Feasibility Study Report

for the Potential Eradication of

Ship Rats, Mice, Rabbits and Feral Cats from

New Island,

Falkland Islands.

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Version History:

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EXECUTIVE SUMMARY

This report assesses the justification for and feasibility of eradication of the introduced ship rat, mouse, rabbit and feral cat from New Island (2240ha), one of the most westerly islands within the Falkland Islands, a UK Overseas Territory in the south-west Atlantic Ocean. New Island is owned and managed by the New Island Conservation Trust (NICT). It is a very important conservation island, and supports at least 39 breeding species, including significant populations of thin-billed prions, black-browed albatross, rockhopper, gentoo and Magellanic penguin, king cormorant, striated caracara, Falklands steamer duck, and white-chinned petrel.

Some but not all native species on New Island are vulnerable to introduced mammalian predators such as the ship rat, house mouse and feral cat, while rabbits compete with seabirds for burrow space and may affect flora diversity, habitats and vegetation recovery. If invasive mammal eradication is considered, this study strongly recommends an ‘all or nothing approach’, with all four species targeted for eradication simultaneously or none at all, to avoid potential for unforeseen consequences and surviving pest species to further impact on the environment.

Eradicating the invasive mammal species from New Island would eliminate the only known local population of ship rats in the Falklands, would benefit a range of native species, and would aid in the restoration of normal ecosystem processes. Some wildlife species would be unaffected by mammal removal, while there is a possibility a few species (especially raptors) that may benefit from invasive mammal presence could see population decreases. A range of native species may also be temporarily affected, some potentially at a significant level, by the methods used for eradication, and losses of individuals would be expected.

Any eradication will need to include all islands within 1km with known or suspected rodent presence, and these include Landsend Bluff and possibly others. Eradication of rodents from these and New Island would enable the entire New Island group of islands to become free of introduced mammalian pests, and improve biosecurity on neighbouring rodent-free islands. The location and current management and visitation of the island mean that effective biosecurity measures can be practically implemented, and the risk of re-introduction of invasive mammals is considered low.

Eradication of the invasive mammal species on New Island appears technically feasible, and despite some challenges such as vegetated cliff areas has a very high prospect of success for rats, rabbits and cats, and a lower but still high chance for mice, if adequately resourced and carried out according following established eradication ‘best practice’. However, eradication cannot be guaranteed and the possible implications of partial failure must be considered.

The case for eradication of invasive mammals from New Island is not as clear-cut as would be expected in most other situations, due to a complex interaction between the particular suite of invasive mammals present, which appears to have created a relatively stable current situation, with the most sensitive native species probably already extirpated. Anticipated environmental changes may alter the current equilibrium, and therefore eradication needs to be considered as a future management option for use before any further long-term harm occurs, such as local loss of the white-chinned petrel or sooty shearwater.

Investigation of the need for some control or eradication work to protect the precariously small WCP colony is required. While there is clear evidence of negative effects of invasive mammals on this species from elsewhere, there is limited evidence of effect of cats and rats on this species on New Island. Either further research is required, or a decision to manage on the basis of the limited information available. Management is recommended to help ensure the survival of the colony, and eradication of cats (along with the other invasive mammals) is not the only option available but is a practical measure by which to achieve this. Eradication of all mammal species will also allow recovery of populations of other species suppressed by the mammal presence, and to facilitate potential re-establishment of self-sustaining breeding populations of Cobb's wren and tussacbird and possibly other pest-sensitive species such as camel cricket and diving petrels and storm petrels, and in the case of rabbits permit further and unrestricted vegetation recovery.

By far the most prevalent and successful method of eradicating rodents from islands (and as the primary technique for multi-species eradications) is the use of an anticoagulant toxin within a highly palatable cereal-based pelleted bait, distributed in a comprehensive pattern over the entire treatment area. Other control options have not been proven for eradication of rodents, and because of the higher risk of failure should not be currently considered as a realistic option here. Brodifacoum is the most commonly used toxin for eradication of rodents, and would be the recommended option, though it has short-term and in some cases significant risks to some non-target species that must be either be accepted or mitigated for. Other possible toxin options would add further risk to an eradication attempt.

