Management of North Island weka and wallabies on Kawau Island

DOC SCIENCE INTERNAL SERIES 54

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Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy are also included.

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ISSN 1175-6519

ISBN 0-478-22272-6

This is a client report commissioned by Auckland Conservancy and funded from the Unprogrammed Science Advice fund. It was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Geoff Gregory. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

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ABSTRACT

The largest island population of North Island weka (*Gallirallus australis greyi*) in New Zealand, a Category B threatened species, is about 2100–5000 birds on Kawau Island in the Hauraki Gulf. Kawau I. is also inhabited by a number of pest mammal species, including four species of wallaby, believed to be a threat to the habitat of weka and other species. This report assesses the scientific evidence for wallabies as a key factor in affecting age-specific survival and/or fecundity of weka. It also examines other factors that could affect weka dynamics adversely. It was considered that North Island weka would benefit from wallaby removal, as would kiwi, through the regeneration of ground cover and ultimately the recovery of indigenous forest. However, wallaby eradication would not make weka immune from declines caused by combinations of disease, increased predation pressure, fire risk, and non-target kills from possum control operations, and it might involve some by-kill of weka from wallaby poisoning programmes. It is suggested that the Department of Conservation (DOC) should liaise with relevant Australian authorities to ensure, if warranted, that the four wallaby species are repatriated to Australia, where three of them are regarded as Near Threatened and one as Vulnerable. It is also suggested that DOC should work with an appropriate lead agency, such as the Auckland Regional Council to build on the wallaby control programme and community support already developed by the Pohutukawa Trust.

Keywords: North Island weka, *Gallirallus australis greyi*, threatened species, wallaby species, mammal pests, pest eradication, wallaby repatriation, Kawau Island, Inner Gulf Islands Ecological District, New Zealand.

Shaw, W.B.; Pierce, R.J. 2002: Management of North Island weka and wallabies on Kawau Island. *DOC Science Internal Series 54*. Department of Conservation, Wellington. 28 p.

1. Introduction

North Island weka (*Gallirallus australis greyi*) is one of four subspecies of weka. It was originally widespread and common throughout the North Island, particularly after European settlement, but it now persists in greatly reduced numbers only in the eastern North Island and also on a small number of islands. The largest island population (c. 2100–5000 birds), which stems from a reintroduction of 31 birds in 1976, is on Kawau Island (2058 ha) in the inner Hauraki Gulf (Fig. 1). North Island weka are currently listed as a Category B threatened species (Molloy & Davis 1994); a recovery plan has been published by the Department of Conservation (DOC) (King, D. unpubl. 1999).

Populations of bird species in New Zealand interact with their physical and biotic environments, and their population dynamics reflect an interplay of interspecific interactions, physical constraints of the environment, and frequently, human intervention. For example, many species of bird in New Zealand are affected by introduced predators at various stages of the life cycle. Kawau I. is inhabited by a number of pest mammal species, including four species of wallaby introduced during the nineteenth century. Because of a perceived threat by wallabies to the habitat of weka and other species (Beauchamp et al. 1999), the DOC Weka Recovery Group has advocated the removal of wallabies from Kawau I. (King, D. unpubl. 1999).

1.1 OBJECTIVES

1. Assess the scientific evidence for wallabies as a key factor in affecting age-specific survival and/or fecundity of weka, and any other factors that could affect weka dynamics adversely.
2. Assuming evidence is sound, assess the cost and feasibility of wallaby eradication.
3. Outline the social/economic constraints inherent on Kawau I. that might affect weka dynamics and/or eradication attempts.

1.2 FIELD VISIT

A field visit was made to Kawau I. on 7–8 September 2001. The following activities were undertaken:

- Walk from Mansion House corner to Dispute Cove on the afternoon of 7 September.
- A meeting with local residents and DOC staff, afternoon 7 September.
- Spotlighting from Mansion House Corner to Dispute Cove and back. One hour of kiwi listening was undertaken.
- Visit to DOC boundary fence early morning, 8 September.
- Boat trip to North Cove.
- Inspection of Freeman property, which has been fenced to exclude wallabies. Also lengthy discussions with local property owners.
- Inspection of the wallaby fence between head of North Cove and Vivian Bay.

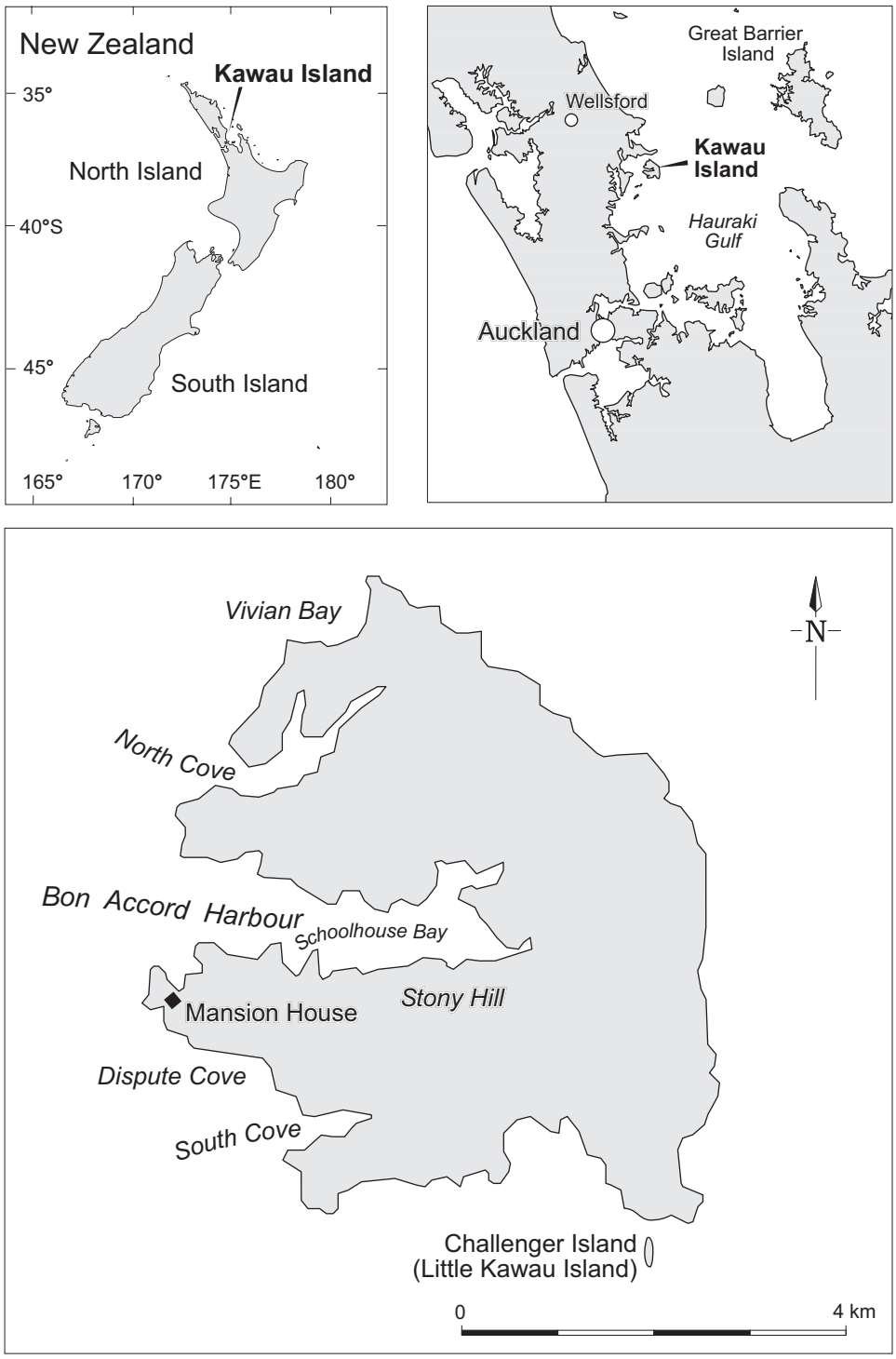

Figure 1. Map of Kawau Island.

