawa flowers (Towns 1994; Eiffler 1995). The latter species is now encountered in coastal habitats at rates equivalent to those on Middle I. (Towns 2002a)
- Abundant moko skinks in grassland, flax and coastal areas, and copper skinks, previously regarded as rare on the island (Hicks et al. 1975), are now widespread in forest and coastal areas (Towns 1994)
- Sightings of kereru that appear to regularly commute to the island. These are likely to have spread small numbers of karaka seeds, large numbers of tawapou seed, and two taraire seeds, of which the seedlings subsequently died in 1997 (I.A.E. Atkinson unpubl. data)

7.3 ECOLOGICAL RESTORATION

Direct restoration of species to Korapuki I. has so far been confined to two species of invertebrates and four species of skinks. Reintroductions of *Cyclodina* skinks to the island followed recommendations in species recovery plans (Towns 1992, 1999). Releases of invertebrates were designed to test translocation methods (C. Green pers. comm.). All of the released species are assumed to have been on Korapuki I. in the past.

The invertebrates

- Tree weta translocated from Double I. to Korapuki I. Double I. was the only location in the Mercury Is group where tree weta had survived. Morgan-Richards (1997) found distinctive chromosomal karyotypes in the Double I. population, possibly as a result of long isolation. Beginning with 52 weta in May 1997, the Double I. tree weta populations had increased at least 900% on Korapuki I. by March 2001 (C. Green pers. comm.).
- Large darkling beetles translocated from Middle I. from March 2000. None of the >50 darkling beetles or their progeny had been seen on Korapuki I (as of 2002).

The skinks

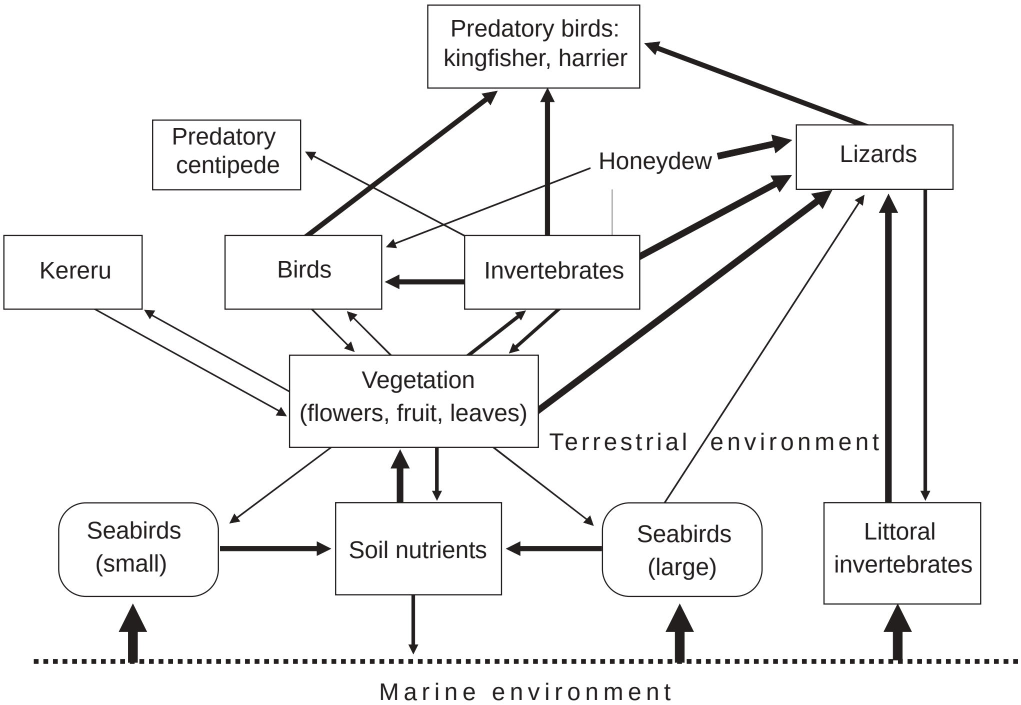
- Whitaker's skink, reintroduced from Middle I. in 1988 from a starting population of 25. This species is now successfully breeding and increasing in numbers on the island at an estimated 7% per annum (Towns 1992, 1994, 1999; Towns & Ferreira 2001).
- Robust skink, reintroduced from Green I. in 1992introduced1993 from an initial population of 15. Breeding of the population has been confirmed and there is evidence of dispersal from the release site. To date, population estimates are not sufficiently accurate to determine the expansion rate of this population (Towns 1992, 1999; Towns & Ferreira 2001).
- Marbled skink, reintroduced from Green I. in 1992–1993 from an initial population of 25. This population has not been intensively monitored, but breeding has been confirmed (Towns 1999).
- Suter's skink, reintroduced from Green I. in 1992 as part of an experiment to test population release models. An initial population of 30 (20 females and 10 males) was used. These are breeding on Korapuki I. and the population is expanding at up to 24% per annum (Towns & Ferreira 2001). A second population of 83 was released in 2001 (D.R. Towns unpubl. data). These were all juveniles hatched in captivity from eggs laid by females from Green I. (Hare et al. 2002). This population has not yet been monitored.

7.4 EFFECTS OF REGENERATION AND RESTORATION

Natural regeneration combined with the restorative actions above have led to a more complex system on Korapuki I. in 2002 than in 1986 (Fig. 4) including:

- Greater use by lizards of littoral invertebrates as lizard abundances increase in coastal areas
- Spread of honeydew and increased use by an expanding population of geckos
- Increasing use of seabird burrows by gradually expanding populations of large, nocturnal skinks

Figure 4. Simplified interaction web for Korapuki Island as of 2002 in the absence of introduced mammals; line width is proportional to interaction strengths.



- Increased abundance of kingfishers apparently associated with increases in the numbers of large invertebrates and lizards
- Increased availability and spread of plants that produce fleshy fruit used by birds and lizards
- Increased survival and spread of plants that produce large, fleshy fruit as a result of dispersal to or within the island by kereru
- Disappearance of moreporks, which although uncommon until 1986, have only since been recorded as vagrants on the island

However, the Korapuki I. interaction web (Fig. 4) still differs from that on Middle I. (see Fig. 3) because of:

- The absence of most large predatory invertebrates: notably tusked weta, ground weta and *Cambridgea* spiders
- The absence of tuatara as the top terrestrial predator
- Localised impacts of seabirds on soils

8. Conceptual model for the restoration of Korapuki Island

A conceptual model for the completing the restoration of Korapuki I. is affected by the following considerations. The soils and biota of Korapuki I. were extensively and repeatedly modified by fires and the presence of kiore (for an unknown period) and rabbits (for about 90 years). Fires have determined the predominant vegetation on the island, but this has further been modified by rabbit browsing. On the other hand, rabbits may have only had indirect effects on fauna. For example, modification of the vegetation, and the predominance of pohutukawa, can influence the density and diversity of litter invertebrates. In contrast, kiore are likely to have had direct effects on fauna demonstrated by the type and rate of recovery after kiore were removed. Studies on Korapuki I. and elsewhere indicate that these effects are selective, particularly of large, ground-dwelling flightless species of invertebrates, large nocturnal species of reptiles and small-bodied winter-nesting seabirds (Atkinson & Towns 2001).

