Predator control to limit island reinvasion and restore the mainland, eastern Bay of Islands

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	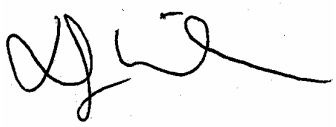
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Project and Client

Information about the presence, behaviour and control of introduced pest mammals on the eastern Bay of Islands mainland was collated by Landcare Research for the Northland Regional Council, under an Envirolink small advice grant (519-NLRC76), in November 2008.

Objectives

- To collate technical information about possible pest control on the eastern Bay of Islands mainland to prevent reinvasion of near-shore islands for which pest eradication is planned by the Department of Conservation and other stakeholders.
- To describe the likely benefits of such mainland control for the mainland itself.

Methods

- Information on pest distribution, biology (particularly swimming behaviour), and control was collated from existing literature and from discussion with staff of Northland Regional Council and Department of Conservation, with Auckland University researchers who studied Bay of Islands rats, and with some local Bay of Islands residents.

Results

- In order of decreasing distribution, small mammal pests in the Ipipiri archipelago are Norway rat, stoat, ship rat and kiore. Mice and cats may be present.
- These distributions are consistent with current knowledge about how small mammals arrive on near-shore islands, including by swimming; Norway rats and stoats may swim 2.2 km and 1.5 km respectively to reach islands.
- Using smaller islands as stepping stones, pests could swim to Urupukapuka, Waewaetorea, Okahu and associated islets with a maximum swim of 543 m, and could swim to all islands with a maximum swim of 970 m.
- A much wider range of pests occurs on the Bay of Islands mainland.

Conclusions

- Safeguarding Ipipiri islands from damaging reinvasion could be achieved by either targeting the numerous potential emigrants on the adjacent mainland or the rarer successful immigrants once they have swum to the islands themselves, or both.
- Acknowledging this uncertainty, protecting Ipipiri sustainably therefore must be regarded as an ongoing experiment with the key objective of balancing these two strategies.
- The safest initial position is to target the most likely swimming pests (in order of decreasing swimming ability: Norway rats, stoats, ship rats) on the mainland adjacent to closest islands as well as to have strong surveillance and removal systems on the islands themselves.
- Mainland pest control that limits pest emigration to Ipipiri will not deliver substantial benefit to mainland biodiversity due to its small scale and linear shape, and because it does not target the full range of pests that threaten mainland forests, particularly possums.
- Many mainland restoration projects at a range of scales are nevertheless possible around Rawhiti.

- The best opportunity for a large-scale, 'mainland-island' type biodiversity restoration project in this vicinity undoubtedly lies in the large, adjacent Cape Brett Peninsula Forest.

Recommendations

Northland Regional Council (together with the Department of Conservation, Guardians of the Bay of Islands, Te Rawhiti, Ngati Kuta and Patukeha, and other stakeholders) should:

- Limit reinvasion of the Ipipiri islands by killing Norway rats, ship rats and stoats on the coastal fringe around Rawhiti (from Rawhiti Point to Wairiki Point), and Norway rats on the coast west of Parekura Bay (from Parorenui Bay to Whangaiwahine Point).
- As an interim position, regard stoat control west of Parekura Bay as optional, provided that strong stoat detection systems are in place on Motuarohia, Moturua and Poroporo Islands.
- Encourage the Russell Kiwi Project to continue, with the additional objective of preventing stoats and Norway rats leaving there to swim to Ipipiri.
- Design the mainland pest control in collaboration with surveillance and pest removal systems on the islands themselves, with a view to finding the best balance between the two approaches over forthcoming years. Initially, both island and mainland approaches should be taken.
- Undertake all pest control using tools and techniques described by the Department of Conservation as 'Best practice' on the Department's Intranet.
- Extend the pest control on the coast southwest of Rawhiti Peninsula inland on any scale (the more the better) to further assist kiwi, weka, pateke, and other coastal birds beyond the existing plans for the 60 ha Rawhiti Peninsula.
- In time, discuss desired objectives and required resources of other possible mainland biodiversity restoration projects on the mainland in the eastern Bay of Islands.

1. Introduction

Northland Regional Council requested that Landcare Research collate information about the presence, behaviour and control of introduced pest mammals on the eastern Bay of Islands mainland, under an Envirolink small advice grant (519-NLRC76), in May–November 2008.

2. Background

Invasive alien vertebrates, especially rodents, are a major cause of the loss of native biodiversity around the world (Clout 2002), including New Zealand (Towns et al. 1997). However, rodents have been eradicated from 284 islands (47 628 ha) worldwide (Howald et al. 2007) and (to 2004) 100 in New Zealand (Clout & Russell 2006). Such eradications in New Zealand have resulted in substantial benefits for native ecosystems (Towns et al. 1997).