- Visit to Little Kawau I. (Challenger I.).
- Visit to Pah Farm (Bon Accord Harbour) and inspection of wallaby holding pens and habitat of brown teal (*Anas aucklandica chlorotis*). Discussion with local residents.

1.3 LAND STATUS

Most of Kawau I. (total area 2058 ha) is private land, with four areas administered by DOC:

- Kawau Island Historic Reserve, 178.69 ha
- Stony Hill Recreation Reserve, 38.40 ha
- School House Bay Recreation Reserve, 0.37 ha
- Smelting House Historic Reserve, 1.08 ha

Stony Hill Recreation Reserve is contiguous with the Kawau Island Historic Reserve. There is also a small reserve in North Cove (Horner Reserve, 8.85 ha), which is Protected Private Land protected under the Reserves Act 1977 (White undated). The total area of reserve is 218.54 ha, with the balance (1839.46 ha) in private ownership constituting 90% of the island.

2. Conservation values of Kawau Island

2.1 CONSERVATION MANAGEMENT STRATEGY

The Conservation Management Strategy (CMS) of the Auckland Conservancy of DOC lists Kawau I. as a 'key area', for its significant historic resources, potential for interpretation of the contribution of Sir George Grey and the copper mining to New Zealand history, and potential for interpretation of human effects on New Zealand's indigenous environment. The following extract is from the CMS:

Plants, animals and habitat

On the lands administered by the Department, past land clearance, exotic plantings and the influence of wallabies and possums have resulted in the development of unusual forest areas composed largely of exotic species such as radiata pine. Much of the privately-owned parts of the island is covered with regenerating scrub growing to the coastal edge.

Wallabies and possums are causing accelerated erosion. Wallaby browsing eliminates seedlings of almost all native species so that there is no significant regenerating. The main outcome of possum browsing is to threaten pohutukawa stands, many of which have been destroyed on the island. The removal of possums and feral wallabies from Kawau is a desirable long term objective. A Trust has been incorporated locally, with the main objective being to rehabilitate the native flora and fauna of Kawau Island.

Areas of regenerating scrub also offer the potential for increasing habitat values once browsing pressure by animal pests is alleviated.

Kiwi, probably descendants of birds introduced to Kawau in the 1860s, are present throughout the island. The threatened North Island weka, another early introduction to Kawau, was reintroduced in 1976. The island is now a major habitat for this threatened species.

2.2 VEGETATION AND HABITATS ON KAWAU ISLAND

An early account of the botany of Kawau I. is provided by Buchanan (1876).

Kawau I. is covered predominantly with indigenous vegetation. It was farmed for a lengthy period and most of the original vegetation was removed by Maori burning, intensive logging of indigenous forest (mainly kauri, *Agathis australis*), and clearance for farming and firewood production (Taylor 1990). There are many remnants of the original forest cover, mainly in gullies and locally on headlands, and on the margins of inlets. Taylor (1990) has mapped these remnants in the northern part of the island, which are dominated by kauri, taraire (*Beilschmiedia tarairi*), puriri (*Vitex lucens*), and pohutukawa (*Metrosideros excelsa*). Other species locally common in these remnants include rewarewa (*Knightia excelsa*), nikau (*Rhopalostylis sapida*), miro (*Prumnopitys ferruginea*), hinau (*Elaeocarpus dentatus*), kamahi (*Weinmannia racemosa*), pigeonwood (*Hedycarya arborea*), and karaka (*Corynocarpus laevigatus*) (Taylor 1990). The balance of the island is covered with an extensive area of kanuka (*Kunzea ericoides*) forest with smaller areas of planted *Pinus radiata* plantation and untended pine stands in the Kawau Island Historic Reserve (see Gardner 1993). The large areas of kanuka forest on Kawau I. have a variable but relatively open understorey, with ponga (*Cyathea dealbata*) locally common. Weed species were evident in many of the sites we visited during the field visit. Arum lily (*Zantedeschia aethiopica*) is widespread, as is boneseed (*Chrysanthemoides monolifera*) on slopes adjacent to the coastline. There is a considerable number of small land holdings on the island margins, many of which have been built on for permanent or holiday residences.

Large areas of pasture that were present on the island c.1940 had been invaded with kanuka and manuka (*Leptospermum scoparium*) by 1982 (Taylor 1990).

Little Kawau I. (Challenger I.), on the southern coast of Kawau I., does not have wallabies and possums (*Trichosurus vulpecula*). This means that palatable coastal species thrive here, and 'kohekohe, mahoe and tawapou regenerate as nowhere else in the region' (Esler 1971). There appeared to be a significant reduction in the extent and health of remnant pohutukawa stands between 1960 and 1982, in contrast to stands on Little Kawau I. (Challenger I.) which remained in a healthy state (Taylor 1990; Hosking et al. 1989).

The various harbours and inlets on Kawau I. have examples of mangrove (*Avicennia resinifera*) shrubland and saltmarsh in more sheltered sites.

2.3 OTHER SIGNIFICANT INDIGENOUS SPECIES ON KAWAU ISLAND

Kawau I. is relatively well known for the national significance of its North Island weka population, but it also has populations of other significant and/or threatened indigenous species.

North Island kiwi (*Apteryx mantelli*) are present on the island. One was heard in the Historic Reserve during about one hour of listening after dark on 7 September 2001. Monitoring results suggest kiwi densities are low (Auckland Conservancy unpubl. report 1993, Barfoot 1994).

Blue penguins (*Eudyptula minor)* were heard offshore and three were seen ashore in Dispute Cove during a brief visit after dark on 7 September. The island is likely to have significant numbers of breeding birds.

Grey-faced petrels (*Pterodroma macroptera*) were breeding when we visited Little Kawau I. (Challenger I.) off the southern coast of Kawau I.

Brown teal (*Anas aucklandica chlorotis*) are present in the upper end of Bon Accord Harbour. Small numbers have been recorded recently at three locations, Pah Farm, Hokimai, and Smelting House Bay, with other sites also being likely locations for them (A. Young pers. comm.).

Variable oystercatchers (*Haematopus unicolor)* were observed in several bays and estuaries at low tide.

New Zealand pigeons (*Hemiphaga novaeseelandiae*) are common in the Mansion House grounds and throughout the Historic Reserve, and are present in broadleaf forest remnants elsewhere. Display flights, indicative of breeding behaviour, were seen at several sites. Birds were seen feeding on berries of monkey apple (*Acmena smithii*), Moreton Bay fig (*Ficus macrophylla*), and taraire. Numbers on the island probably exceeded 100 birds at the time of our visit.

North Island kaka (*Nestor meridionalis septentrionalis*) are occasional visitors to the island, and bellbirds (*Anthornis melanura*) also visit the island.

Banded rail (*Rallus philippensis*) are present in mangrove shrubland in some of the inlets.

Long-tailed bats (*Chalinolobus tuberculata*) have been reported (R. Lentle pers. comm.). Their current status on the island should be determined.