Three established options exist for distribution of bait for rodent eradications, but only one - aerial application using a GPS-guided helicopter – would be practical for an island the size and topography of New Island. Use of hand-broadcasting or bait stations is considered unsuitable due to the enormous logistical input required on such a large island and inability to safely cover cliff areas. Rabbits and cats would also be vulnerable to the rodent bait containing anticoagulant toxins, but follow-up ground measures such as hunting and trapping would be required to target expected surviving individuals. Logistics for an eradication of rodents, rabbits and cats in such a location would be difficult and costly but not insurmountable.

In addition to the significant challenges posed for potential eradication by technical feasibility, a key issue is reducing the potential risks for key non-target species vulnerable to the toxin (particularly the striated caracara) from such an operation to an acceptable level for stakeholders. The risk to individual caracara and to the island's population is currently difficult to quantify but it would be prudent to plan for a significant impact. Should an eradication of rodents, rabbits and cats be implemented on New Island, options to mitigate potential effects on striated caracara and possibly other species need to be determined in advance. The most practical options appear to be either captive holding of a proportion of the population; or 'do-nothing' and allow natural recovery of the population; or to delay any actions to further investigate and research other options.

Another important issue will be obtaining agreement between key stakeholders (including the Falklands Government and owners of adjacent islands) as to the most appropriate way of developing implementation of eradications on New Island.

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1. INTRODUCTION

The intention of this study is to examine the feasibility of eradication of invasive mammals (ship rats *Rattus rattus*, house mice *Mus musculus*, feral cats *Felis catus* and rabbits (either or both *Syvilagus* sp. or *Oryctolagus cuniculus* from New Island (and as required from any adjacent islands within 1km of its shores) in the Falkland Islands, a UK Overseas Territory in the South Atlantic.

The findings of this study represent the view of the author, and do not necessarily represent the views of the NICT or other stakeholders.

A feasibility study should endeavour to broadly pose and address three key questions – why do it, can it be done, and what will it take?

This feasibility study was initiated and conducted on behalf of the New Island Conservation Trust, arising from recommendations at the NICT Scientific Workshop in April 2013 (NICT, 2013). It has been conducted by Derek Brown, an independent New Zealand-based island specialist, with threatened species management, island restoration and pest eradication experience, and over 30 years of experience in eradication of 11 invasive mammal species, including several projects within the Falkland Islands and elsewhere in the UK Overseas Territories.

The study was greatly aided by Sally Poncet, a Falklands-based wildlife biologist who has been involved in numerous rodent and other pest eradication projects in the Falklands and South Georgia and numerous biological surveys and scientific studies of rodents and their effect on island biota.

Leiv Poncet undertook some brief but important surveys of Ship and Cliff Knob Islands to ascertain their rodent status and bird species present.

The feasibility report is intended to assist New island Conservation Trust assess the possible options, costs and challenges, and the likely benefits and risks associated with any eradication attempt.

The study will be used to assess whether eradication is feasible and worthwhile, and if so, identify key issues that need to be resolved and any additional research potentially required before an eradication project should proceed. It provides some recommendations from which a possible operational plan could be prepared.

2. GOAL, OBJECTIVES and OUTCOMES

2.1 Supporting Documents

Potential eradication of invasive mammals on New Island is consistent with the general principles and visions of the New Island Conservation Trust's objectives, as well as the Falkland Island Government's Environment Charter and the Biodiversity Action Plan, and international conservation agreements such as the Agreement on the Conservation of Albatrosses and Petrels (ACAP).

The New Island Conservation Trust's objectives are to promote the study and appreciation of ecology and wildlife conservation throughout the Falkland Islands, and to assist in developing plans for the management and conservation of its exceptional natural environment for the future.