The Northland Conservancy of the Department of Conservation (DOC), supported by local hapu Patukeha and Ngati kuta and other stakeholders, has obtained resource consent to eradicate four rodent species (Norway rat *Rattus norvegicus*, ship rat *Rattus rattus*, kiore *Rattus exulans*, mouse *Mus musculus*) and stoats (*Mustela erminea*) from ca 20 islands in the eastern Bay of Islands. Objectives of the eradication are to restore island ecosystems and to improve resident and visitor experiences (DOC 2007). There are seven 'large' islands (8–208 ha) and many smaller ones including rock stacks (Fig. 1) in an archipelago known to local Maori as Ipipiri (DOC 2007). The total land area includes 587 ha of public land managed by DOC, 94 ha of private land and 17 ha of unknown status (indeterminate Crown or Maori; DOC 2007).

Fig. 1 Ipipiri and adjacent mainland, eastern Bay of Islands.

Maintaining islands to be predator-free after eradication depends on preventing reinvasion from both swimming animals and those carried by boats and other human transport. Therefore controlling rats and other pests in a buffer zone on the mainland adjacent to the eradicated islands is seen by DOC as crucial to the long-term success of the project (DOC 2007). This mainland control is also an opportunity to contribute to restoration of mainland ecosystems themselves. To guide or to undertake this control, Northland Regional Council (NRC) needs information about the pest species present on the adjacent mainland, their swimming ability, options for their effective control, and possible benefits for mainland species and ecosystems.

3. Objectives

- To collate technical information about possible pest control on the eastern Bay of Islands mainland to prevent reinvasion of near-shore islands for which pest eradication is planned by the Department of Conservation and other stakeholders.
- To describe the likely benefits of such mainland control for the mainland itself.

4. Methods

Information on pest distribution, biology (particularly swimming behaviour), and control was collated from existing literature and from discussion with staff of Northland Regional Council and Department of Conservation, with Auckland University researchers who studied Bay of Islands rats, and with some local Bay of Islands residents.

5. Results

5.1 Small mammal pests on Ipipiri

Knowledge of small mammal distribution arises partly from trapping that targeted rodents and mustelids on five Ipipiri islands in 1984 (3613 effective trap-nights; Moller & Tilley 1986) and again targeted rodents on 10 islands in January and May 2005 (1332 uncorrected trap-nights, King 2005 a; 1832 uncorrected trap-nights, 2005 b).

Norway rats (Fig. 2) are widespread in the archipelago and other species less so (Table 1). Ship rats (Fig. 3) were not detected by Moller and Tilley (1986) in March 1984 trapping but are now present on at least three islands. Mice were explicitly targeted by trapping in both 1984 and May 2005 but none were caught. Mice may be present but being held at extremely low levels by rats. Motuoi and Round Island have not been surveyed by trapping but their close proximity to Rangiatea and Urupukapuka respectively, where Norway rats have been trapped, suggests Norway rat presence is likely. Stoat footprints were reported on Motuarohia in September 2008 but no stoats have been captured subsequently. Stoats have been trapped on Moturua in 2005 and 2008, and on Motukiekie in 2001–02, and there have been occasional sightings on other islands. A domestic-looking cat was killed by trapping on Motuarohia in April 2008. Possums are not known from the islands (A. Walker, pers. comm.).

Figure 2 Adult Norway rat. Note tail shorter than body and pale on underside.

Island	Area (ha)	Norway rat	Ship Rat	Kiore	Mouse	Stoat	Cat
Urupukapuka	207.9	√	√		?	√	
Moturua	161.7	√	√	√	?	√	
Motuarohia	65.4	√			?		
Waewaetorea	51.5	√			?	√	
Motukiekie	34.0	√			?	√	
Okahu	27.7	√	√		?	√	
Poroporo	8.3	√			?	√	
Motuoi	2.8	√	?	?	?	?	?
Round Island	2.2	√	?	?	?	?	?
Rangiatea	1.8	√			?	√	
Motungarara	1.3	√			?	√	
Te Ao	1.2		√		?	√	

Table 1. Area and pest mammal fauna of 12 major islands of Ipipiri (Moller & Tilley 1986; DOC 2007; A. Walker pers. comm.).

Figure 3 Ship rat (top) and kiore. Note ship rat tail longer than body and dark all round, cf. Norway rat (Figure 2).

5.2 Small mammal pests on the adjacent mainland

There are few accounts of reliable identifications of rats from trapping in coastal Northland habitats.

Rodent trapping by Auckland University contractors in and near Rawhiti in January and May–June 2005 obtained one Norway rat and 33 ship rats, and a further three ship rats and one Norway rat were trapped at the Russell Boat Club. The ship rats were trapped in a variety of coastal habitats including pine forest, manuka shrubland and shoreline, whereas the Norway rats came from the Rawhiti Campground and the Russell Boat Club (Fewster 2006; R. Fewster pers. comm.). Trapping in coastal dunes at Mimiwhangata in ca 2001 to protect pateke *Anas chlorotis* caught both Norway and ship rats; Norway rats have been trapped "well away from the coast" but were generally associated with wetter, flatter sites (N. Miller pers. comm.).