Giant indigenous earthworms are present, including the same species known to be present on Little Barrier I. (C. Roberts pers. comm.).

3. North Island weka

3.1 GENERAL

Weka are flightless rails that occur in a variety of habitats including forests, shrublands and wetlands and several modified habitats. They are omnivorous, feeding on a variety of soil- and litter-dwelling invertebrates and fruit, but also small vertebrates and carrion. Weka are usually territorial year round, but many birds on Kawau I. have home ranges that are based on sources of food. Breeding can occur throughout the year depending on the availability of food, but most laying occurs in August–January. Nests are constructed at ground level in the shelter of vegetation or in hollow logs and tree trunks. Clutches comprise up to six (normally 2–3) eggs, with up to four broods raised per year (Heather & Robertson 2000), but productivity is highly variable and often very low, e.g. 0.03–1.00 young per pair per season over six years on Kapiti I., compared with 1.37–3.45 per year at Kawau I. over four years (Beauchamp et al. 1999). Populations fluctuate greatly, which is thought to be a

response to changes in food supply (Beauchamp et al. 1999), although experimental data are still lacking.

3.2 POPULATION DECLINE AND ITS CAUSES

North Island weka have declined drastically on the mainland since the nineteenth century. Although there have been some temporarily successful reintroductions (e.g. Northland in the 1970s), the general population trend has been downward. This has included the loss of the reintroduced Northland population during the 1990s and the decline of birds in the mainland stronghold of East Coast. Sites currently supporting viable or near-viable populations of NI weka are listed in Table 1.

The causes of weka declines are poorly known. In most cases, several factors have been postulated as contributing to declines, including predation, starvation, disease, vehicle kills, and poisoning or trapping (Beauchamp et al. 1999).

TABLE 1. SITES WITH SIGNIFICANT NORTH ISLAND WEKA POPULATIONS, LATE 1990s TO 2001.

Data from Beauchamp et al. (1999), Beauchamp & Chambers (2000), King (unpubl. data 2001).

SITE	AREA (ha)	POPULATION
Kawau I., Hauraki Gulf	2058	c. 2100–5000
Rakitu I., Hauraki Gulf	350	c. 135
Pakatoa I., Hauraki Gulf	289	c. 100
Whanganui I., Coromandel	30	22+
Mokoia I., Lake Rotorua	120	100+?
East Coast North Island	large	1000+?

Note: Weka on Kapiti I. have been excluded as they are thought to be hybrids between North Island weka and western weka (*G. a. australis*) (Beauchamp et al. 1999).

Predation

Predation has been shown to have had an impact on weka populations on the mainland. Feral house cats (*Felis catus*) are a major threat to the survival of weka chicks (Bramley 1996). In the East Coast area, recent predator control has been accompanied by a positive response in weka survivorship compared with that in a non-treatment block (S. Sawyer pers. comm.). In one recently failed translocation to an unmanaged site, Karangahake Gorge, ferrets (*Mustela furo*) and dogs (*Canis familiaris*) contributed to the deaths of many birds (Beauchamp et al. 2000). Predators were thought to be significant in the decline and eventual loss of Bay of Islands weka in the 1990s, although little proof was obtained (Beauchamp et al. 1998). Several instances of wandering dogs killing weka are known from Kawau I. (M. Ambrose and Gerry Freeman pers. comm. 2001). Rats are thought to be nest predators of weka, although there are no confirmed records (Beauchamp et al. 1999).

Starvation

Weka have been known to decline in numbers during and/or following dry summers, as occurred in the Bay of Islands in the early 1990s when the population declined to

extinction (Beauchamp et al. 1998). On Kawau I. in the early 1990s the population is thought to have declined due to starvation (Beauchamp & Chambers 2000), although this apparent decline preceded the period of intensive monitoring, and relevant data were unable to be collected. In 1998/99 the Kawau I. population declined and starvation is thought to have played a key role in the deaths of many birds (Beauchamp & Chambers 2000), but key data have yet to be analysed and/or published (A.J. Beauchamp, pers. comm.).

The declines following dry summers are thought to come about through food becoming scarce, causing juvenile and sub-adult weka in particular to lose condition and starve to death (A.J. Beauchamp pers. comm.). During these periods, surviving weka possibly also become more susceptible to disease, although it is noticeable that the one documented disease incident of considerable magnitude that occurred on Kawau I. (in autumn 1996) coincided with a wet year in which the birds were in good condition (Beauchamp 1997a).

Disease

Disease has contributed to weka deaths at Kawau I. in 1996 (Beauchamp 1997a) and possibly elsewhere historically (Beauchamp et al. 1999), but the precise causes are unknown.

Pest control operations

Weka have been killed unintentionally during pest control operations, notably through the use of traps and anticoagulant poisons (e.g. Beauchamp et al. 1999).

Road kills

Many weka have been killed by road vehicles in the Bay of Islands (Beauchamp et al. 1998) and the East Coast (Beauchamp 1997b).

The proportional contribution of these five factors to weka mortality are generally not well known, because there have been few intensively monitored samples of weka from which quantitative data can be drawn, e.g. Karangahake Gorge releases (Beauchamp et al. 2000). Other sudden death scenarios, road kills and pest operation by-kills, have also provided many specimens, indicating that adults and sub-adults are potentially vulnerable.

3.3 WEKA POPULATION ON KAWAU ISLAND

3.3.1 Population dynamics

A previous population of weka introduced to Kawau I. in 1863 (Buller 1892) apparently died out before the 1920s (Beauchamp et al. 1999). Thirty-one weka were reintroduced in 1976 and the population had reached at least c.2100 birds by 1991. From monitoring in the Kawau Island Historic Reserve and surveys elsewhere on the island, it was estimated that the weka population on Kawau I. fluctuated between about 2100 and 5000 birds during the 1990s (Beauchamp & Chambers 2000). The data and precise methodology that underpin these estimates, however, are unavailable.

3.3.2 Threats

Predators

Mammalian predator species known from Kawau I. include stoats (*Mustela erminea*), dogs, cats and ship rats (*Rattus rattus*) (Atkinson & Moller 1995). Sightings of stoats or detection of stoat sign have been infrequent (M. Ambrose pers. comm.), but there has been no specific monitoring for them (A.J. Beauchamp pers. comm.). Ray Weaver (pers. comm.) first noted stoats on the island in 1985, and since then has seen and sometimes killed several individuals. There are no confirmed records of ferrets or weasels (*Mustela nivalis*) from Kawau I., or of other rat species.

Dogs are uncommon on the island, but those that are present appear to have had significant impacts on weka. One dog is reported to have killed weka over a large part of the island, including in the Historic Reserve and on the adjacent peninsula (M. Ambrose pers. comm.). Several other local landowners (including dog owners) indicated to us that they had seen dogs chasing and/or killing weka (and kiwi).

Small numbers of feral cats have been reported on Kawau I. by residents at widely spaced localities across the island (B. Vercoe, A. Young pers. comm.) and we saw one adult tabby cat after dark in the Historic Reserve on 7 September 2001. House-based cats are present in possibly up to 50% of residences on the island (B. Vercoe, G. Freeman pers. comm.).

The survival of adult weka is threatened especially by dogs and possibly by stoats. Juvenile recruitment is likely to be affected by cats and possibly stoats. With increased residential development of the island and increased visitation, there is the potential for a corresponding increase in predation impacts from pet cats and dogs. The role of rats as nest predators of weka is unknown (Beauchamp et al. 1999), so it is difficult to predict the outcome of any increase in rat densities.