The Original Memorandum of the NICT was "*To establish the island as a wildlife reserve, to encourage conservation and research while developing specialised wildlife tourism*" and this remains in place today, and under the NICT the property is required by law to continue as a wildlife reserve in perpetuity.

2.2 Goal

Any island restoration project (including eradications) should have very clear goals and objectives. If, and it must be stressed *if* eradication of invasive mammals is undertaken for New Island, a suitable goal for any attempt at eradication of on New Island could be:

The recovery, as far as is practicable, of indigenous biota, ecosystems and natural processes of New Island, through eradication of ship rats, house mice, rabbits and feral cats.

2.3 Possible Objectives and Outcomes

The objectives that an eradication project could achieve, and the outcomes that could be seen as a result of achieving these objectives could be summarised as:

Objectives	Outcomes
1. Eradicate ship rat, mice, rabbits and feral cats from New Island (and adjacent islands as required)	1.1. No rat, mouse, rabbit or cat populations on New Island
	1.2. Re-establishment of self-sustaining breeding populations of Cobb's wren and tussacbird
	1.3. Increase in population of a range of terrestrial passerine species and other predation-vulnerable terrestrial and waterfowl species
	1.4. Possible expansion of prion, white-chinned petrel and sooty shearwater colonies, and possible establishment of populations of other small seabird species, especially storm petrels and diving petrels
	1.5. Increase in population of invertebrate species and restored nutrient cycling processes
	1.6. Natural vegetation recovery is able to occur
	1.7. A 're-balancing' of natural predator-prey relationships and populations on New Island occurs
	1.8. Reduced biosecurity risks to other islands in the New Island IBA
2. Eliminate the ship rat from the Falkland Islands	2.1. Elimination of the local biosecurity risk of transportation of ship rats (currently only recorded on New Island) to other locations in the Falklands.

3 THE SITE

3.1 Location and General Description

New Island (61° 18' W and 51° 43' S) is one of the most westerly of all the Falkland Islands (a UK Overseas Territory) in the South Atlantic Ocean, and is 354km from the nearest point of South America. New Island is 238km from Port Stanley, the major settlement of the Falklands. The nearest inhabited islands are Beaver Island (c.8km distant) and Weddell Island (c. 12 km distant), to the south and south-east respectively. Both islands have a small fixed-wing landing strip to service the settlements there, with an 'on-demand' flight schedule operated by the Falkland Islands Government Air Service (FIGAS).

New Island is accessible by sea from these islands or from further afield, or by helicopter. Required improvements to the former airstrip at New Island are in progress, with the aim to restore FIGAS flights to the island in the foreseeable future.

New Island is approximately 13km long, and on average 750m wide, with a total land area of approximately 2240ha (though figures ranging from 2362ha to 1970ha have been quoted). The length of coastline is estimated to be 84km. It rises to a maximum altitude of 743ft (244m) at South Hill, and there are several other hills of similar stature on the island.

The island tends to be wedge-shaped in section, with formidable cliffs on the western and northern sides, and a gentler slope to the sea on the eastern seaboard. A few caves and 'gulches' occur along the western seaboard. The eastern side is lower-lying with rocky shores, sandy bays and sheltered harbours. The island was formerly heavily grazed and in some places has suffered considerable erosion.

The island's vegetation has been highly modified by the impact of grazing over many years. The highly palatable and keystone Falklands species *Poa flabellata* (tussac), possibly once the dominant vegetation type on New Island, has been reduced to c.2% of the islands area.

The upland areas are either rocky or dominated by a short dwarf shrub heath comprised of diddle-dee *Empetrum rubrum*, mountainberry *Gaultheria pumila* and cushion plants. The small fern *Blechnum penna-marina* and the introduced grass Yorkshire fog *Holcus lanatus* are widespread. Taller palatable grasses including the tussac and blue couch grass *Agropyron magellanicum* are presumably much-reduced from their former range, and occur in concentration only at a few remnant sites, but are slowly recovering.