This is consistent with the little that is known about mainland abundance and habitats of both rats: Norways are apparently localised to commensal and water-edge habitats, and are much less widespread than the smaller, tree-climbing ship rats that occur in most native and exotic vegetation associations, especially those with diverse tree and shrub species and three-dimensional complexity (Craig 1983; Innes 2005a, 2005b; Harper et al. 2005).

Kiore (Fig. 3) are absent from the North Island mainland, but other widespread and often abundant mainland small mammal pests are brushtail possum (*Trichosurus vulpecula*), feral and domestic cat (*Felis catus*), mouse, stoat, ferret (*Mustela furo*), weasel (*Mustela nivalis*), rabbit (*Oryctolagus cuniculus*), hare (*Lepus europaeus*), and hedgehog (*Erinaceus europaeus*; King 2005c). All these species will be present on the mainland adjacent to Ipipiri and

elsewhere, and all can potentially arrive at near-shore islands by swimming or as passengers on boats or other craft.

5.3 Swimming abilities of pest species

While "excellent swimmers", hedgehogs have colonised very few New Zealand islands (Jones & Sanders 2005) and are unlikely to swim to Ipipiri now, given that they have not yet done so. Similarly, possums, cats, rabbits, hares, ferrets, weasels, and mice can all swim but are unlikely to invade these islands by swimming. All recorded mouse arrivals at islands have been by transport in stores rather than by swimming (Russell & Clout 2005), although mice have been observed swimming well away from shore in large Fiordland lakes (E. Murphy pers. comm.).

However, ship rats, and particularly Norway rats and stoats, are highly likely to reinvade Ipipiri islands by swimming. Known rodent incursions on New Zealand islands are listed in Russell and Clout (2005), who considered that islands closer than 500 m were accessible to both ship and Norway rats; and that Norway rats may swim to islands further than this, perhaps to 2.2 km, but that the likelihood of invasion varied greatly on an island-by-island basis around New Zealand. They wrote that "the recent invasions of ship rats onto Motutapere and Tawhitinui both involved crossings of approximately 500 m in calm waters. Both invasions were presumably by swimming, and they extend the distance which this species has been suspected of swimming". The catching of two ship rats on Matakohe (Limestone) Island (Whangarei; ca 500 m from shore) and the interception of another in the water support this view (P. Mitchell pers. comm.).

Most known rat incursions on islands are by Norway rats. Russell and Clout (2005) write that "From the distribution and recorded reinvasions of Norway rats it appears that they can cross up to 1 km of water comfortably, and up to 2 km of open water more rarely when conditions are suitable (mudflats, intermediate rocky islets, tidal flow, etc.). The Noises Islands, 2.2 km offshore, have possibly been reinvaded up to six times from neighbouring Rakino, after apparently successful eradications".

Swimming duration may be positively linked to water temperature, and ability may be developed by learning (Russell 2007). Both possibilities suggest rats living in coastal habitats near calm, warm Bay of Islands water should be targeted to prevent reinvasion of Ipipiri after eradication.

Stoats "swim readily and well, in both fresh and salt water, and have reached, unaided, many offshore islands within c. 1–1.5 km of the mainland coast" (King & Murphy 2005). Elliott et al. (unpub. data) considered that Fiordland stoats only rarely cross water gaps larger than 300 m. However, trapping on Matakohe (Limestone) Island caught stoats each year (total 12 stoats) during 2004–07, showing that a 500-m gap is swum regularly near Whangarei, and stoats have swum to the Cavalli Islands, Northland, at least 1.2 km offshore (N. Miller pers. comm.). The current ubiquitous distribution of stoats on Ipipiri islands (Table 1) shows that all these are accessible.

It is worth remembering that ocean currents can potentially carry these pests many kilometres if they can stay afloat, so that pests need not swim the whole distance under their own steam.

5.4 Distances from mainland to islands and between islands

The closest distance from the mainland direct to a main island (Orerewai Point to Urupukapuka) is 783 m, but from a headland (Te Tawa Hill) near Rawhiti, a pest could swim to Urupukapuka via islands with a maximum swimming distance of 544 m (via lines C, E and G in Figure 4). Distances from the headland west of Parekura Bay direct to Moturua and Motuarohia Islands are larger (ca 1500 m; lines P, Q and R in Figure 4) but within the known

swimming capability of Norway rats and stoats. If the summary of swimming abilities in 5.3 is accurate, both Norway rats and stoats could reach the entire archipelago by swimming between islands. Ship rats would struggle to reach Urupukapuka from the mainland but once there could swim to Waewaetorea and Okahu. The known present distribution of these species (Table 1) supports this view.