Starvation

There is some evidence that weka populations on Kawau I. have declined following the effects of prolonged drought. Beauchamp & Chambers (2000) considered that 'severe drought conditions' in 1990–92 contributed to a weka decline on the island at that time, although there was apparently no intensive monitoring of weka before and during this period. During a shorter period of drought in 1999, many Kawau I. weka died, although other factors might also have contributed, as birds with potentially lethal levels of brodifacoum were found (Beauchamp & Chambers 2000).

Unfortunately, the relevant analyses, i.e. weka condition and demographics in relation to climate and food supply, have not been published and the data were not available to us. As a preliminary analysis, we used the autumn counts contained in Beauchamp & Chambers (2000) to examine the relationship between population counts and summer rainfall recorded at Warkworth, the nearest meteorological station, c. 15 km from Kawau I. There was no clear relationship between summer rainfall and weka numbers. Moreover, the driest summer (1993/94) during the 7-year period of that study, coincided with one of the greatest inter-year increases (an increase of 1.45 times) in counts. Weka population changes in the Kawau I. study area over four dry summers (Warkworth rainfall less than the 1990s summer average of 208 mm) ranged from 0.66 to 1.45 times that of the previous year, and averaged 1.05 times. Weka population responses over three higher rainfall summers ranged from 0.79 to 1.51 times that of the previous year, and averaged 1.18 times.

This sort of analysis is superficial, because of the potential influences of other key factors (e.g. poisoning, supplementary feeding, different levels of wallaby abundance and impact), which have not been constant during this period. In addition, it does not take into account the full range of effects associated with desiccating winds that can accompany El Niño years. These are likely to contribute to extreme drying out of the topsoil, with associated depletion of invertebrate numbers. However, it does suggest a degree of resilience in the weka population, which is currently surviving in an environment with a ground cover that has been heavily depleted by wallabies.

Wallabies are considered by the Weka Recovery Group (Beauchamp et al. 1999) to be a serious threat to long-term weka survival on Kawau I. as they compete directly with weka for food and indirectly affect them through their impact on forest composition and regeneration.

Clearly, other factors also contribute to weka population dynamics (Beauchamp & Chambers 2000). On Kawau I., many weka also obtain food from people. However, this feeding is on an ad hoc basis, with long periods of no feeding when house occupants and visitors are few. Feeding at Mansion House is primarily during summer when the kiosk is open (A. Young pers. comm.). Using data from Beauchamp & Chambers (2000), we compared weka population responses between sites with and without interactions with humans. We found that there were greater inter-year fluctuations in weka numbers at sites where human interactions occur. At sites without human interactions, the maximum weka count was only 1.84 times greater than that of the lowest, whereas at sites with interactions in which the maximum count was 3.26 times that of the lowest count. If this trend is real, it could be because weka are attracted to and can reach artificially higher numbers at sites with feeding by humans, but in the absence of this feeding (or if they are poisoned) their numbers decline through mortality and/or dispersal. Conversely, at the sites without feeding, birds would be buffered to some extent from the effects of erratic food supplies, but might receive immigrants from the feeding sites.

Another factor that probably contributes to the local drying out of the soil and litter layers is the pine plantation that occupies much of the Kawau Island Historic Reserve. Pines are well known for their depletion of catchment water (le Maitre et al. 1996), although pine needle layers may protect the soil from moisture loss temporarily, possibly compensating to some degree for the existence of the pine trees.

Disease and parasites

Weka are susceptible to a number of different diseases and parasites (Beauchamp et al. 1999). Two previous incidents of sudden death on Kawau I. have been documented (Beauchamp 1997a), but in both cases precise causes were not found. Birds were generally in good condition (some with fat reserves) at the time of death. Overall, weka numbers on Kawau I. were unaffected or recovered after each event.

Pest control operations

During possum control operations in the Historic Reserve in 1986–90, R. Weaver (pers. comm.) recorded six weka deaths in Timms traps in the course of removing c. 3000 possums. Weka deaths were minimised by setting traps in the evenings and disarming them early in the mornings. In the period 1988–90 R. Weaver (pers. comm.) also reported weka deaths in the Historic Reserve during the hand laying of poison for possums, and this could have contributed to the apparent decline in weka

at that time. We are not aware of autopsies being performed. More recently, weka have been found with potentially lethal levels of brodifacoum in their livers (Beauchamp & Chambers 2000) and there is anecdotal evidence of weka getting access to poison bait stations intended for wallabies and/or possums in different parts of the island (M. Ambrose, R. Weaver, A. Young, pers. comm.) and to poison intended for rats (King, D. unpubl. 2001).

Road kills

There are very few formed vehicle tracks on Kawau I. and we are not aware of any reports of weka deaths there from vehicles.

4. Wallaby species on Kawau Island

Five species of wallaby were released on Kawau I. by Sir George Grey in about 1870 (Warburton & Sadleir 1995a–d; Sadleir & Warburton 2001). There are now four species of wallaby on the island: dama (tammar) (*Macropus eugenii*); parma (*Macropus parma*); brush-tailed rock wallaby (*Petrogale penicillata penicillata*); and swamp wallaby (*Wallabia bicolor*).

Dama and parma are the most common species on Kawau I., with smaller numbers of brush-tailed rock wallaby and swamp wallaby.

Damawallaby are also present over a wide area in the Bay of Plenty. The other three species are now restricted to Kawau I., although brush-tailed rock wallaby were previously present on Rangitoto and Motutapu Islands but were eradicated in the 1990s. Black-striped wallaby (*Macropus dorsalis*) were present on Kawau I. for over 80 years but are now thought to be extremely rare or extinct (Warburton & Sadleir 1995a–d). The only other wallaby species in New Zealand, Bennett's wallaby (*Macropus rufogriseus rufogriseus*), is restricted to South Canterbury.

4.1 IMPACTS OF WALLABIES ON HABITATS

The negative impacts of wallabies (and possums) on the vegetation of Kawau I. has been known for several decades:

> I have determined beyond doubt that the trees were killed by opossums on the island, not a disease as you suggested. Wallabies destroy almost all of the seedlings, and now the opossums have started to attack the larger trees, mostly the pohutukawa, as far as I have seen at the moment.
>
> What is happening on Kawau Island is a serious problem and there is a lot to learn I think, for New Zealand, before the problems become more widespread elsewhere.
>
> (R. Weaver, 1955, letter to Department of Lands and Survey; *in* Weaver 1999)

Wallaby ecology and biology on Kawau I. were the subject of three MSc theses in the 1970s (Kinloch 1973; Vujcich, M.V. 1979; Vujcich, V.C. 1979). Key points from this

work in relation to vegetation and habitat were summarised by Taylor (1990), especially from Vujcich, V.C. (1979) with respect to feeding ecology. Both studies found little feeding on kanuka or manuka by dama and parma wallabies, which graze primarily on grass species. There was evidence of swamp wallabies browsing dicotyledonous food sources. Vujcich, V.C. (1979) used exclosures and found ample evidence of grass growth inside exclosures that possums could get into, but only limited evidence of browsing impacts in kanuka forest, with preferential browsing of mapou (*Myrsine australis*).

Warburton (1986) produced a summary of the situation in the mid-1980s:

> On Kawau Island, the remnant areas of indigenous forest have little remaining understorey. The heavy browsing pressure from high numbers of wallabies prevents any replacement of palatable species. Bare ground is common, and the only persisting understorey vegetation is comopsed of tree ferns and introduced species such as Arum lilies (*Zantedeschia aethiopica*).