The vegetation is likely to change continually over the forthcoming years as the slow regenerative process occurs after removal of sheep and cattle, though this is impaired by serious soil erosion at many locations, and will be further slowed by the continued effect of rabbits in particular but also to some extent by rodents.

The island has two large freshwater ponds, one at the South end of 3.6ha, and one in North Harbour of 0.5ha. Several natural springs and seepages occur, and these feed a few small streams.

One of the main streams of the oceanic Falkland Current passes to the west of New Island, bringing productive feeding grounds for the seabird and marine mammal species in the area.

Associated Islands

New Island has an associated group of approximately 12 smaller 'satellite' islands all within c.1.7km of New Island's coast (see Table 1). At least two, Landsend Bluff and Burnt Island, **must** automatically be included within any consideration of pest eradication proposals developed for New Island in future, while it would be highly prudent to include other islands in the group (especially Ship Island which appears rodent-free but may be vulnerable to invasion (Poncet 2013)) into any planning unless shown to be completely pest-free immediately prior to any eradication operation on New Island.

For the purposes of this document, Burnt Island and Landsend Bluff, and possibly Ship Island (with potential for rodent presence) should be considered as part of the treatment area.

Burnt Island, lying just off the settlement at New Island is tidally linked and generally considered as part of New Island. Most of the other islands in the satellite group are owned and managed by another conservation charity organisation, Falkland Conservation, while the southern outlier of the group, Seal Rocks have been granted to the NICT in 2000 by the Falkland Island Government (FIG). Due to their relative remoteness and difficulty of access in some cases both geographically and physically, some of these islands are not well surveyed for their conservation value, but those that have are rated very highly.

Photo 1. Landsend Bluff, with New Island to the left and behind, showing the scale of the western cliffs.

(Photo courtesy of Ian Strange)

Table 1. The 'Satellite' Islands of New Island.

[Coloured rows indicate islands that must be included in any consideration of eradication of mammals from New Island, unless and until a pest-free status can be confirmed for each]

Island	Size (ha)	Pest Status	Distance to New Island	Notes
Landsend Bluff	7-14	Unknown but presumed rodent presence	<50m	Two near vertical-sided towering stacks off the NW point of New Island, both with elevation of around 100 m. The bluffs are deeply fissured and provide cliff nesting habitat for colonial seabirds. Plateau on larger stack has dense tussac. Black-browed albatross colony, breeding fur seals.
Burnt	<2	Invasive mammals as for New Island	<40m (tidal)	Modified habitat, tidally linked to New Is.
Ship	9	Probably rat-free but may be subject to periodic invasion?	450m	Low hummock island, 15m max height. Grazed until 1972, and possibly burnt. Small amount of recovering tussac. Skua and terns present. Southern giant petrels breeding (Poncet 2013). Thin-billed prions may be present? Distance to New Island suggests it may be vulnerable to rat invasion.
Cliff Knob	2	Pest-free	470m	Possibly pristine? 25m high, difficult to access. High density of thin-billed prion (and possibly other burrowing petrels), tussacbird, Cobb's wren. Distance to New Island suggests it may be vulnerable to rat invasion.
Saddle	35	Pest-free	1.3km	Tussac-dominated. Max height c.75m. Thin-billed prions, Cobb's wren, tussacbird present. "*Ecological value extremely high*" (Poncet & Passfield 2011)
North	75	Pest-free	500m to Saddle Is	70m max altitude. May be one of the most pristine islands in the Falklands? Difficult landing. Tussac covered with interior balsam bog and bluegrass plateau. BBA colony, rockhopper penguin, Cobb's wren.
Beef	10	Pest-free	780m, and 1.24km to Coffin	Tussac-dominated, 50m high island, stocked until 1972. "*Outstanding example of rat-free passerine habitat*" (Poncet & Passfield 2011). Thin-billed prions and Cobb's wren present
Coffin	45	Pest-free	860m	Grazed until 1972. "*Outstanding example of rat-free passerine habitat*" (Poncet & Passfield 2011). Recovering tussac on slopes, with heath and grassland and cushion plants near 122m summit. Prions, Cobb's wren present.
Seal Rocks (4 islands)	10	Pest-free	1.66km	Three tussac islands and several low rocks. Many prion burrows, tussacbirds, diving petrels.