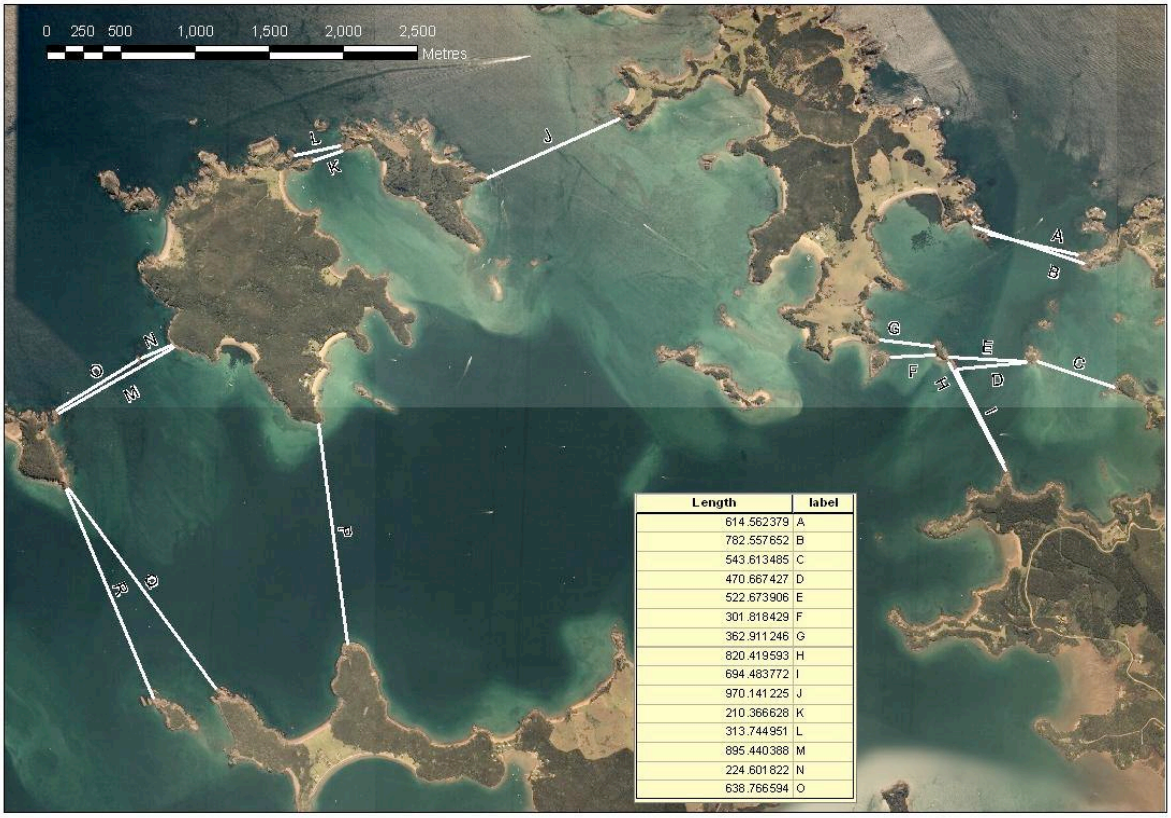

Figure 4 Swimming distances from mainland to islands and between islands, eastern Bay of Islands (reproduced from DOC 2007, with kind permission of A. Walker). Distances not mentioned in the table are P 1405 m, Q 1599 m and R 1373 m.

The required 2.7 km swim from Russell Peninsula direct to Motuarohia Island should be too far for any pest to swim, although stopping over at Oturori Rock would leave a 2.0-km swim that may be achievable for a Norway rat.

5.5 Options for control of pests on the adjacent mainland to limit reinvasion of eradicated islands

The case above suggests that mainland pest control to limit reinvasion by swimming of the Ipipiri islands after eradication should focus primarily on killing stoats and Norway rats on coastal headlands around Rawhiti and west of Parekura Bay. Ship rats should also be targeted around Rawhiti; the chances of ship rats swimming to Urupukapuka are probably much smaller than the other two species but ship rats can be very damaging to biodiversity if they establish (Innes 2005b), and pest control techniques that target Norway rats will also kill ship rats anyway.

Both the larger distance from Russell Peninsula to Motuarohia and the current intensive stoat and rat control for biodiversity protection on the Peninsula by Russell Kiwi Project staff

suggest no additional pest control effort is needed on the Russell Peninsula. However, the Russell Kiwi Project should continue, with the additional objective of preventing stoats and Norway rats leaving there to swim to Ipipiri.

5.5.1 Is mainland control necessary?

Damaging reinvasion of the islands by either rats or stoats could be prevented by either: a) rapidly detecting and then removing the few reinvaders that make it to the nearest islands, or b) killing larger numbers on the adjacent mainland in the hope that this prevents pests from reaching the islands at all. Doing both is clearly safer, but also more expensive. There is currently no easy way to decide whether one action by itself would be enough in this particular situation. **Acknowledging this uncertainty, protecting Ipipiri sustainably therefore must be regarded as an ongoing experiment with trial regimes that are subject to explicit monitoring and ongoing revision**.