The effects of wallabies (and possums and rats) on indigenous vegetation on Kawau I. were assessed and reported on by Taylor (1990). She established a series of exclosures in the northern part of the island, and also assessed regeneration within areas previously fenced by landowners to exclude wallabies. A browsing experiment was also undertaken, along with soil tests, including assessment of soil compaction.

Taylor (1990) found that wallaby browsing influenced species composition, numbers, seedling survivorship, and heights of browsed species:

- Areas subject to marsupial browse were characterised by lower species richness, heights and abundances of seedlings, than in areas not browsed by marsupials.
- Browsing by wallaby and (possibly) possum limits both the regeneration of forest species in the kanuka forest and the replacement of existing forest canopy species. Further long term studies are required to determine the full effects of marsupials on aspects of forest regeneration and weed control on the Island. Furthermore, regeneration is likely to proceed slowly even if steps are taken to remove browsing animals.
- In the longer term the continued presence of wallabies may well have severe repercussions associated with inadequate regeneration and failure to sustain existing forest cover.
- Distance to seed source was found to influence regeneration. Studies of exclosures, seed rain and seed bank indicated that the seed and forest species seldom occurred beyond the forest remnants. (She was referring to the remnants of primary forest present in many gullies and on the margins of some inlets.)

Taylor (1990) also found that:

- Soils under kanuka forest had lower moisture and organic carbon content than soil from the remnants of primary forest present on Kawau I.
- Even recently fenced areas showed evidence of considerable regeneration of many indigenous species, including those preferred by wallabies.
- There were no discernible regeneration effects on kanuka and manuka.

Hosking et al. (1989), referring to pohutukawa on Kawau I., noted that:

> Very high numbers of wallabies are present on Kawau Island and DOC staff believe they are having a serious impact on regeneration. This view is supported by regeneration only being present in areas inaccessible to wallabies.

It was evident from our brief inspection of the Historic Reserve that indigenous species palatable and unpalatable to wallabies are present in the understorey tiers higher than the wallaby browse level. This is likely to reflect regeneration pulses associated with previous high levels of control in the reserve. This is in marked contrast to the currently heavily browsed forest floor, associated with the presence of high numbers of wallabies. The open nature of the groundcover is likely to be affecting soil moisture levels, and hence populations of soil invertebrates, as drier conditions lead to lower densities of invertebrates.

4.2 PEST STATUS IN AUCKLAND REGION

Wallabies are classified as 'declared animal pests' in the operative Auckland Regional Animal Pest Management Strategy (Auckland Regional Council (ARC) 1998). The objectives in the proposed Regional Pest Management Strategy (ARC 2002) are to confine wallabies to Kawau I., to promote community awareness of the impacts of wallabies on native ecosystems, and, within the next five years, to assist with the eradication of wallabies from the region.

4.3 STATUS OF THESE WALLABY SPECIES IN AUSTRALIA

All of the four species present on Kawau I. have declined in the wild in Australia: dama < 10% (Kangaroo I.), > 90% (Western Australia), and 100% (South Australia); parma 10–50%; brush-tailed rock wallaby (50–90%); and swamp wallaby (< 10%) (Maxwell et al. 1996).

The presence of parma wallabies on Kawau I. was confirmed in 1966 and, at the request of the International Union for the Conservation of Nature and Natural Resources (IUCN), they were protected by ministerial gazette until viable breeding populations were established or rediscovered in Australia. From 1967 to 1975, permits were issued for the live capture of wallabies, and 1824 dama, 736 parma, 210 brush-tailed rock wallabies, and 67 swamp wallabies were exported to Australia (Fokerd 1977, *in* Warburton 1986). Protection was revoked in 1984 after a review indicated that parma wallabies were locally common there and in no danger of extinction (Maynes 1977, *in* Warburton 1986). They are currently regarded as having a conservation ranking of Lower Risk (near threatened) (Maxwell et al. 1996) in Australia.

It has been shown that the brush-tailed rock wallaby population on Kawau I. originated from New South Wales, where populations are now considered to be threatened or extinct (Eldridge et al. 2001; *NZ Herald*, 22 Oct 2001, page A18). This species was ranked as Vulnerable in Maxwell et al. (1996); it is believed to be rapidly declining and may meet criteria for Endangered (it was regarded as being Endangered in Victoria and New South Wales in the mid-1990s).

The Kawau I. population of dama (tammar) seems to represent the mainland South Australian form classed as Extinct-in-the-Wild, and Australian workers propose to repatriate animals to the southern mainland of Eyre Peninsula, into a 29 000 ha national park. There are also other forms of the tammar on the mainland and on

islands in Western Australia, and taxonomists have not decided on their specific or sub-specific classifications with respect to the South Australian populations (P. Copley pers. comm.). The conservation ranking for the species on Kangaroo I. and in Western Australia is Lower Risk (Near Threatened) (Maxwell et al. 1996).

Swamp wallaby have a conservation ranking in Australia of Lower Risk (Maxwell et al. 1996).

5. Wallaby control on Kawau Island

5.1 CONTROL HISTORY

A brief history of wallaby control operations is set out in Warburton & Sadleir (1995):

> Control … was carried out as early as 1923, and then periodically (especially in 1964–66) up until 1969. Most of the wallabies were shot, although poison (possibly cyanide) was also used (Warburton 1986). The parma wallaby was protected by Ministerial gazette in 1969; shooting of the other three wallaby species on the island continued for some years but ceased in 1973 when farming was abandoned. In 1984, protection for the parma was removed, but control of this and other wallabies on the island has not so far been reinstated.

Taylor (1990) also provides a history of the control of wallabies and possums on Kawau I. Wallaby shoots were held during Sir George Grey's time there, with as many as 200 being killed in a weekend (Druett 1983 *in* Taylor 1990).

A private landowner poisoned an estimated 13 000 wallabies from 1964 to 1966 using cyanide mixed with flour and aniseed (Heawood 1968 *in* Warburton 1986).

Wallaby shooting was undertaken by the New Zealand Forest Service (NZFS), at the request of a landowner, with 816 wallabies shot in 1970 and 1051 in 1973. These operations had no significant effect on the populations (Purdon 1973 *in* Warburton 1986).

It was also suggested by NZFS that the Historic Reserve be used as a parma sanctuary and the remainder of the island be treated with 1080 (Pracey 1969 *in* Warburton 1986). This was not implemented because 'noxious animals' could not then be held legally within the reserve. The reserve was fenced in 1983 and a request was made to NZFS for all wallabies to be removed from the reserve.

Recreational hunters visit Kawau I. (e.g. see Burdon 2000). Trapping operations have been carried out there for many years, subject to live capture and holding permits, which are issued by DOC. Cage trapping of wallabies is still undertaken on private land on Kawau I., with holding pens at Pah Farm in Bon Accord Harbour.

Wallaby control has been carried out on private land, associated with pine plantings. This has been done by shooting and also using poisons such as pindone, brodifacoum (Pestoff® cereal baits), and Feratox® (cyanide pellets). Dead wallabies are fed on by weka (Burdon 2000, R. Weaver pers. comm.).

Wallaby control was undertaken in the Historic Reserve by Ray Weaver over the period 1988–95. He considers that wallabies are reasonably well controlled north of Bon Accord Harbour and his intention is to either eradicate or reduce the wallaby population to a very low level across all of the island by 2005. He has observed wallaby starvation in dry years. Bait stations have also been used to control possums and wallabies, and non-target weka deaths are also likely to have occurred.