3.2 Conservation Value and Biota

New Island has conservation values which are significant on a global scale, and it is one of the most important biodiversity and conservation sites within the Falkland Islands.

New Island (South) is a National Nature Reserve, one of 17 in the Falklands (Otley et al. 2008).

New Island, in association with most of its surrounding islands, is recognised by Birdlife International as an Important Bird Area (IBA), one of 22 such sites in the Falklands, which together cover 5.9% of the total land area of the islands (FC 2006).

The New Island group of islands qualifies as an IBA based upon the presence of several IUCN/BirdLife Red List species, most notably the 'Endangered' black-browed albatross (*Thalassarche melanophrys*), along with the 'Vulnerable' southern rockhopper penguin (*Eudyptes chrysocome*) and white-chinned petrel (*Procellaria aequinoctialis*), and the 'Near Threatened' gentoo penguin (*Pygoscelis papua*), Magellanic penguin (*Spheniscus magellanicus*) and striated caracara (*Phalcoboenus australis)*.

In addition, species with a restricted range of less than 50,000 km^2 are present on the New Island group, and these include the striated caracara, ruddy-headed goose (*Chloephaga rubidiceps*), the white-bridled finch (formerly known as the black-throated finch or canary-winged finch, *Melanodera melanodera*), the endemic Falkland steamer duck (*Tachyeres brachypterus*), and tussacbird/blackish cinclodes (*Cinclodes antarcticus antarcticus*), and on some of the offshore islands only, the endemic Cobb's wren *Troglodytes cobbi*.

The king or imperial shag *Phalacrocorax atriceps* and the thin-billed prion *Pachyptila belcheri* qualify under separate subsections of IBA criteria A4, with New Island having congregations of more than 1% of the biogeographic population of congregational waterbirds and more than 1% of the global population of seabirds respectively.

The endemic and IUCN-classified 'Vulnerable' Cobb's wren (*Troglodytes cobbi*), is present and breeding on some of the smaller islands in the New Island group though notably not on New Island itself, and the lack of a breeding population there is in the author's opinion a clear result of predation, given its presence on most of the smaller surrounding islands that are without invasive predators. Given these circumstances it is inconceivable that Cobb's wren was not naturally present on New Island in the past. Its current absence on New Island may not be due to a sole factor such as predators however, as a combination of other factors such as lack of tussac-lined boulder beaches or other favoured habitats, relative lack of taller vegetation (e.g. coastal tussac) for nesting, and possible absence of invertebrate prey items due to vegetation loss and competition from rodents.

Three species listed under the Agreement for the Conservation of Albatrosses and Petrels (ACAP) are present; the black-browed albatross, the southern giant petrel *Macronectes giganteus*, and the white-chinned petrel.

See Table 2 (Section 4.2) for a list of notable species present on New Island and the probable effect of invasive mammals on each species.

The Royal Society for Protection of Birds (RSPB) has recently been undertaking a prioritisation exercise for all of the islands within the UK Overseas Territories, reviewing which invasive species are present, which native species are present, and the feasibility of removing invasive species. The Actual Conservation Value (ACV) of removing all invasive species is to be calculated for 2,499 islands in the UKOTs, based on the irreplaceability of the native species, severity of impact of the invasive species, and the current feasibility for eradication. This report has yet to be finalised but the current draft suggests New Island ranks very highly within the Falklands and relatively highly overall within the UKOT.