Two case studies suggest that both mainland control and island monitoring should be undertaken.

First, very intensive targeting of Norway rats that had completed the 250-m swim to Pearl Island from Stewart Island failed to prevent their establishment, showing that in that situation mainland control to prevent rat establishment was essential. In contrast, trapping on Ulva Island (800 m from Stewart Is) "seems quite effective at killing rats when they arrive" (B. Beaven pers. comm.), presumably partly because so many fewer rats swim this larger distance. Swim distances from around Rawhiti to Ipipiri are between these two numbers.

Second, Matakohe Island (Whangarei; 500 m from shore) is protected by both on-island and buffer zone (stepping stone islands plus adjacent mainland) poisoning and trapping that targets Norway rats, ship rats and stoats, but all three species still occasionally reach the Island, suggesting both actions are needed. Peter Mitchell, the present Ranger, thinks increasing the regularity of control in the buffer zone has contributed substantially to limiting reinvasion (P. Mitchell pers. comm.).

However, Russell et al. (2008) concluded that "With surveillance systems comprising an array of tested biosecurity devices, and where necessary a contingency response using alternative methods, it should be possible to maintain islands as rat-free even when they have a high invasion rate". About half the male Norway rats released experimentally onto islands in recent research were caught within 2 weeks, although some were never recaught (Russell et al. 2008). Complete coverage of islands with surveillance devices increased detection success, suggesting that if control effort was scaled down on the adjacent mainland at Rawhiti, it would only work as a strategy if detection effort was scaled up on the islands themselves. Balancing these two efforts should be regarded as the main aim of the Ipipiri protection 'experiment'.

Blumine (380 m swimming distance), Adele (770 m), and Maud (850 m) Islands in the Marlborough Sounds or Abel Tasman National Park are protected against stoat invasion by kill traps both on the island and on the adjacent shoreline (P. Gaze pers. comm.), which is sometimes true mainland and sometimes a larger island.

Some large Fiordland islands have been protected against stoats by trapping (aiming at eradication) on the islands themselves and by more trapping (aiming at preventing reinvasion) on surrounding islands or mainland (G. Elliott, M. Willans et al. unpubl. data). These authors conclude that "stoats in Fiordland cross water gaps of more than 300 m quite rarely, and that trapping networks with traps placed at densities as low as 1 trap per 18 ha can eradicate them. It is likely that large islands like Resolution, Secretary, Long and Coal, if permanently trapped for stoats, will have no stoats on them for most of the time, and short periods where a low number of stoats are killed in the traps. The impact of stoats on endangered species re-introduced to these islands is likely to be very small."

My own view, however, is that a policy of not targeting mainland populations but relying on detecting invaders on the islands and then removing them would be more risky for stoats than rats. Individual rats are unlikely to seriously damage whole populations of valued prey such as translocated birds unless their numbers are first allowed to build up by breeding, by which time they would undoubtedly be detected and targeted for removal. However, single stoats could seriously impact on small threatened bird populations before being noticed and caught, and furthermore female stoats are nearly always pregnant.

Whether island trapping alone could protect threatened species placed on Ipipiri islands from either rats or stoats requires direct experiment in that particular situation. Major parameters determining the outcome of this would be the numbers of swimming invaders that arrive, the probability that they are rapidly detected and then killed, and the rate at which they damage threatened species populations before they are killed. **The safest strategy is clearly to target Norway rats, ship rats and stoats both on the mainland and on the islands themselves.** If this works, a fallback position of trialling just doing one or the other location could be attempted.

5.5.2 Suggested strategies for mainland pest control to limit island reinvasion

Best practice for small mammal pest control in New Zealand is collated in a web-based system by the Northern Regional Office of the Department of Conservation (key contact Alastair Fairweather, Hamilton) and updated when required. Unfortunately it is available only on the DOC Intranet (i.e. to DOC staff) but should be available for the asking from any relevant DOC staff-person. The information collated there has arisen from years of field trials as well as discussion between scientists and experienced field staff over many years, and is current agreed best practice. Currently covered pests are rats, ferrets, stoats, and feral cats, and standard headings for each are: technique, equipment, skill required, standards, sustaining control over the long term, limitations, information, under development, and references. Information includes superb drawings of best traps and how to set them, and recommended trap covers, with dimensions that enable construction.

The guidelines remind users that strategies and tools of any pest control may vary depending on the objective(s) of the operation, but they do not differentiate limiting island reinvasion as such a different objective that it needs its own approach, other than control being targeted at the coastline adjacent to each island.