5.2 WALLABY FENCES

There are a number of wallaby fences, in various states of repair, on Kawau I.:

- A 2 m high fence that extends between Vivian Bay and the head of North Cove. Built in 1992 by the RNZAF (40 Squadron), DOC, and local residents. In reasonably good condition and excludes most wallabies, and residents actively control any wallabies within the fence. Wallabies can get around the ends of the fence at low tides.
- Fences on individual properties (e.g. 1.25 m high fence on the Freeman property in North Cove). There was evidence of healthy regeneration of palatable indigenous plants on the Freeman property and this is consistent with an assessment of regeneration in a fenced property by Taylor (1990).
- Wallaby enclosure in the Mansion House valley. The fence is in a very poor state of repair and does not restrict wallaby movement.
- Wallaby fence along DOC-private land boundary, between the head of South Cove and Bon Accord Harbour. The section we saw was in a good state of repair, although the entire fence would need to be checked. There are reports of various gaps in this fence. Wallabies can get around the ends of the fence at low tides. Wallabies are very abundant inside the fence, in the Historic Reserve.

5.3 RISK OF ESTABLISHMENT OF NEW WALLABY POPULATIONS

Warburton (1986) summarised the issues as follows:

> As the wallabies in the Auckland district are currently restricted to three islands, they cannot spread to occupy additional agricultural land or ecologically sensitive areas. Unfortunately, however, they can be distributed further by illegal liberations. Such a liberation occurred in 1981 when brush-tailed rock wallabies were released on Great Barrier Island. All animals were believed to have been removed, but recent unsubstantiated sightings have been reported. Although this problem is present in all districts with wallabies, it is especially pertinent in the Auckland district as illegal liberations could negate the advantage to management of the restriction of dispersal by natural barriers.

Wallabies have also been live-captured on Kawau I. and released in the Waitakere Ranges (C. Roberts pers. comm.). The risk of establishment of new populations is a major issue which will continue to be a threat to mainland ecosystems for as long as wallabies remain on Kawau.

5.4 LANDOWNER VIEWS ON WALLABY CONTROL

We met with a small number of landowners during the field visit and also subsequently discussed matters with key landowners, such as Ray Weaver.

A survey of landowner (and visitor) attitudes to marsupials on Kawau I. was undertaken by Taylor (1990), and the following extracts are from her work:

> The majority of all groups of respondents thought that marsupials damage native bush, with possums seen to be the most detrimental. Visitors perceived wallabies to be less detrimental than did residents and landowners.
>
> About 60% of respondents thought that wallabies were beneficial to Kawau Island in terms of history or tourism. However, about 80% thought that if wallabies were only present in enclosures in the Mansion House Park, this would be adequate to show wallabies to visitors.
>
> Of the visitors, residents and landowners, 65%, 75% and 85% respectively answered that removal of marsupials would be acceptable if they were shown to damage native bush.

It is interesting to note that in 1990 there was a strong desire to protect indigenous vegetation on Kawau I. Based on the our limited discussions with Kawau I. landowners and DOC staff, it appears that there is now an even stronger desire to remove wallabies from Kawau I. This view is, however, clearly not universal, as illustrated by dissenting opinions expressed in a recent letter to the *NZ Herald* (C. Paine, 17 Oct 2001, p. A14).

Many landowners on Kawau I. are now actively involved in wallaby (and possum) control, including on the two largest properties that cover much of the island. Much of this work is being undertaken by the Pohutukawa Trust.

5.5 WALLABY CONTROL BY THE POHUTUKAWA TRUST

The following information was provided by Ray Weaver (pers. comm.); refer also to Weaver (1999). The Pohutukawa Trust New Zealand was established with the following aims:

- To rehabilitate the native flora and fauna of Kawau Island.
- To promote the conservation of indigenous species in New Zealand.

The Trust is run by a Board of five people, with 185 associate members (Weaver 1999). Trust members have been undertaking active control of possums and wallabies since the 1980s. Initially this work entailed using an extensive network of Timms traps, but this has extended to a bait station network north of Bon Accord Harbour. This initiative apparently has wallabies (and possums) under a high level of sustained control north of Bon Accord Harbour and the Trust is aiming to either eradicate wallabies from Kawau I. or reduce numbers to extremely low levels by 2005.

Initially (in the 1980s), there was a lot of opposition to the need for wallaby control, but this changed markedly with the obvious success of the possum control undertaken by 1990. The island has been divided into nine pest management units, based on topography and tenure. The Trust raises funds through donations, and it is

also supported by FOAM (Friends of Auckland Maritime). The funding is used to purchase traps, materials, and poison, and volunteer labour is used to maintain a bait station network. The Trust has established a high level of control north of Bon Accord Harbour and wants to extend this southwards to cover the entire island. The aim is to either eradicate wallabies or to have them at very low levels by March 2005. Their experience to date has led them to consider that this is feasible. The best period for population 'knock down' is late summer when food is in particularly short supply.

Their current control costs, using volunteer labour, are less than $1 per wallaby killed.

The greatest use of bait stations has been on the peninsula between Bon Accord Harbour and North Cove, and there is considered to be a strong population of weka remaining on the isthmus. The latest method is to use brodifacoum cereal baits in heat-sealed plastic bags in large plastic bait stations, and stations are considered to have an effective control coverage of up to 600 m radius from the station.

The Trust has a good relationship with most landowners (there are some exceptions), including the owners of the largest private landholdings on the island.

6. Key issues in management of weka and wallabies

6.1 COMMUNITY ASPIRATIONS

There is a high level of support for recovery of weka, kiwi, and other threatened species—residents would supplementary-feed weka in dry years (or regularly) and would trap predators and help with dog control.

Increased development on the island is leading to increased potential for predation from pets. Pet-free subdivisions or enclosures could be considered by the community.

Residents are already controlling wallabies north of Bon Accord Harbour and intend extending control to the south over the next five years.

There is strong support for wallaby removal (though this is not universal).

Increase public involvement in weka management. Encouraging public interest in organised weka monitoring and feeding would increase chances of survival of birds in poor feeding conditions, and increase community ownership of sustainable management of weka.

6.2 WEKA ECOLOGY

There is a need to get weka data analysed, peer reviewed and published (especially data on demographics, diet, and condition). Until this is done, we are not able to provide further assessment of the adequacy of research undertaken to date in addressing questions of wallaby impacts on weka.

Several interrelated factors appear to contribute to weka productivity and survival.

There have been severe drought years, but weka maintained high densities (c.1/ha). Wallaby removal would not immediately buffer weka from the effects of drought, because of vegetation recovery lag, and El Niño events will continue to bring drought conditions in the future.

Wallaby eradication would not make weka immune from declines caused by combinations of disease, increased predation pressure, fire risk, and non-target kills from possum control operations. It could potentially involve some by-kill of weka from poisoning.

The need or otherwise for regular supplementary feeding on Kawau I. as a buffer to drought-induced starvation should be considered.

Consideration should also be given to establishing weka at mainland sites with appropriate predator management (e.g. Waipoua area) where El Niño impacts are likely to be less than those on leeward islands where most weka populations have been established.

Factors other than wallabies (e.g. pines) also contribute to drying out of substrates, and may also influence weka ecology.

6.3 ECOSYSTEM AND SPECIES RESTORATION

Kiwi would benefit from wallaby removal through the regeneration of ground cover and ultimately the recovery of indigenous forest. Control of predators would also be required to achieve a recovery in kiwi numbers. Weka and kiwi co-exist at several localities, notably Kapiti I.

Penguins would benefit from wallaby removal through the improvement in ground cover for nesting, but predator and dog control would also be desirable.