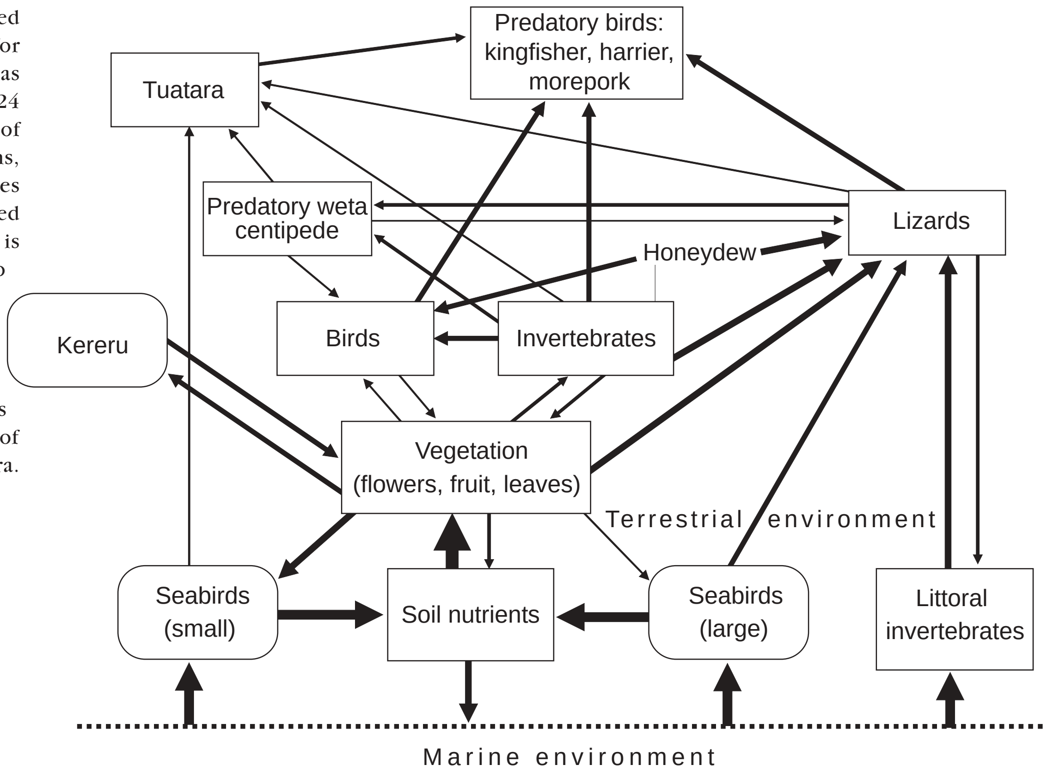
Korapuki I. was connected to Green and Middle Is subsequent to the fragmentation of the rest of the Mercury Is group through rising sea-levels about 8000 years ago. However, despite these connections, the geology, topography and soils of Korapuki I. are distinctive, and the systems present will reflect these local influences.

The density of burrowing seabirds can have direct and indirect effects on the abundance of many other species. These densities are in turn influenced by the distribution of friable tuffaceous soils (I.A.E. Atkinson unpubl. data). Such soils appear to be less widespread on Korapuki than on Middle I. Furthermore, the use of islands by seabirds may be influenced by topography. Unlike Green and Middle Is, Korapuki may never have been as extensively used by diving petrels. This is supported by the spider fauna, which is indicative of islands with relatively low levels of ground disturbance (B.M. Fitzgerald pers. comm.).

If components present on Middle I. (such as large invertebrates, some lizards, and tuatara) were established on Korapuki I., the predicted interaction web for Korapuki (Fig. 5) would eventually resemble that for present-day Middle I. This would result from the natural recovery of giant centipedes (present, but still rare on Korapuki I.), and the possible return of moreporks as the fauna of large invertebrates continued to expand. However, through regular visits by kereru, Korapuki I. has an additional keystone species that, in contrast, shows little evidence of its effects on Middle I. Kereru are likely to provide an increasingly important role in the spread of large-fruited tree species on Korapuki I. for three reasons:

- Korapuki I. is located on the flight path of kereru travelling between Red Mercury and Stanley Is and the mainland.
- Korapuki I. is one of the few islands in the group with permanent fresh water pools that may attract kereru.

Figure 5. Simplified interaction web for Korapuki Island as predicted for 2024 following completion of proposed reintroductions, with keystone species identified as rounded boxes; line width is proportional to interaction strength. Note the increasing effects from expanding populations of small seabirds, but weak effects of small populations of larger seabirds and tuatara.



- Kereru populations are likely to increase if there is increased nesting success due to kiore removal and improvements in kereru habitat following successional changes on Stanley and Red Mercury Is. As these populations expand, visits by kereru to Korapuki I. are likely to increase in frequency.

The webs in Figs 3 and 5 are greatly simplified summaries of complex interacting elements. These summaries hide subtle differences between islands and significant interactions within the component groups. For example the category 'invertebrates' is comprised of numerous interacting species, including distinctive elements unique to each island.

It is, therefore, necessary to assess these components individually. These assessments have been approached by making the following assumptions (Towns 2002b):

- All species were once capable of distributing throughout the islands because Middle, Green and Korapuki I. (along with the other islands in the group) were previously connected. Although reasonable, this assumption has to be modified to account for species-area effects such as the minimum size of a patch capable of supporting viable populations and site specific geochemical differences that affect the distribution of plants and invertebrates such as land snails.
- Differences between islands are the result of human-induced disturbance such as through burning and the introduction of introduced mammals. The above comments indicate that this assumption cannot be entirely supported.

Weaknesses in these assumptions can only be resolved by understanding the general effects of introduced organisms on native species. There is now a rich literature that enables models of these effects to be produced. In addition, it may require quite detailed knowledge of the relationships between soils, succession and distribution for some groups. In many cases, such information is patchy or lacking. Therefore, the following approach to restoration forms the basis for recommended actions in the following sections:

- The recolonisation of Korapuki I. by plants and animals will, as far as possible, rely on natural dispersal. For some species of invertebrates and reptiles, dispersal over water is clearly impossible, so translocations will be required. However, the dispersal mechanisms or capabilities of many plants are unclear. For that reason, propagation on Korapuki I. should only apply to threatened species (at least in the short term), to obtain data on mechanisms of dispersal by natural agents.
- Species translocated to Korapuki I. would be confined to those for which there is strong evidence that their absence is related to the detrimental effects of kiore, rabbits, or habitat destruction by humans. For example, species of minute land snails (see Section 10.1.1) may have distributions that reflect local geochemical properties rather than predator effects.

9. Restoration of flora

9.1 CURRENT SITUATION

The vegetation of Korapuki I. (as of 2002) was described by I.A.E. Atkinson (unpubl. data) who concluded:

- The predominant cover is of pohutukawa forest, 80–100 years old, reaching up to 14 m high. This canopy is complete over much of the island. The density of pohutukawa is decreasing as less vigorous trees decline and die at rates of 35–47 trees/ha/yr.
- Few of the naturally recovering species are capable of reaching the tall pohutukawa canopy. However, several are likely to form a tall subcanopy capable of exploiting canopy gaps as they appear. These include houpara, karaka, mahoe, milktree, tawapou, and wharangi.
- Declining pohutukawa cover, and replacement by other species, is likely to be a slow process, because of the young age of the pohutukawa. Pohutukawa cover is likely to persist on some parts of the island for at least another 100 years.
- The rates of subcanopy development and height of the pohutukawa canopy vary with exposure, moisture content, and fertility levels of the soils.
- Two widespread species—flax and mahoe—have decreased in cover at some sites. An area of mahoe and flaxland in the central basin is regenerating to coastal broadleaf scrub containing ngaio and coastal karamu, with little influence by pohutukawa.
- With natural recovery since 1986, the flora of Korapuki I. is larger than that on Middle I. (see Table 3). For example, Korapuki I. has twice the number of fern species and 30% more native dicotyledons than are recorded on Middle I.