Uncertainties about swimming distances and the behaviour of individual rats and stoats in different years with different population densities mean there is no obvious ‘best’ trapping and poisoning regime to protect Ipipiri. This must be refined over the years (always using best practice) and will be influenced strongly by available resources such as labour.

However I suggest:

a) Control targeting Norway rats on the coastline north of the red line in Figure 5, and Norway rats, ship rats and stoats west of the black line, is *necessary* to prevent reinvasion by these species. This entire coastline is within known swimming distances for Norway rats. Water channels from headlands around Rawhiti to Ipipiri (lines A to I in Fig. 4) are clearly also swimmable by stoats. It is possible control could be intensified on the closest headlands rather than dispersed along the whole coast, but initially I recommend dispersed control.

b) Stoats should be targeted using DOC best practice trapping techniques, with trap stations 100–200 m along the road and accessible coastline, ridges, tracks and waterways where stoats are more likely to be caught and traps are easiest to service. Traps should be kept baited and serviced all year round, and cleared at least monthly. DOC guidelines suggest “Trap lines will protect a strip approximately 400 m either side of the line”, so trapping on the Rawhiti road should protect most of the coast line.

Additional traps may be useful between Okuia Point and Whau Point, and on Orerewai Point. DOC 150 and 200 kill traps will target both stoats and Norway rats.

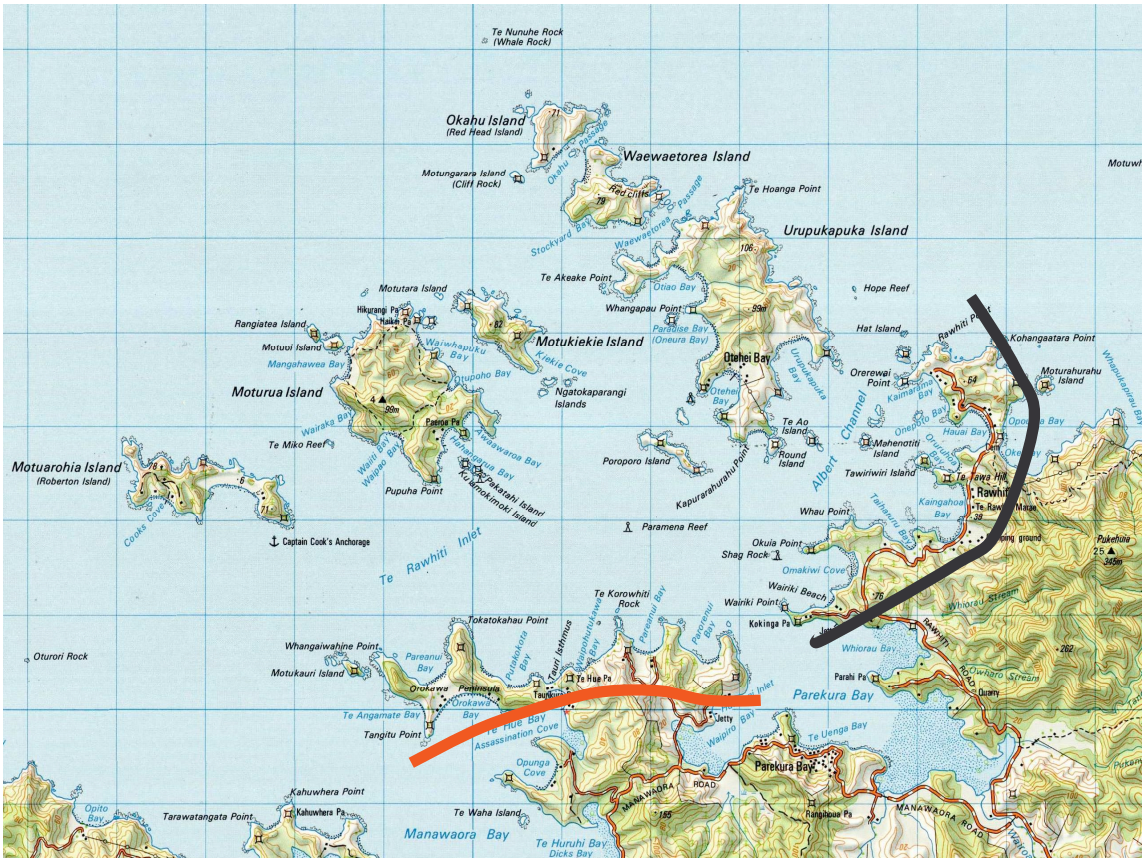

Fig. 5 Possible areas for pest control on the mainland to protect Ipipiri islands from reinvasion.