Brown teal would probably benefit from predator and dog control or removal, although some initial work is needed to determine numbers of brown teal present and their feeding, breeding, and flocking areas.

New Zealand pigeons would benefit from the restoration of indigenous forest on the island (and also from predator control).

Increased food supplies will increase the potential for higher rodent numbers, which could lead to higher levels of ship rat predation on some bird species.

There is a significant opportunity for an ecological restoration programme which would gain wide support (which is already evident) and would best be driven by residents.

There is potential to link with Auckland Regional Council's Tawharanui initiative to prevent stoat reinvasion across 1500 m of open water.

There is potential for further research into ecological restoration techniques and outcomes.

A restoration plan should be prepared to guide future work including monitoring (cf. Shaw et al. 1996).

6.4 WALLABY CONTROL OR ERADICATION

All four wallaby species on Kawau I. are regarded as declining in Australia. Brush-tailed rock wallaby have a conservation ranking of Vulnerable in Australia. Dama (tammar) are ranked as Lower Risk (Near Threatened) on Kangaroo I. and in Western Australia, but are considered to be extinct in South Australia (Kawau I. animals may have come from there, along with the Rotorua population). Parma and swamp wallaby are ranked as Lower Risk (Near Threatened).

The genetic relationship between dama (tammar) on Kawau I. and near Rotorua may need to be determined.

Current wallaby control scenarios (such as inside the Vivian Bay fence) and future control in the Kawau Island Historic Reserve provide opportunities for measuring ecological benefits and the costs of wallaby control.

Potential ripple effects of wallaby removal should be considered, e.g. possible increase in rodents, predators (especially stoats), weeds.

Wallaby eradication would undoubtedly enable enhanced regeneration of indigenous understorey species and, ultimately, more avifauna food (berries, invertebrates). A healthier understorey would promote better water retention in catchments and better food supplies.

There were opportunities for an experimental approach, e.g. maintain wallaby control in the Vivian Bay area and implement control throughout Mansion House Historic Reserve, with non-treatment elsewhere. This would provide a good long-term experiment which should be accompanied by monitoring of regeneration, weka survival, rodents, predators, and wallaby numbers. This is still an option but is unlikely to be practical if eradication is the primary objective.

Methods of control and eradication need further evaluation/fine-tuning (cf. eradication poisoning and shooting). An operational plan should be prepared including control/eradication methods, and roles and responsibilities.

6.5 PREDATOR CONTROL AND MONITORING

There has been no predator or rodent monitoring on the island to date.

Increased dog and cat control is needed.

Predator and rodent monitoring will be required if wallaby control/eradication occurs, and the capability to implement predator control should be assessed if their impacts become excessive.

Stoat eradication on Kawau I. and the Tawharanui Peninsula would provide a substantial buffer to reinvasion.

6.6 PINE REMOVAL

Pine removal from the Kawau Island Historic Reserve would provide increased light levels, and promote the establishment of indigenous forest. It would also increase the potential for recovery of soil moisture and water table levels.

7. Wallaby eradication

7.1 JUSTIFICATION

Kawau I. is a substantial island with a significant set of ecological values. These values are associated with the existence of remnant primary forest, coverage of most of the remainder of the island with secondary indigenous forest, and the existence of populations of a suite of threatened indigenous fauna. There are significant ecological threats to these values, including wallabies, possums, stoats, rats, cats (domestic and feral), domestic dogs, and various pest plant species. These threats are significant, but are nevertheless not considered to be beyond control.

It is not clear, from the information that we have been able to compile, whether wallabies pose a definite threat to the sustainability of North Island weka on Kawau I. However, there is clear evidence that the removal of wallabies would ultimately result in significant improvements in overall habitat quality, and this is likely to provide benefits to weka and to a range of other threatened species. It must be noted, however, that the removal of wallabies, which are currently a major component of the island ecosystem, could result in various 'ripple effects' that may take some years to settle down.

In our view, the eradication of wallabies (and possums) from Kawau I. is justified in ecological terms because of the significant damage they have caused, and are continuing to cause, to indigenous vegetation and to habitat quality in general.

7.2 FEASIBILITY

Kawau I. is smaller than Rangitoto I. (2326 ha) and not much larger than Motutapu I. (1559 ha), and brush-tailed rock wallabies have been eradicated from both of these islands. The terrain on Rangitoto I. is also particularly challenging, being much rougher than Kawau I. Kawau I. is also well served with foot and ATV tracks, and boat access points. In ***physical terms***, eradication of wallabies from Kawau I. would probably be relatively straightforward. The key to the achievement of eradication is to obtain the support and commitment of private landowners. This has already been achieved, to a large degree, by the Pohutukawa Trust. The achievement of eradication would need to include the following:

- Develop a vision for the future state of island ecosystems. This will have an important bearing on the suite of pests to be removed or controlled.
- Decide on the most appropriate eradication techniques to be used. These are likely to include a combination of bait stations and hunting, with dogs used when very low numbers have been attained.
- Prepare a comprehensive operational plan.
- Subject to risk assessments provided by DOC, remove a substantial number of weka to a safe holding facility.
- Establish weka monitoring across the island.

- Establish a wallaby monitoring network, to determine the relative numbers and densities of wallabies on Kawau I.
- Remove examples of all four wallaby species to the Auckland Zoo or, preferably, Australian zoos or institutions.
- Allocate sufficient resources to achieve eradication.
- Implement either a 'rolling front' approach to eradication or establish an island-wide control programme.
- Implement annual reviews to assess the relative success of the eradication programme, and continue the eradication programme until all wallabies are removed.

It would be possible to eradicate possums at the same time, although this is likely to require a more intensive programme.

7.3 PROBABLE COSTS OF WALLABY ERADICATION

Given the social constraints on eradication techniques, it is very difficult to estimate a total cost of eradication, especially given that much of the work may be undertaken by volunteers associated with the Pohutukawa Trust. If the aim was to achieve eradication within five years using a combination of bait stations and hunting, costs are likely to be in the order of $250,000–$500,000. This would include establishment and maintenance of an intensive bait station network, wallaby monitoring, and follow-up intensive hunting using dogs. The spacing of bait stations will have a major influence on costs. If a spacing of 150 m is used, which will be suitable for both wallabies and possums, 915 stations will be required to cover the island. (Note that the Pohutukawa Trust considers that a wider spacing will achieve a high level of wallaby control.) Wider spacings of stations would reduce the numbers required: 200 m, 515; 300 m, 230; 400 m, 130; 500 m, 83. It should be noted, however, that a grid layout may not be the most appropriate design if only wallabies are being targeted.

7.4 ERADICATION RISKS

The most significant risk is the issue of private land ownership and likely opposition from some parties to the eradication of wallabies. All landowners would have to be committed to the programme, as otherwise a residual population could remain on part of the island.

Depending on the techniques used to achieve eradication, there could also be some risks to weka and other non-target threatened species. The precise risks would need to be evaluated and appropriate contingencies put in place. There may also be some ripple effects on other species which would need to be assessed and accommodated.

7.5 DEPARTMENT OF CONSERVATION ROLES

Careful consideration would need to be given the leadership and management of an eradication project. Given that most of the island is private land, DOC is not an appropriate lead agency, whereas the Auckland Regional Council (ARC) is. The ARC should build on the control programme and community support already developed by the Pohutukawa Trust.

DOC needs to develop a clear position on wallabies on land it administers, and, if justified, to eradicate wallabies from this area. It is suggested that DOC should also liaise with relevant Australian authorities to ensure, if warranted, that wallaby species are repatriated to Australia.