Birdlife

The New Island group is considered to be one of the finest wildlife areas in the Falklands. New Island has 39 regularly breeding species of bird (NICT website), equating to 65% of the total number of breeding species found in the Falkland Islands, and the number of breeding species may actually be higher, with at least 46 bird species possibly regularly present. Many but not all of the conservation values are present on New Island, and significant populations of many species occur on the smaller off-lying islands in the group.

Seabirds

New Island is probably the world's most important breeding ground for the thin-billed prion. There are colonies of black-browed albatross, gentoo and rockhopper penguins and a colony of about 50 pairs of southern giant petrel. There is a significant breeding population of Falkland skua (*Catharacta antarctica*), numbering >400 pairs in 2004. There are possibly a few pairs of macaroni *Eudyptes chrysolophus* and king penguins *Aptenodytes patagonicus* within colonies of other penguins but their breeding status is unclear.

White-chinned petrels occur in a single very small colony on New Island. This is one of only four known sites in the Falklands (Reid et al. 2007, Poncet et al. 2012). While the New Island colony of perhaps 20-30 pairs is not of huge significance on a global scale it is very important within the Falklands, being geographically isolated from the cluster of other known colonies (Kidney, Top and Bottom Islands, c.250km distant). The population of white-chinned petrels in the Falklands is less than 1% of the total world population, but has the potential to be an important, if small, genetic reserve for the wider species' conservation. The Falklands population may be vulnerable to local extinction due to mortality associated with fishing, and with all known sites being similarly small, each known colony is therefore of considerable importance. Reid et al. (2007) estimated the total known Falklands population at a minimum of just 55 pairs, but recent surveys (Poncet et al. 2012) have recently discovered Top and Bottom Islands may have a population of "*several hundred breeding pairs*". Further survey work may well indicate other islands with breeding white-chinned petrels, and some of the satellite islands around New Island may be suitable habitat and may warrant further survey.

Sooty shearwaters (*Puffinus griseus*) are also present, with "*extremely small numbers on Rookery Hill, amongst prions and white-chinned petrels*" (Strange 2007) with only one active nest discovered in both 1981 and 2004 but with the chance "*a few more might have gone unnoticed*".

Species that have been reported from New Island but not recorded as breeding are Wilson's storm-petrel (*Oceanites oceanicus*), dove prion (*Pachyptila turtur*) and common diving petrel (*Pelecaniodes urinatrix*).

Land birds

Birds of prey resident on New Island include the peregrine falcon (*Falco peregrinus cassini,* an estimated minimum of 6 pairs), striated caracara (c.85 pairs), the southern or crested caracara (*Caracara plancus*, several pairs), variable hawk (*Buteo polyosoma*, c. 3 pairs), turkey vulture (*Cathartes aura*) and short-eared owl (*Asio flammeus,* 3-4 pairs in the southern half of the island) (Strange 2007). Barn owls (*Tyto alba*) are sometimes present but not confirmed breeding.

A number of passerines (song bird) species are present, including dark-faced ground-tyrant (*Muscisaxicola maclovianus*), Falkland thrush (*Turdus falcklandii*), Falkland pipit (*Anthus correndera*), long-tailed meadowlark (*Sturnella loyca*), black-chinned siskin (*Carduelis barbata*), grass wren (*Cistothorus platensis*), the tussacbird and the white-bridled finch.

<u>Shore and Wetland birds</u>

King shags are breeding in large numbers, while Rock shags (*Phalacrocorax magellanicus*) and black-crowned night herons (*Nycticorax nycticorax falklandicus*) are present in smaller numbers. There are also populations of Magellanic oystercatcher (*Haematopus leucopodus*) and blackish oystercatchers (*Haematopus ater*).