c) Norway rats should be targeted using DOC best practice poisoning and trapping techniques on the coastline itself and up creeks and streams if there are any, because this is probably where they live (most inland rats are ship rats), and because it is possible that swimming is a learned behaviour and these are the individuals that are the best at it (Russell 2007). Using both techniques acknowledges that Norway rats may have "variable susceptibilities to biosecurity methods" (Russell et al. 2008). Suitable kill traps are DOC 150 and 200 kill traps that will also target stoats, or Victor professional snapbacks that have also passed National Animal Welfare Advisory Committee kill trap guidelines. DOC best practice guidelines cover both first- and second-generation anticoagulant poisons as well as 1080 pellets. Note that there is significant concern about secondary poisoning and ecological persistence of brodifacoum, the commonest second generation anticoagulant (reviewed in Hoare and Hare 2006), despite its undoubted effectiveness, supermarket availability, and ongoing use for sustained control by bureaucracies other than DOC. Traps and bait stations need to be near the ground (Norway rats climb but poorly), and perhaps at 100-m spacing. Possums will need to be either controlled or excluded from bait stations unless they are also targeted, otherwise they will consume a lot of bait. Ship rats cannot be excluded from traps or bait stations since they are smaller than Norways, so it is inevitable that most bait take will be by ship rats, given their greater mainland

abundance. If traps or stations around the entire shoreline are impractical, the fallback position is to target closest headlands (from the north: Rawhiti to Orerewai point, Te Tawa Hill and Tawiriwiri Island, and Whau Point to Okuia Point), or undertake initial trapping (see (e) below) to identify priority sites. These are probably the only necessary control sites for ship rats, given their smaller swimming capability than the other two species.

d) The only monitoring outcome that really matters is the number of detected reinvasions on Ipipiri Islands after eradication, and this should be the main measure of success. If NRC wishes to monitor abundance of stoats and rats in the targeted mainland habitat before or after the operation, then standard DOC footprint tracking procedures should be used, although this will not distinguish ship from Norway rats.

e) Kill-trapping on the coastal foreshore before pest control starts may resolve where or even whether Norway rats are present, and may guide where control should be targeted. However, previous trapping has confirmed that some are present (see 5.2 above); catch rates are typically low and catching none with a modest trapping effort may be an unreliable guide to actual Norway rat presence.

f) Control targeting stoats on the coastline north of the red line in Figure 5 is *desirable* but the swimming distances required (lines P to R in Fig. 4) are marginal for stoats by current knowledge; it is possible that stoat spread through Ipipiri has been island-to-island after initial invasion from near Rawhiti. If resources are limited, it seems reasonable to do no stoat control in this area *as an interim position, provided strong stoat detection systems are in place on Motuarohia and Moturua Islands, and on Poroporo Island*.

5.6 Options for control of pests on the adjacent mainland to restore mainland ecosystems

The regime in 5.5.2 to limit island reinvasion would offer minimal restoration to mainland forest biodiversity due to constant reinvasion, but it might offer some protection to coastal fauna such as nesting penguins, gulls and shags, and perhaps nesting fernbirds *Bowdleria punctata*, crakes *Porzana* sp., pateke *Anas chlorotis* or weka *Gallirallus australis* if these exist in coastal wetlands and shrublands. Rapid reinvasion is especially likely for stoats, whose home ranges may be 40–100 ha in North Island forest (King & Murphy 2005) and for which small-scale control is probably pointless other than to limit island reinvasion. Whereas the two key threats to island reinvasion are Norway rats and stoats, mainland restoration of most forest birds, invertebrates, flowers, and fruits requires targeting the ubiquitous, abundant and omnivorous ship rats and possums; kiwi protection may additionally require ferret, feral cat, and dog management, and for certain objectives control of mice, hedgehogs, and goats *Capra hircus* may be valuable.

Localised control of ship rats and possums in forest areas of a few hectares will protect the few native birds that nest there. If these include wide-ranging species such as kereru and tui, then a few extra individuals will survive to range wider in the area, but the numbers will be small and probably too small to monitor. Any increase in the scale of control will also increase the magnitude of benefits, but also costs. Some fenced sanctuaries are quite small, such as Bushy Park (Wanganui, 90 ha), Karori Sanctuary (Wellington, 220 ha), Rotokare (Taranaki, 229 ha), and Kotuku (Great Barrier Island, 230 ha). Island reserves are sometimes smaller: Matakohe-Limestone Island (Whangarei) is 38 ha. Unfenced mainland restoration areas that control rather than eradicate pests vary hugely from a few hectares to ‘Mainland Islands’ such as Ark in the Park (Waitakeres, 2000 ha).

Clear thresholds of scale exist for some threatened species programmes but otherwise biodiversity restoration focused on control of ship rats and possums in particular is perfectly

scaleable – there are benefits at very small scale as well as large. Kiwi *Apteryx australis* management areas that demand effective stoat control should be at least 10 000 ha to accommodate the dispersing juveniles (Basse & McLennan 2003); NI kokako *Callaeas cinerea wilsoni* are translocated only to managed sites primarily targeting ship rats and possums larger than 500 ha to accommodate juvenile dispersal and to allow a genetically sound number of individuals to coexist; most NI robin *Petroica australis* juveniles disperse from the 80- ha Wenderholm reserve near Auckland where again ship rats and possums are the key target pests (Lovegrove et al. 2002).