DOC also needs to recognise that there is some community sensitivity to its roles in relation to private land on Kawau I., and to establish good communication protocols with ARC and landowners. This should include the development of protocols for landowner liaison and media involvement.

DOC currently issues permits for the live capture, holding and export of wallabies from Kawau I., and these should be reviewed and terminated.

8. Acknowledgements

This project was commissioned by the Department of Conservation (Auckland Conservancy), and Jan Coates and Sam Ferreira provided project liaison. Useful information and assistance was provided by Ray Weaver, Simon Mowbray, Ian McFadden, Roger Lentle, Mike Ambrose, Gerald and Sonia Freeman, Brian Vercoe, Steve Hix, Bruce Mossman, Phil Alley, and Dale Williams. Tony Beauchamp provided copies of weka publications and some other comments. Field assistance and useful discussion was provided by Andrew Young, Richard Griffiths, and Sam Ferreira. Peter Copley (South Australia) and Chris Schultz (New South Wales) provided information on the conservation status of wallaby species in Australia. Kevin McGill (NIWA, Wellington) supplied climate data.

9. References

Anon. 1993: Kawau Island kiwi survey. Unpublished report, Department of Conservation, Auckland Conservancy.

Atkinson I.A.E.; Moller H. 1995: Kiore, Polynesian rat. Pp. 175–192 *in*: King C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press.

Auckland Regional Council. 1998: Regional Plant Pest Management Strategy and Regional Animal Pest Management Strategy, July 1977.

Auckland Regional Council. 2002: Proposed Auckland Regional Pest Management Strategy, March 2002.

Barfoot, C. 1994: Kawau Island kiwi survey. Unpublished report, Department of Conservation, Auckland Conservancy.

Beauchamp, A.J. 1997a: Sudden death of weka (*Gallirallus australis*) on Kawau Island, New Zealand. *Notornis 44*: 165–170.

Beauchamp, A.J. 1997b: The decline of the North Island weka (*Gallirallus australis greyi*) in the East Coast and Opotiki regions, North Island, New Zealand. *Notornis 44*: 27–35.

Beauchamp, A.J.; Chambers, R. 2000: Population density changes of adult North Island weka (*Gallirallus australis greyi*) in the Mansion House Historic Reserve, Kawau Island, in 1992–1999. *Notornis 47*: 82–89.

Beauchamp, A.J.; van Berkum, B.; Closs, M.J. 1998: The decline of North Island weka (*Gallirallus australis greyi)* at Parekura Bay, Bay of Islands. *Notornis 45*: 31–43.

Beauchamp, A.J.; Butler, D.J.; King, D. 1999: Weka (*Gallirallus australis*) Recovery Plan 1999–2009. *Threatened Species Recovery Plan 29*. Department of Conservation, Wellington. 94 p.

Beauchamp, A.J; Staples, G.C.; Staples, E.O.; Graeme, A.; Graeme, B.; Fox, E. 2000: Failed establishment of North Island weka (*Gallirallus australis greyi*) at Karangahake Gorge, North Island, New Zealand. *Notornis 47*: 90–96.

Bramley, G.N. 1996: A small predator removal experiment to protect North Island weka (*Gallirallus australis greyi*) and the case for for single-subject approaches in determining agents of decline. *New Zealand Journal of Ecology 20*: 37–43.

Buchanan, J. 1876: On the botany of Kawau Island. Physical features and causes influencing distribution of species. *Transactions and Proceedings of the New Zealand Institute 9*: 503–527.

Buller, W.R.B. 1892: Notes on New Zealand birds. *Transactions of the New Zealand Institute 25*: 53–88.

Burdon, B. 2000: A Letter from Bendigo Creek (Cromwell, Otago). Memories from a lifetime of hunting. The Halcyon Press. 160 p.

Eldridge, D.B.; Browning, T.L.; Close, R.L. 2001: Provenance of a New Zealand brush-tailed rock wallaby (*Petrogale penicillata*) population determined by mitochondrial DNA sequence analysis. *Molecular ecology 10*: 2561–2567.

Esler, A.E. 1971: Observations on the botany of Kawau Island Domain. Unpublished report, Botany Division, Department of Scientific and Industrial Research, Auckland.

Gardner, R.O. 1993: Vegetation and Flora of the Kawau Island Historic Reserve. Unpublished report to Department of Conservation, Auckland.

Heather, B.D.; Robertson, H.R. 2000: The field guide to the birds of New Zealand. (2nd edn) Auckland, Viking.

Hosking G.P.; Hutcheson J.A.; Dick M.A. and Herbert J.W. 1989: Conservation of pohutukawa regional assessment. Final report. Prepared for Department of Conservation, Wellington. 42 pp.

Kinloch, 1973: Ecology of the parma wallaby, Macropus parma Waterhouse 1846, and other wallabies on Kawau Island, New Zealand. MSc thesis, University of Auckland.

Le Maitre, D.C.; van Wilgen, R.A.; Chapman, R.A.; McKelly, D.H. 1996: Invasive plants and water resources in the Western Cape Province, South Africa: modelling the consequences of a lack of management. *Journal of Applied Ecology 33*: 161–172.

Maxwell, S.; Burbidge, A.A.; Morris, K. (eds) 1996: Action Plan for the Australian Marsupials and Monotremes. Australasian Marsupial and Monotreme Specialist Group, IUCN Species Survival Commission.

Molloy, J.; Davis, A.D. 1994: Setting priorities for the conservation of New Zealand's threatened plants and animals. (2nd edn, collated by Tisdall, C.) Department of Conservation, Wellington.

Sadleir, R.M.F.; Warburton, B. 2001: Advances in New Zealand mammology 1990–2000: Wallabies. *Journal of the Royal Society of New Zealand 31(1)*: 7–14.

Shaw, W.B.; Shaw, P.G.; Gooch, L. 1997: Northern Te Urewera ecosystem restoration strategy. Wildland Consultants Ltd Contract Report No. 154. Prepared for Department of Conservation, Gisborne.

Taylor, 1990: C.M. 1990: Assessment of the regeneration potential of a disturbed native forest subject to continued marsupial browse: some management options for Kawau Island. MSc thesis, University of Auckland.

Vujcich, M.V. 1979: Aspects of the biology of the parma (*Macropus parma* Waterhouse) and dama (*Macropus eugenii* Desmarest) wallabies with particular emphasis on social organisation. MSc thesis, University of Auckland.

Vujcich, V.C. 1979: The feeding ecology of the parma wallaby, *Macropus parma* Waterhouse 1846 and dama wallaby, *M. eugenii* on Kawau Island. MSc thesis, University of Auckland.

Warburton, B. 1986: Wallabies in New Zealand: history, current status, research, and management need. *FRI Bulletin 114*. Forest Research Institute, Christchurch. 29 p.

Warburton, B.; Sadleir, R.M.F. 1995a: Dama wallaby. Pp. 35–44 *in*: King, C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Warburton, B.; Sadleir, R.M.F. 1995b: Parma wallaby. Pp. 51–57 *in*: King, C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Warburton, B.; Sadleir, R.M.F. 1995c: Brushtail rock wallaby. Pp. 58–64 *in*: King, C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Warburton, B.; Sadleir, R.M.F. 1995d: Swamp wallaby. Pp. 65–67 *in*: King, C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press, Auckland.

Weaver R. 1999: Kawau Island. A community pest management project. Control of possum and wallaby. Pohutukawa Trust New Zealand. 12 p.

White P. undated: Horner Reserve Management Plan. Royal Forest and Bird Protection Society, Auckland. 32 p.