Waterfowl include crested ducks (*Lophonetta specularioides*), Falkland steamer ducks, kelp geese (*Chloephaga hybrida*), upland goose (*C. picta*), ruddy-headed goose (*C. rubidiceps*), and speckled teal (*Anas flavirostris)*.

Flocks of the two-banded plover (*Charadrius falklandicus)* and an occasional white-rumped sandpiper (*Calidris fuscicollis*) can be observed.

Kelp gull (*Larus dominicanus*) and dolphin gulls (*Leucophaeus scoresbii*), and South America terns (*Sterna hirundinacea*), can also be found breeding on the island's coast and on the smaller islands offshore.

The snowy sheathbill (*Chionis alba*) is a regular non-breeding visitor.

Marine Mammals

New Island has one of the Falklands' most important breeding locations for South American fur seal (*Arctocephalus australis*) near Landsend Bluff, with an estimated total population of about 2,500 animals, and this is one of relatively few breeding locations within the Falklands for this species.

The islands in the New Island group are also breeding grounds and haul-out sites for a small number of southern sea lion (*Otaria flavescens*).

Southern elephant seals *(Mirounga leonina)* and leopard seals (*Hydrurga leptonyx*) haul out in small numbers on New Island and some of the surrounding islands.

Peale's dolphin (*Lagenorhynchus australis*), Commerson's dolphin (*Cephalorhynchus commersonii*) and orca (*Orcinus orca*) and other cetaceans are known from the surrounding seas.

Flora

Upson (2011) noted that 73 native and 43 introduced vascular plants have been recorded from New Island. The number of native plants represents 42% of the total species list known for the Falklands. Six of the Falkland's 14 known endemics are located on the island. A total of 22 broad habitat types were recognized by Upson, the largest by total area being improved grasslands, dwarf shrub heath, coastal cushion heath and bare ground.

Endemic plants present on New Island include lady's slipper (*Calceolaria fothergillii*), vanilla daisy (*Leucheria suaveolens*), coastal nassauvia (*Nassauvia gaudichaudii*), woolly Falkland ragwort (*Senecio littoralis*), and smooth Falkland ragwort (*Senecio vaginatus*), while the snake plant (*Nassauvia serpens*) was formerly present. Other interesting plants are whitlowgrass (*Draba funiculosa*), tufted azorella (*Azorella monantha*) and yellow orchid (*Gavilea littoralis*).

New Island (one site in North Harbour), Coffin and Beef Islands have populations of an unidentified purslane (*Calandrinia* cf. *axiliflora*), possibly a native and perhaps a new endemic plant, but this needs further taxonomic study.

The iconic Falklands tussac grass was presumably originally far more common on the island (Strange et al. 1988), and perhaps was the dominant vegetation type (Upson 2011) but has been much reduced by former grazing. The current estimate of tussac coverage is c.39ha (2%), with scattered and mixed tussac associations perhaps occurring over an additional 30-plus hectares. Potential recovery has formerly been prohibited by livestock grazing and possibly still slowed by rabbit presence, and has also suffered from natural fires, soil erosion, some die-back, and attack by pathogens such as rust.

There is a mixture of introduced and native grasses, likely resulting from extensive grazing in the past. Introduced plant species including sheep’s sorrel (*Rumex acetosella*), Yorkshire fog (*Holcus lanatus*), groundsel (*Senecio vulgaris*) and bent (*Agrostis* spp.) are widespread. The lowland grassland is interspersed with relatively large areas of dwarf shrub heath, dominated by species such as diddle-dee (*Empetrum rubrum*) and Christmas-bush (*Baccharis magellanica*).

On higher slopes, soil is relatively thin and cushion-type vegetation is typical, including coastal nassauvia (*Nassauvia gaudichaudii*), emerald-bog (*Colobanthus subulatus*) and wiry and tufted azorella (*Azorella filamentosa; A. monantha*).

While a range of introduced plants exist, only a few appear to warrant control or monitoring, including gorse (*Ulex europaeus*) and prickly sow thistle (*Sonchus asper*) and control efforts have been recommended for these species (Upson 2011).