Restoration zones can start small and then grow when resources allow, and can also take 'years off' with no serious, long-term harm. There are now hundreds of such projects underway nationally, and they have diverse objectives and scales.

Objectives need to be clear at the outset – the protection of nesting birds, for example, means pests can be lowered for the nesting season only, whereas protecting skinks or invertebrates requires year-round control. A crucial part of sustaining such operations is that at least basic objectives (e.g., to increase sightings of tui and kereru) are explicitly agreed by involved parties, and that these outcomes are occasionally monitored if practicable.

Targeting ship rats and possums will reduce predation on nesting forest birds, and probably lizards and invertebrates, and increase flowering, fruiting and regeneration. Maximum benefit clearly would accrue from targeting places where most valued birds nest, probably complex, taller primary forest rather than secondary associations. The major candidate for such a venture in the vicinity of Rawhiti is clearly the 2580-ha Cape Brett Peninsula Forest, described by Booth (2005) as "The largest and least modified coastal promontory in the Whangaruru Ecological District, which contains a high number of threatened animal and plant species".

The already approved community pest control plan for the 60-ha Te Rawhiti peninsula is an excellent start, with clear objectives and a geography that greatly limits reinvasion. The pest control on the coast southwest of Rawhiti Peninsula, as recommended in 5.5.2, could valuably be extended inland on any scale (the more the better) to further assist kiwi, weka, pateke and other coastal birds.

Pest control tools and techniques are again best taken from DOC's Best Practice guidelines referred to above. Effective ship rat and possum control requires devices to be placed at no greater than 100 × 150 m apart, and in places or years of high rat density, spacing should perhaps be 75 × 75 m. Stoat traps to protect kiwi should be 200 m apart on lines no further apart than 800 m (DOC guidelines). Establishing a large 'mainland island'-type project in Cape Brett Peninsula Forest is feasible but a vastly larger undertaking than the project recommended above to limit reinvasion of Ipipiri from the adjacent mainland.

6. Conclusions

In order of declining known swimming ability, Norway rats, stoats and ship rats should be targeted on the mainland adjacent to Ipipiri islands to limit reinvasion of the islands after eradications. The area of mainland habitat in which these three species need to be targeted declines as their swimming ability declines. That is, Norway rats should be targeted over the largest length of coastline, and ship rats least. Current 'best practice' control tools and strategies as collated by the Department of Conservation should be used initially, and updated in the future. The most cost-effective balance between targeting these pests on the mainland to limit the number of swimming emigrants versus detecting and removing them as island immigrants is unclear. Resolving this should be the primary objective of the experimental project over the coming years. The safest initial position is to implement mainland control *as*

well as island surveillance and control. One or both of these could then be scaled back in future strategy iterations.

The mainland pest control required to limit pest emigration to Ipipiri will not deliver substantial benefit to mainland biodiversity by itself, partly because of its small scale and linear shape, and partly because it does not focus on the full range of pests that threaten mainland forests and other communities. Many mainland restoration projects at a range of scales are possible around Rawhiti. The best opportunity for a large-scale, 'mainland-island' type biodiversity restoration project in this vicinity undoubtedly lies in the large, adjacent Cape Brett Peninsula Forest.

7. Recommendations

Northland Regional Council (together with the Department of Conservation, Guardians of the Bay of Islands, Te Rawhiti, Ngati Kuta and Patukeha, and other stakeholders) should:

- Limit reinvasion of the Ipipiri islands by killing Norway rats, ship rats and stoats on the coastal fringe around Rawhiti (from Rawhiti Point to Wairiki Point), and Norway rats on the coast west of Parekura Bay (from Parorenui Bay to Whangaiwahine Point).
- As an interim position, regard stoat control west of Parekura Bay as optional, provided strong stoat detection systems are in place on Motuarohia, Moturua and Poroporo Islands.
- Encourage the Russell Kiwi Project to continue, with the additional objective of preventing stoats and Norway rats leaving there to swim to Ipipiri.
- Design the mainland pest control in collaboration with surveillance and pest removal systems on the islands themselves, with a view to finding the best balance between the two approaches over forthcoming years. Initially, both island and mainland approaches should be taken.
- Undertake all pest control using tools and techniques described by the Department of Conservation as 'Best practice' on the Department's Intranet.
- Extend the pest control on the coast southwest of Rawhiti Peninsula inland on any scale (the more the better) to further assist kiwi, weka, pateke and other coastal birds beyond the existing plans for the 60-ha Rawhiti Peninsula.
- In time, discuss desired objectives and available resources of other possible mainland biodiversity restoration projects on the mainland in the eastern Bay of Islands.

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