9.2 MODEL OF THE ORIGINAL KORAPUKI ISLAND VEGETATION

On many modified islands, pockets of the original cover provide glimpses of possible historic forest composition. Unfortunately, small size combined with extensive modification have removed any trace of the original forest on Korapuki I. Towns (2002b) proposed a successional model as a means of identifying the dynamics of vegetation in the Mercury Is. The model viewed the islands as patches; the larger the islands are, the more patches they contained. Consequently, small islands usually had only one patch or vegetation type, such as bird-burrowed hymenanthera scrub. Larger islands had areas of bird-burrowed scrub, but also bird-burrowed forest containing karo, karamu, wharangi, and milktree. The largest islands were predominantly hardwood forest, but also likely to contain patches of bird-burrowed forest and bird-burrowed scrub.

Korapuki I. is in the middle size range of Mercury islands, so the successional model predicts that it is likely to have supported at least three patch types:

- Bird-burrowed hymenanthera/taupata/ngaio scrub—The most likely sites for this are the flaxlands and pohutukawa scrub on the south eastern side of the island where the vegetation is exposed to marine influences similar to those on the smaller islands.
- Bird-burrowed forest with karo, coastal karamu, mahoe, wharangi and milktree—This type is most likely to develop on dry sites on the southwestern plateau and other north-west facing slopes at present occupied by pohutukawa.
- Bird-burrowed forest containing hardwood species such as karaka and kohekohe—The most likely sites for these are in the damper sites such as the central basin at present occupied by tall pohutukawa, plus mahoe and flax.

Based on detailed analyses of succession on northern islands, further details to the above model can be added (I.A.E. Atkinson unpubl. data):

- Coastline and cliff vegetation of varying aged pohutukawa plus karaka, tawapou, milktree, houpara and coastal maire
- Forest vegetation on the main slopes that may have included karaka, kohekohe, mahoe, wharangi, milktree, tawapou, puriri and coastal maire. Drier sites may have supported some rewarewa and moister sites (such as the central basin) taraire and parapara
- Forest vegetation on very dry sites, such as boulder slopes, of pohutukawa, mahoe, wharangi, houpara, tawapou, coastal maire and milktree
- The ridges presently covered by ratstail and patotara grassland may have supported stunted forest of species such as coastal karamu, mapou and perhaps *Pittosporum umbellatum*

9.3 RESTORATION OPTIONS

Whether active restoration of the scrub and forest communities of Korapuki I. is needed, requires answers to the following questions:

- Is Middle I. an adequate model?
- Does the flora of Korapuki I. contain the likely components of a Middle I. model?

It is reasonable to concede that Middle I. is the best model available, in part because the native flora of Korapuki I. already contains more species than on Middle I. Consequently, most of the prerequisites for natural recovery are already available on Korapuki I.

Several of the species proposed as likely components of the original vegetation of Korapuki I. are absent from Middle I. Should any of these be introduced to Korapuki I. from elsewhere in the Mercury Is? One answer to this can be found from natural spread of species previously identified as needing translocation. For example, the following actions proposed by Towns et al. (1990) were not undertaken, but have since proceeded naturally:

- Spread of resident karaka onto bouldery slopes on the southwestern plateau—Karaka is slowly spreading in the central basin presumably as a result of seed dispersal by kereru and is, therefore, likely to reach the southwestern plateau and other sites through natural dispersal.
- Spread of seedlings of resident wharangi, to establish wharangi-mahoe forest—Wharangi is also naturally spreading, with at least 50 individuals exceeding 5 cm in height by 1998 (I.A.E. Atkinson unpubl. data).
- Establishment of seedlings of kaihua from Middle I. (Towns & Green 1997)—A single plant has established naturally on the northern slopes of the island (I.A.E. Atkinson unpubl. data).
- Spread of seedlings of tawapou to the southwestern plateau—These have already reached the southwestern plateau, presumably as a result of dispersal by kereru. Furthermore, there are now also numerous plants in the central basin (I.A.E. Atkinson unpubl. data).
- Establishment of seedlings of milktree from Middle I. if natural seedlings do not appear by 1990—Seedlings have established naturally, with small numbers of saplings and seedlings (≤ 5/location) scattered on the northern slopes, central basin, and southwestern plateau.

Given the size of the flora of Korapuki I., the amount of natural colonisation that has been recorded, and the likely effects of kereru on the spread of species that bear large fruit, there is no immediate need to artificially add forest hardwood species to Korapuki.

One species present on Middle I., but threatened throughout New Zealand is Cook's scurvy grass (Cameron 1990). This species appears to be associated with seabird activity (Norton & de Lange 1999) and may have limited capacity for distribution between islands because of the small size of the seeds which, however, appear too large to be dispersed by wind.

9.4 RECOMMENDED ACTIONS

- Investigate the potential and need to establish Cook's scurvy grass on Korapuki I.
- Review whether additional hardwood species should be spread to Korapuki I. in 2009. This will be > 20 years after removal of the last rabbits from the island.

10. Restoration of invertebrates

10.1 CURRENT SITUATION

10.1.1 Terrestrial molluscs

The known terrestrial mollusc fauna of Korapuki I. comprises 24 species. These include a leaf vein slug (*Athoracophorus bitentanalis*), a freshwater species present in the permanent pools (*Potamopyrgus antipodarum*), a terrestrial species tolerant of salt spray (*Suterilla neozelandica*), and one introduced species of small slug (*Arion intermedius*) (R. Parrish & D.R. Towns unpubl. data). The remaining fauna of 20 species of minute land snail is particularly diverse for a small island, despite very low species diversity under pohutukawa (R. Parrish and D.R. Towns unpubl. data). For example, an equivalent sized fauna (19 species) has been collected from 102 ha Whatupuke I. and a smaller fauna (13 species) from 80 ha Coppermine I. (R. Parrish pers. comm.). The high diversity on Korapuki I. is surprising given the extensive habitat modification on the island; such modification is far less evident on Whatupuke I. (Ritchie & Ritchie 1970).

The Middle I. land snail fauna (22 species) is slightly smaller than that of Korapuki I. However, despite the similar size of the faunas, each island has distinctive elements. Leaf vein slugs have not been found on Middle I., nor have seven (30%) of the land snails. Conversely, six (27%) of the species recorded from Middle I. have not been found on Korapuki I. (R. Parrish pers. comm.).

10.1.2 Spiders

With at least 70 species, the spider fauna of Korapuki I. is particularly large for an island of its size, and is at least double the number of species recorded on Middle I. (B.M. Fitzgerald pers. comm.). These include species that are able to balloon between locations as spiderlings on gossamer threads. Species not capable of this form of dispersal are also represented on the island. This high diversity may reflect the variety of habitats available. For example, grassland habitats present on Korapuki I., but not well represented elsewhere, support distinctive spider assemblages (B.M. Fitzgerald pers. comm.).

The spiders potentially susceptible to kiore predation are large species that inhabit the forest floor. On Middle and Green Is, three species fit this category. However, on Korapuki I., this assemblage is represented by more than twice the number of species (7) than on Middle and Green Is. One forest floor species widely distributed throughout the Mercury Is, but inexplicably absent from Korapuki I., is the large *Cambridgea mercurialis*, a species unable to disperse by ballooning (B.M. Fitzgerald pers. comm.).

10.1.3 Insects and other invertebrates

There has not been a systematic assessment of the insect fauna of the Mercury Is, however, some comparative data have been obtained for various invertebrate groups. For example, litter invertebrates occur at much lower density and diversity on dry soils under pohutukawa stands than under other vegetation types (Hicks et al. 1975; D.R. Towns unpubl. data). Under the tawapou and mahoe stands, density and diversity in 2001 were not significantly different from those under milktree and karaka on Middle I. (D.R. Towns unpubl. data).

Flying insects apparently show similar relationships with forest succession, with little difference between pan-trap samples obtained in 2002 under tawapou and mahoe on Korapuki I. and those obtained under milktree and karaka forest on Middle I. One notable difference was in the number of native wasp taxa, with double the number of species often obtained on Middle I. compared with Korapuki I. (D.R. Towns unpubl. data).

10.2 MODEL OF THE ORIGINAL KORAPUKI ISLAND INVERTEBRATE FAUNA

The earlier dry land connections between Middle, Green, and Korapuki Is were probably reflected in the invertebrate fauna of Korapuki I., which would have included:

- The large, ground-dwelling *Cambridgea mercurialis*, which builds webs in disused seabird burrows, and against large objects on the forest floor
- The predatory land snail, *Rhytida greenwoodi*, identified from dead shells on Green I. (P. Mayhill pers. comm.)
- The large darkling beetle, *Mimopeus opaculus*, a species widely distributed on islands, which feeds on encrusting algae on tree trunks and rocks
- At least three species of weta, including the predatory ground weta and Mercury Islands tusked weta
- At least one (and possibly several) types of scale insect that produce honeydew. One species widely distributed on the karo of Green and Middle Is and locally common on Korapuki I. is *Coelostomidia zealandica* (Towns 2002a)

The distribution and abundance of invertebrate assemblages is subject to many local influences including:

- Geochemical effects that can influence the distribution of land snails
- Successional effects that provide habitats for spiders, hosts for scale insects, variations in the quality and volume of litter for a wide range of species, and differences in the range of prey for predatory and parasitic wasps
- Island size and floristic diversity, which are likely to influence the size of the spider fauna (B.M. Fitzgerald pers. comm.) and invertebrates including land snails

- Variations in exposure to salt and moisture retention properties of the soil, which may also influence the composition and diversity of land snail and other invertebrate assemblages
- Over-riding these have been the effects of kiore, which have apparently selectively removed large flightless species of insects, and the effects of rabbits, which have indirectly influenced litter composition

Litter and pan-trap samples from Korapuki I. indicate that the island has small patches of forest capable of supporting invertebrate assemblages at densities and diversities similar to those on Middle I. As succession proceeds, the damper parts of Korapuki I. (such as the central basin) are likely to provide habitats for invertebrates not available on the dry plateaux of Middle I. It is conceivable also that some of the minute land snails found on Middle I., but not recorded on Korapuki I., are present but not detected and will reappear as the forest matures. Succession to broadleaved sub-canopy species will also enable the establishment of a wider range of invertebrates whose larvae are parasitized or preyed on by native wasps.

For a large part of the invertebrate fauna, assemblages are likely to directly reflect succession from the present pohutukawa-dominated forest to more mixed vegetation. This process may not need to be enhanced.

10.3 RESTORATION OPTIONS

In the absence of detailed comparisons of the insect faunas of Middle and Korapuki Is, the need for restoration of some groups is difficult to assess. On the other hand, where there are data for land snails and spiders, there is evidence of qualitative difference between islands that may reflect differences in site conditions rather than the effects of mammals. Furthermore, the dispersal capabilities of some groups of spiders are unclear.

It is suggested, therefore, that the only translocations should be of large invertebrates for which distributional data is available, and where the effects of rats may have been demonstrated. Where there has been little obvious effects of rats, as on the ground spider faunas of islands such as East and West Double Is (B.M. Fitzgerald pers. comm.), we suggest restricting translocations to test the dispersal capabilities of the species at present absent from Korapuki I., with one exception (see below). In addition to the release of tree weta and large darkling beetles, the following species of invertebrates are proposed as candidates for re-introduction to Korapuki I.:

- *Rhytida greenwoodi*—These predatory snails have only so far been found on Green I., and were suggested as possible candidates for translocation by P. Mayhill (pers. comm.). A related species, *Amborhytida tarangensis*, apparently became extinct on Lady Alice I. following the arrival of kiore (Brook 1999). It is very early in the recovery of Korapuki forest systems to be sure that *R. greenwoodi* has indeed been eliminated. Furthermore, its successful establishment may rely on abundant litter invertebrates (including other land snails). At present these faunas are depleted over much of the island.

- *Cambridgea mercurialis*—This spider is abundant on Green and Middle Is and is present on other Mercury islands, despite the previous presence of kiore. Given the intensity of search effort for spiders on Korapuki I., *C. mercurialis* should have been found if it is present. The reasons for its absence are unclear, but it is possible that the combined effects of frequent burning and the presence of kiore were more severe on Korapuki I. than elsewhere (B.M. Fitzgerald pers. comm.). The species appears unable to disperse over water. This is the only species of spider proposed for re-introduction to Korapuki I. Re-introduction of *C. mercurialis* could start at any time, possibly from populations on Green I.
- *Hemiandrus* sp.—Ground weta are predators of other invertebrates and can be extremely abundant on the forest floor, where they can be important in the diet of tuatara and probably of large lizards. The species is suppressed by kiore, which are likely to have eliminated them from Korapuki I. (C. Green pers. comm.). They are present on Middle I. and have survived on some of the larger islands such as Red Mercury I. where kiore were present (G. Ussher pers. comm.). The species could be re-introduced at any time, probably using populations from Middle I.
- *Motuweta isolata*—Mercury Is tusked weta are the largest of the insect predators on the Mercury Is group. Studies on Middle I. indicate that the species has a strong preference for damp sites (R. Chappell pers. comm.). The central basin of Korapuki I. almost certainly has better moisture retention properties than the dampest sites inhabited by tusked weta on Middle I. The species could be re-introduced at any time, probably derived from animals raised in captivity.

10.4 RECOMMENDED ACTIONS

- Prepare plans for the translocation of *Cambridgea mercurialis* spiders, ground weta, and Mercury Is tusked weta to Korapuki I.
- Defer decisions about translocation of *Rhytida* snails until their absence from Korapuki I. is confirmed by repeat sampling at 5-year intervals until 2014.

11. Restoration of reptiles

11.1 CURRENT SITUATION

Until 1987, when kiore and rabbit eradications were completed on Korapuki I., five species of lizards were recorded: copper skinks, moko skinks and shore skinks, common gecko and Duvaucel's gecko. Whitaker (1973) and Hicks et al. (1975) concluded that both species of gecko and copper skinks were rare. Indeed, Hicks et al. were unable to locate any copper skinks. Samples obtained using catch per unit effort in 1985 and pitfall traps in 1986 and 1987 produced similar results; the only species considered abundant being shore skinks (Towns 1991).

The recovery of lizards after the removal of kiore and rabbits has been documented by Towns (1991, 1994, 1996, 2002a). In brief, these demonstrated rapid increases in the capture rates of shore skinks, especially in coastal sites with large boulders (Towns 1991, 1996), increased sightings and captures of common geckos and Duvaucel's geckos (especially on coastal vegetation such as flax) and their attraction to honeydew produced by scale insects (Towns 1994, 2002a). However, there has been no measurable change in the abundance of moko skinks.

In addition to natural recovery of resident species, four lizard species present on Middle I. and/or Green I. have been reintroduced as part of recovery actions proposed by Towns et al. (1990) and in recovery plans for rare *Cyclodina* skinks (Towns 1992, 1999). The origin of these species and success with the translocations are summarised in Section 7.3. The current lizard fauna of Korapuki I. comprises nine species, five that are resident and four that are reintroduced (Table 4). All reintroduced species are breeding on the island and for two of them—Whitaker's skink and Suter's skink—rates of population expansion have been calculated (Towns 1994; Towns & Ferreira 2001).

11.2 MODEL OF THE ORIGINAL KORAPUKI ISLAND REPTILE FAUNA

Given the historic dry-land connection between Korapuki, Green, and Middle Is, it is reasonable to expect that the same pool of lizard species was shared between all three. Furthermore, the presence of subfossil remains of tuatara on Korapuki I. (Hicks et al. 1975; Towns 1994), indicates that tuatara were common to all three islands. The reptile fauna of Middle I. does not lack any species present elsewhere in the Mercury Is group, or islands in the wider geographic area (e.g. Aldermen Is). It is likely that a reptile fauna of tuatara and up to 10 species of lizards once inhabited all of the larger islands in the Mercury group, including Korapuki.

TABLE 4. REPTILES OF KORAPUKI AND MIDDLE ISLANDS, AS OF 2002.

SPECIES	MIDDLE ISLAND	KORAPUKI ISLAND
Tuatara	Estimated numbers in the low thousands; throughout forest	Subfossil remains only
Common gecko	Very abundant in coastal habitats, present in forest	Becoming abundant in some coastal habitats, present in forest
Duvaucel's gecko	Present in all habitats, most abundant in coastal areas	Present and increasing in abundance in all habitats
Pacific gecko	Present, largely in forest	Absent
Copper skink	Very rare	Present and increasing in abundance in all habitats
Marbled skink	Present, largely in forest	Released on Korapuki I. from 1992, breeding recorded
Robust skink	Present in forest especially in heavily burrowed areas	Released on Korapuki Island from 1992, breeding recorded but still small population
Whitaker's skink	Present in forest, especially in heavily burrowed areas	Released on Korapuki Island from 1988; population increasing, slowly spreading range
Moko skink	Very rare	Widespread in forest and coastal habitats
Shore skink	Widespread in coastal habitats	Widespread in coastal habitats; very abundant at some sites
Suter's skink	Widespread in coastal habitats	Released from 1992 and now spreading from original release sites

11.3 RESTORATION OPTIONS FOR REPTILES

Distances between Korapuki and other islands in the Mercury group (≥ 1000 m) are well beyond the natural dispersal capabilities of most New Zealand lizards. Some species are also physiologically constrained from crossing seawater. Tuatara and some lizards have extremely high rates of cutaneous water loss (Cree et al. unpubl. data; Neilson 2002), which means that immersion in seawater is likely to prove fatal due to dehydration. Translocation of reptiles is, therefore, the most effective means of reconstructing island assemblages.

Two reptile species on Middle I—tuatara and Pacific geckos—are still absent from Korapuki I. (Table 4).

Tuatara have been identified (in Section 8) as a key component of northern island systems. They were proposed as a species to be reintroduced late in the restoration sequence by Towns et al. (1990). However, their potential rate of population increase is so low (Towns 1994), they are unlikely to have a significant impact on other reintroduced species. Tuatara are most likely to affect ground dwelling skinks with low rates of reproductive output, all of which are now established and breeding on the island. Tyrrell et al. (2000) suggested that tuatara from Green I. would be an appropriate source. This was not only because of geographic proximity, but also to test the hypothesis that small mean body size and low percentage gravidity of the Green I. adults reflected competitive effects of a high tuatara density.

Pacific geckos are present on Middle and Green Is, but have not been found on Korapuki. They were identified as a candidate for reintroduction by

Towns et al. (1990). The species often inhabits forest and sometimes survives on islands inhabited by kiore, although usually these sites have had less severely modified vegetation than on Korapuki. There is a slight chance that populations of Pacific geckos survived on Korapuki I. and have yet to be detected. Intensive surveys for this species throughout all available habitats need to be completed before translocations are planned.

11.4 RECOMMENDED ACTIONS

- Prepare and implement plan for translocation of tuatara from Green I. to Korapuki I. This can be undertaken at any time, but might need to consider timetables and locations for the release of large invertebrates.
- Survey for Pacific geckos on Middle and Korapuki Is. Surveys on Middle I. should identify likely habitats to be checked on Korapuki I.

12. Restoration of avifauna

12.1 CURRENT SITUATION

Korapuki I. currently has a small fauna of resident native forest birds (5 species), but compared with Middle I., a comparatively large fauna (7 species) of burrowing seabirds (Table 5). The seabird fauna of Korapuki I. is diverse, but scattered. By comparison, that of Middle I. has lower diversity, but much higher density. The relative roles of harvesting, habitat modification, and kiore in these differences are unclear.

Of the terrestrial species, vagrant kereru may visit Korapuki I. more frequently than Middle I. (see Section 8), whereas moreporks appear to be resident on Middle I. and vagrant on Korapuki I. There have not been detailed counts of birds in the course of the eradication campaigns on Korapuki I. The only species showing conspicuous changes in abundance has been the kingfisher, which was uncommon when the island was surveyed in 1974 (Hicks et al. 1975), but is now widespread and frequent.

12.2 MODEL OF THE ORIGINAL KORAPUKI ISLAND AVIFAUNA

The original seabird fauna of Korapuki I. may not have included many more species than at present. Only one species absent from Korapuki, Middle, and Green Is occupies neighbouring islands. The white-faced storm petrel, a species highly vulnerable to rodents (Imber 1975), is abundant on Hongiora I. (Aldermen Is) (Fogarty & Douglas 1973), and locally abundant on Ohinauiti I. (Blackburn 1970).

If the abundance and distribution of seabirds on Middle I. was replicated on Korapuki I., the dominant species would have been diving petrels. However, if Korapuki I. was similar to other islands with gentle topography, such as some of the Aldermen Is (Fogarty & Douglas 1973), grey-faced petrels may have dominated over diving petrels. The present predominance of grey-faced petrels may continue, with diving petrels more common on steep faces and near forest edges. The presence of a larger fauna of forest-floor spiders on Korapuki than on Middle I. may provide evidence to support a predominance of larger seabirds (B.M. Fitzgerald pers. comm.).

It is unclear whether Middle I. once supported a larger fauna of native forest birds than at present. Conceivably, periodic human activity such as occasional fires might have resulted in the loss of small forest birds such as wrens and snipe that are now extinct throughout their range. However, there is no evidence of this on Middle I. or elsewhere on small islands < 50 ha.

Korapuki I. almost certainly once supported a more diverse fauna of native forest birds than at present, However, all elements of this fauna are present within the Mercury group and are highly mobile. For example, with a wider

TABLE 5. STATUS OF BIRDS OF KORAPUKI AND MIDDLE ISLANDS UP TO 2003.

Based on Hicks et al. (1975), Southey (1985), G. Taylor (pers. comm.) and personal observations (D.R.Towns).

SPECIES	MIDDLE ISLAND	KORAPUKI ISLAND
Blue penguin	Present; not a stronghold in the Mercury Is	Widespread and numerous
Diving petrel	Extremely abundant, predominant seabird species	Scattered populations in 1974; spreading around coast and equally common as fluttering shearwaters in 2003
Grey-faced petrel	Not abundant	Scattered populations over the island, one of the most abundant seabirds in 1974 and still the most abundant in 2003
Pycroft's petrel	Absent	Scattered populations
White-faced storm petrel	Rare records	Absent
Flesh-footed shearwater	One of the most common seabirds	Uncommon
Fluttering shearwater	Present but not abundant	Locally abundant; with diving petrels the second most common species in 2003
Little shearwater	Not common	Scattered populations
Sooty shearwater	Absent	Present in 1974, but not recently confirmed as breeding
Harrier	Regular visitor	Regular visitor, recorded as breeding
Red-crowned kakariki	Throughout	Throughout
Long-tailed cuckoo	Absent	One record
Shining cuckoo	Not recorded	Present in spring
Kingfisher	Common throughout	Common throughout
Morepork	Rarely recorded	Possibly present before kiore removed, but no longer resident
Welcome swallow	Frequently seen around coast	Frequently seen around coast
Fantail	Present throughout	Present throughout
Grey warbler	Present	Present throughout
Hedge sparrow*	Present	Regularly heard calling
Bellbird	Common and present throughout	Common and present throughout
Tui	Not recorded	Recorded once—rare vagrant
Blackbird*	Frequently heard calling	Frequently heard calling
Silvereye	Common	Common
Chaffinch*	Frequently heard	Frequently heard
Greenfinch*	Rarely reported	Not reported
Goldfinch*	Rarely reported	Not reported
House sparrow*	Rarely reported (vagrant?)	Not reported
Starling*	Often large flocks	Abundant
Kereru	Visitor	Frequent visitor

* Introduced species.

range of forest trees that produce blossom and fruit, combined with extensive infestations of honeydew, species such as kaka, kereru, and tui may have been resident in small numbers, or at least present seasonally, but resident on the neighbouring islands. Similarly, one or two pairs of moreporks are likely to have been resident when the island had a full complement of reptiles, large invertebrates and small-bodied seabirds.

All of these species are capable of re-colonising naturally, but are unlikely to become resident until there are substantial changes in forest vegetation. This is a slow process that may take many decades.

Korapuki I. also supports at least four introduced species. Their effects on native species are largely unknown. Two that potentially have detrimental effects are starlings and blackbirds. These effects may be mostly competitive, with introduced organisms (such as starlings) competing with native bellbirds and geckos for nectar sources. However, starlings and blackbirds are also known to feed on native invertebrates; and small lizards and starlings are also likely to spread boxthorn seeds (another introduced species). On the other hand, both starlings and lizards may be responsible for spreading seed of native species between the islands.

12.3 RESTORATION OPTIONS FOR BIRDS

Korapuki I. either contains most avifauna likely to have been present, or is accessible to those that would colonise if sufficient resources were available. There is, therefore, no need to actively reintroduce any species at this stage. However, because seabirds are such an important part of the island system, their distribution, rates of increase and effects on other components of the system should be measured.

12.4 RECOMMENDED ACTION

- Assess distribution and abundance of seabirds. These measures need to be obtained as soon as possible.

13. Restoration of native mammals

Neither species of native bat has been known to inhabit small islands. Even mobile species, such as long-tailed bats do not inhabit islands such as the Poor Knights, some of which are much larger than Middle or Korapuki Is. The only native mammals likely to have been permanently resident are New Zealand fur seals or Hooker's sea lions. Rounded pebbles scattered across Korapuki I. have occasionally been attributed to seal gastroliths (crop stones), an interpretation open to endless debate (B. McFadgen pers. comm.). Seals and sea lions were once widely distributed along the coast, with hauling out areas for fur seals probably on many northern offshore islands (Crawley 1990). Fur seals may re-establish at some stage in the future as they expand into their former range.

14. Control of pest species

Twenty five species of introduced plants have been recorded from Korapuki I. (I.A.E. Atkinson unpubl. data). This is not a particularly large number, since 25 species (although not all the same ones) have also been recorded on Middle I. (see Table 3). Only a few of the introduced species are regarded as problem weeds (Table 6). These include boxthorn, Mexican devil, and pampas. Control programmes for these species are under way.

Restoration of the island could be threatened by a large number of introduced organisms present on the mainland. They include: eastern rosellas, Argentine ants, African praying mantis, cockroaches, a large fauna of introduced spiders, many species of weeds, and some pathogens. Contingency plans against invasions of rodents or the release of cats or possums are already in place. However, for many invertebrate pests and weeds, invasion prevention must rely on effective and consistently applied preventative measures currently being prepared as a biosecurity plan for islands in Waikato Conservancy (J. Roxburgh pers. comm.).

14.1 RECOMMENDED ACTIONS

- Continue weed surveillance and control annually for the next 5 years, then reassess required frequency.
- Ensure all visitors to the island comply with gear, footwear, and clothing protocols defined for Nature Reserves in Waikato Conservancy.

TABLE 6. INTRODUCED SPECIES OF FLORA AND FAUNA WHICH HAVE BEEN RECORDED FROM KORAPUKI ISLAND, AND MAY REPRESENT POSSIBLE THREATS TO RESTORATION.

COMMON NAME	FORMAL NAME	DISTRIBUTION	COMMENTS
Boxthorn	*Lycium ferocissium*	Scattered plants especially on cliffs	Under control
Pampas	*Cortaderia* spp.	Scattered plants	Under control
Mexican devil	*Ageratina adenophora*	Occasional plants on eastern slopes	Pulled and bagged when found
Australian paper wasp	*Polistes humilis*	Abundant, especially in autumn	Effects on native species need to be determined on islands but no effective control methods presently available?
White-footed ant	*Technomyrmex albiceps*	Present throughout, but particularly abundant on northeastern slopes where it forms defined trails	A widely distributed nuisance ant in urban areas. Highly attracted to sweet substances so may influence honeydew scale. Effects on native ants, other invertebrates or lizards in New Zealand unknown
Cabbage white butterfly	*Pieris rapae*	Occasional visitor	Mawhai and Cook's scurvey grass reputed to be at risk from caterpillars
European wasps	*Vespula* spp.	Apparently absent	Anecdotal reports until early 1990s, not seen since
Blackbird	*Turdus merula*	Throughout	Known to occasionally feed on small lizards. Abundance and effects in Mercury Is is unclear

15. Fire

Precautions against fire are listed on landing permits for the island, and fire responses are identified in the Waikato Conservancy fire plan (Anon. 2002).

16. Archaeological sites

Archaeological sites on Korapuki I. will inevitably deteriorate in condition through natural processes of weathering. This deterioration will, in the long term, be accelerated by burrowing seabirds. Site surveys would, therefore, be advisable at an early stage of seabird expansion. The surveys could provide information useful to ecological restoration by:

- Identifying those topographic features that result from previous human activities.
- Adding precision to the restoration goals through identification of organisms trapped in middens. These can be used to reconstruct the palaeoecology of the island.

16.1 RECOMMENDED ACTION

- Commence site surveys as soon as practicable to account for expansions in the abundance and burrowing activities of small seabirds.

17. Research needs

17.1 CRITERIA FOR THE SUCCESS OF ISLAND RESTORATION

Criteria for success need to be defined and regularly measured if progress with restoration is to be assessed. Many criteria have been proposed, ranging from species-based to system-based. Species-based criteria can include simple measures of biological species richness. System-based criteria may include measurements of vegetation change due to forest succession, and changes in soil nutrient composition with expansion of burrowing seabird colonies. Other criteria can include the use of food web analyses to predict changes in the relationships between categories of organisms (such as consumer and decomposer pathways).

A project on the development of measures for ecosystem change has been established by DOC and is at present under way (Science Investigation no. 3493 conducted by D.R. Towns).

17.2 ECOSYSTEM EFFECTS OF RODENTS ON ISLANDS

The effects of invasive species on ecosystem functioning are largely unknown. By comparing islands that range from rat-free through previously rat-inhabited to currently rat-inhabited the effects of the rats on soil food webs, food decomposer systems and nutrient supplies can be determined. This will then enable assessment of the role of seabirds as ecosystem drivers.

The project is under way (as part of a joint Landcare Research/DOC collaboration, Investigation no. 3493) with D.R. Towns as one of the collaborators. Nine rat-free islands are being compared with eleven rat-inhabited islands. Soil fertility, soil and surface litter invertebrates, seedling density and survival, and vegetation composition on each island are being analysed. Middle and Green Is were included as rat-free islands, but Korapuki I. was excluded because of the complicating effects of rabbits.

17.3 STRUCTURE OF INVERTEBRATE ASSEMBLAGES

(Excluding spiders and land snails)

Intensive surveys for terrestrial molluscs and spiders have been conducted on Korapuki and Middle Is by R. Parrish and B.M. Fitzgerald (pers. comm.). Although there have been many other invertebrate surveys on these islands, the material has yet to be analysed and identified.

17.4 METHODS FOR TRANSLOCATION OF GROUND DWELLING INVERTEBRATES

Ground-dwelling invertebrates proposed for translocation to Korapuki I. include ground weta, large darkling beetles, *Cambridgea* spiders, and Mercury Is tusked weta. For most of these, there have never been any attempted island translocations.

Methods for the release of Mercury Is tusked weta are being tested elsewhere within the island group (I. Stringer pers. comm.). Attempts are also being made to transfer large darkling beetles from Middle to Korapuki I. (C. Green pers. comm.). Similar field trials will also be needed for the spiders and ground weta.

TABLE 7. SUMMARY OF PRIORITY ACTIONS OVER THE FIRST 10 YEARS ON KORAPUKI ISLAND (TO 2014).

(Tasks for after the first 10 years have not been included.)

ACTION	EXPLANATION	PERFORMANCE MEASURE	TIMING AND IMPLEMENTATION
Plants			
Investigate need to establish Cook's scurvy grass	Cook's scurvy grass may establish on Korapuki I. naturally, but method of seed dispersal is unknown	Assessment of merits of natural versus assisted dispersal	Search for natural colonisation and review after 5 years
Invertebrates			
Prepare translocation proposals for *Cambridgea* spiders, ground weta and tusked weta. Translocate as populations are identified or become available	These are prominent species on Middle I., but have been lost from Korapuki I.	Successful establishment of each species	Beginning with tusked weta, all identified species should be established within 10 years
Determine structure of invertebrate assemblages	Co-ordinate and collate material obtained from invertebrate surveys (other than spiders and land molluscs)	Comprehensive list of invertebrates known from Korapuki and Middle Is	Under way as part of DOC Science Investigation no. 3493
Reptiles			
Prepare translocation proposal for tuatara. Translocate into a confined suitable site	Tuatara are a prominent species on all rat-free northern islands. Timing may depend on locations and methods to be used for large invertebrates.	Successful establishment (breeding) on the island	Translocation should be completed within 10 years
Survey for Pacific geckos	Confirm the absence of this species from Korapuki I. and identify potential translocation sources and methods based on Middle I.	Methods that can be used to develop translocation proposal	Intensive surveys throughout island within 5 years pending decision about translocation need
Birds			
Assess distribution and abundance of seabirds on Korapuki I.	The most recent systematic surveys for seabirds were in 1974. These used qualitative estimates. More quantitative methods need to be developed and applied on Korapuki and Middle Is	Defined density measures producing data to publication standard	Under way as part of DOC Science Investigation no. 3493
Pest species			
Investigate ecology and effects of *Polistes* wasps and other potential invertebrate pests	*Polistes* wasps are common on some parts of Korapuki, but their effects on local species are unknown. Similarly, the effects of spreading white-footed ants should be determined	Assessment of potential or need for control	Good candidate for a university project
Measures of success			
Conduct measures of ecosystem change	Seabirds strongly influence systems on islands without introduced predators, so recovery and spread of seabirds on Korapuki may influence many other components of the system, including plant succession	Measurements of the effects of seabirds and succession on ecosystem function. Development of performance measures for restoration	Under way as DOC Science Investigation no. 3493
Determine effects of rodents on island ecosystems	Rodents may have diverse and indirect effects on island ecosystems, including affecting litter processing pathways and nutrient flow	Data or models that can be used to assist with developing criteria for success	Underway as a collaboration with Landcare Res. (part DOC Science Investigation no. 3493) on Green and Middle Is

17.5 EFFECTS OF HONEYDEW SCALE ON ISLAND ECOSYSTEMS

The importance of honeydew scale as an energy source for birds has long been known (Beggs 2001). However, the potential importance of this energy source on islands has only recently been identified (Towns 2002a). Since there are many potential sources of honeydew on islands, the range and impact of this on island systems needs to be measured.

17.6 ECOLOGY AND EFFECTS OF INTRODUCED *Polistes* WASPS

(Especially Australian paper wasps)

Polistes or paper wasps are at times locally abundant in the Mercury Is (especially around flax plants). The effects of paper wasps on native invertebrates are unknown. At present, there is no known mechanism for control. The effects of these wasps should be determined and potential for control assessed.

18. Key tasks

The key tasks are management activities and research needs (Table 7) required to continue the restoration of Korapuki I. They are in addition to the standard procedures for surveillance and compliance associated with these islands and identified in the Waikato CMS (Anon. 1996).

18.1 RECOMMENDED ACTIONS

- Undertake translocations, surveys and research as identified in Table 7.
- Continue ongoing research to define criteria for success and to test ecosystem models, and modify criteria and models as necessary.

19. Conclusion

Korapuki I. is a small island that was repeatedly burned until the beginning of the 20^{th} Century. Since then the island has then been allowed to naturally regenerate. The flora and fauna of the island reflect its history, and the effects of invasions by kiore and rabbits, which were removed by 1987. This restoration plan provides actions that should eventually produce communities of plants and animals similar to those on naturally mammal-free islands in the group. Based on this assumption, we used Middle I. as a reference site to define restoration targets for Korapuki I. However, using a reference site can give an overly narrow view of potential change on Korapuki I. Topographic and geological differences between the islands may previously have been reflected in some compositional differences between the two sites. For example, since mammal eradications began in 1986, so many species of plants have recolonised Korapuki I., it now has many more species of ferns and woody plants than Middle I. Similarly, the spider fauna is more diverse on Korapuki I. than on Middle I.

Given the demonstrated colonising abilities of plants, this plan focused on the remaining missing elements of the invertebrate and reptiles assemblages. We have assumed that large invertebrates such as tusked weta, and reptiles such as tuatara and nocturnal skinks, were eliminated from Korapuki I. while kiore were present. Evidence from many other islands supports this assumption (Atkinson & Towns 2001). The plan advocates the translocation of four species of invertebrates and tuatara within 10 years. Two additional species, *Rhytida* snails and Pacific geckos may be translocation candidates in the longer term, if surveys confirm their absence.

The list of species proposed to complete translocations appears small, but some of them present challenges. In theory, predatory species should be the last species for reintroduction. In practice, the potential success of some translocations may have to be balanced against the rate of recovery of key resident species. For example, there is no evidence that the darkling beetle (*Mimopeus opaculus*) has established itself on Korapuki I., despite two translocations from Middle I. (C. Green pers. comm.). The apparent disappearance of beetles translocated to Korapuki I. may reflect a long larval life span after adults have laid eggs, or the effects of expanding and mobile populations of Duvaucel's geckos feeding on the beetles before egg-laying was achieved.

The sequence of remaining translocations now depends on releases of Mercury Is tusked weta. Because of the potential effects of increasing resident lizard populations on Korapuki I., tusked weta should be released there as soon as practicable. Other candidates for translocation, including ground weta, *Cambridgea* spiders, and tuatara are all potential predators of some stage of the life cycle of tusked weta, and logically, should await the weta's establishment.

Ecological systems involve some of the most complex interactions that science has tried to understand (Power 2001). The restoration of ecological communities requires the capability to predict the outcomes of manipulating complex heterogeneous systems. Restoration on islands is conducted in physical environments subjected to extreme and unpredictable fluctuations. Furthermore, the response by island systems to the removal of invasive species may be unpredictable (Zavaleta 2002). The interaction web models used here are an attempt at merging quite simple models with changes following the removal of invasive species and reintroductions of missing species into a dynamic island landscape. Such approaches have rarely been tried, but have been promoted as the most informative and testable approach to complex management problems. The advantage of developing and testing models is that the data gathering can be targeted at specific hypotheses (Power 2001). Applying these models on Korapuki and Middle Is provides a means of testing interaction webs in small areas. We must emphasise that these are models whose predictions need to be tested. If the predictions fail, the models should be modified. On Korapuki I., measurements to test predictions may range from determining the success of single species translocations to evaluating whole system responses to changes in the distribution and abundance of seabirds.

New Zealand has a short history of invasive species eradication and island restoration (Towns & Ballantine 1993; Towns & Broome 2003). If we are to predict the outcome of more ambitious species and habitat management, it is important to understand the consequences of management at a modest scale. Korapuki I. was one of the first locations from which rats were eradicated anywhere in the world. To gain maximum benefit from this achievement, restoration of the island should be seen as the beginning of a process of measurement and understanding, rather than the end of a conservation problem previously caused by invasive mammals.

20. Recommendations

- The suitability of Korapuki I. as a habitat for Mercury Is tusked weta should be determined as soon as possible.
- If Mercury Is tusked weta are to be released on Korapuki I., no predatory invertebrates or reptiles should be released on Korapuki I. until tusked weta are established.
- The development of criteria for success and the construction and testing of interaction web models should be viewed as a long-term (at least 10-year) commitment of potential benefit to many other island restoration projects.

21. Acknowledgements

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Appendix 1

GLOSSARY OF SCIENTIFIC NAMES FOR COMMON NAMES OF SPECIES MENTIONED IN THE TEXT

COMMON NAME	SCIENTIFIC NAME
Plants	
Akepiro	*Olearia furfuracea*
Astelia	*Astelia* sp.
Boxthorn*	*Lycium ferocissium*
Coastal karamu	*Coprosma macrocarpa*
Coastal mahoe	*Melicytus novae-zelandiae*
Coastal maire	*Nestegis apetala*
Cook's scurvy grass	*Lepidium oleraceum* agg.
Flax	*Phormium tenax*
Houpara	*Pseudopanax lesonii*
Kaihua	*Parsonsia capsularis*
Karaka	*Corynocarpus laevigatus*
Karo	*Pittosporum crassifolium*
Kawakawa	*Macropiper excelsum*
Kohekohe	*Dysoxylum spectabile*
Koromiko	*Hebe pubescens* var.
Mahoe	*Melicytus ramiflorus*
Mamaku	*Cyathea medularis*
Manuka	*Leptospermum scoparium*
Mapou	*Myrsine austalis*
Mawhai	*Sicyos* aff. *australis*
Mexican devil*	*Ageratina adenophora*
Milktree	*Streblus banksii*
Mingimingi	*Leucopogon fasciculatus*
Ngaio	*Myoporum laetum*
New Zealand broom	*Carmichaelia australis*
Pampas*	*Cortaderia selloana*
Patotara	*Leucopogon fraseri*
Ponga fern	*Cyathea dealbata*
Pohutukawa	*Metrosideros excelsa*
Poroporo	*Solanum aviculare*
Puriri	*Vitex lucens*
Rangiora	*Brachyglottis repanda*
Ratstail*	*Sporobolus africanus*
Rengarenga	*Arthropodium cirrhatum*
Rewarewa	*Knightia excelsa*
Taraire	*Beilschmedia taraire*
Taupata	*Coprosma repens*
Tauhinu	*Ozothamnus leptophyllus*

COMMON NAME	SCIENTIFIC NAME
Tawapou	*Pouteria costata*
Tutu	*Coriaria arborea*
Wharangi	*Melicope ternata*
Invertebrates	
African praying mantis*	*Miomantis caffra*
Argentine ant*	*Linepithema humile*
Coastal (seashore) earwig	*Anisolabis littorea*
Darkling beetle	*Mimopeus* spp.
Giant centipede	*Cormocephalus rubriceps*
Ground weta	*Hemiandrus* sp.
Large darkling beetle	*Mimopeus opaculus*
Tree weta	*Hemideina thoracica*
Mercury Islands tusked weta	*Motuweta isolata*
Reptiles	
Common gecko	*Hoplodactylus maculatus*
Copper skink	*Cyclodina aenea*
Duvaucel's gecko	*Hoplodactylus duvaucelii*
Marbled skink	*Cyclodina oliveri*
Moko skink	*Oligosoma moco*
Pacific gecko	*Hoplodactylus pacificus*
Robust skink	*Cyclodina alani*
Shore skink	*Oligosoma smithi*
Suter's skink	*O. suteri*
Tuatara	*Sphenodon p. punctatus*
Whitaker's skink	*Cyclodina whitakeri*
Birds	
Bellbird	*Anthornis melanura*
Blackbird*	*Turdus merula*
Blue penguin	*Eudyptula minor*
Chaffinch*	*Fringilla coelebs*
Diving petrel	*Pelecanoides urinatrix*
Eastern rosella*	*Platycercus eximius*
Fantail	*Rhipidura fuliginosa*
Flesh-footed shearwater	*Puffinus carneipes*

* Species introduced to New Zealand.

COMMON NAME	SCIENTIFIC NAME
Fluttering shearwater	*P. gavia*
Greenfinch*	*Carduelis chloris*
Goldfinch*	*C. carduelis*
Grey-faced petrel	*Pterodroma macroptera*
Grey warbler	*Gerygone igata*
Harrier	*Circus approximans*
Hedge sparrow*	*Prunella modularis*
House sparrow*	*Passer domesticus*
Kingfisher	*Halcyon sancta*
Kereru	*Hemiphaga novaeseelandiae*
Little shearwater	*Puffinus assimilis*
Long-tailed cuckoo	*Eudynamis taitensis*
Morepork	*Ninox novaseelandiae*
Pycroft's petrel	*Pterodroma pycrofti*
Red-crowned kakariki	*Cyanoramphus novaezelandiae*
Shining cuckoo	*Chalcites lucidus*
Silvereye	*Zosterops lateralis*
Snipe	*Coenocorypha aucklandica*
Sooty shearwater	*Puffinus griseus*
Starling*	*Sturnus vulgaris*
Tui	*Prosthemadera novaeseelandiae*
Welcome swallow	*Hirundo tahitica*
White-faced storm petrel	*Pelagodroma marina*

COMMON NAME	SCIENTIFIC NAME
Mammals	
Cat*	*Felis catus*
Kiore (Pacific rat)*	*Rattus exulans*
Long-tailed bat	*Chalinolobus tuberculatus*
Possum*	*Trichosurus vulpecula*
Rabbit*	*Oryctolagus cuniculus*
New Zealand fur seal	*Arctocephalus forsteri*
Hooker's sea lion	*Phocarctos hookeri*

* Species introduced to New Zealand.