Invertebrates

In general, due to the former overgrazing of the island and the presence of rats and mice, invertebrates probably occur in much lower densities than would be expected for rodent-free islands. They do not appear to have been intensively studied. The comparison of invertebrate diversity and abundance between New Island and one of the larger and more pristine outlying islands (e.g. Saddle Island) would make a fascinating research study into the effects of habitat modification and presence of invasive predators.

3.3 History and Visitation

As with all the Falkland Islands, New Island was uninhabited until settlement in the 18th century.

By 1784, American whalers had visited and perhaps established a shore-base on the island, and some guano collection and probable harvesting of penguin and albatrosses also occurred. By 1860 sheep-farming had established on the island. Whaling continued episodically until 1916. The island has significant historical value around the remains of the whaling industry.

Cats were brought to the island by whalers, and while domesticated cats were present in the early 1900's it is unclear when the feral cat population later established, but presumably was from this domestic source. Whalers also introduced the rabbits, as a food resource. Rats were not recorded on the island until c.1906-08 but may have been there much earlier, and it is unclear when mice established on the island.

The island had been "grossly overgrazed" at time of purchase for conservation reasons in 1973. Sheep-farming ceased on the southern half of the island by 1978-79, and all stock was removed from the entire island by 2006. This was a significant achievement for the restoration of the island, and already several mammal species have been removed from the island – sheep, cattle, horses, pigs, and dogs.

New Island is seasonally inhabited, and there is a research station for use by visiting scientists. It tends to be occupied between September and April, while being shut down in the winter months. There are 3 main houses and 3 smaller buildings, able to accommodate the island managers and up to 8 visiting researchers. Research is open to any creditable scientific agency by application and granting of a permit from the Trust, and a subsequent approval for research from the FIG's Environmental Planning Department.

Limited tourism has occurred since 1973, principally to view the black-browed albatross colonies, and to view breeding colonies of other notable Falkland species such as rockhopper penguins.

Only 'expedition' vessels of less than 160 passengers are permitted to visit, and these are generally associated with vessels heading to or from Antarctic Peninsula tourism. In 2005 (considered a representative year), 19 visits by 11 different expedition vessels occurred landing approximately 1,535 tourists in total (an average of 81 people per visit), with each visit lasting an average of 3.5 hours. Data available from later years 2007-2009 and 2011-2013 showed between 1390 and 3468 passenger landings per season, with an average of 1974 passenger landings per year.

All landings are 'wet' landings via inflatable zodiac-type boats (Strange 2007), with relatively little biosecurity risk.

There is a designated 'red zone' for aircraft around portions of New Island, indicating that aircraft must maintain a minimum altitude of 1,500ft. This is largely to protect colonies of potentially sensitive species such as penguin, albatross and giant petrel from potential disturbance, as some types of aircraft activity can and have caused disturbance and impacted upon breeding success.

Access is currently either helicopter from Mount Pleasant Airport (MPA) or FIGAS flights from Stanley to Beaver Island and boat from Beaver to New. The New Island airstrip has recently been lengthened to the required new minimum length but it will probably be another year before it is ready for flying operations (S. Poncet pers. comm.).

3.4 Ownership and Management

New Island was farmed from the 1860's up to the mid 1970's (on the southern half of the island) and up to about 1995 on the northern end. Grazing on the southern sector ceased shortly after Ian Strange and Roddy Napier purchased the island in 1972.

From the mid-1970's, the northern and southern sections of the island were managed separately, with the southern end being designated in 1999 as a Nature Reserve and administered from 1995 by the New Island South Conservation Trust. The northern section of the island was eventually also acquired by the Trust in 2006, and the entire island could at last be run as a single conservation management unit.

New Island is one of the most important sites for wildlife and biodiversity in the Falkland Islands and has become the leading site in the Falklands for long-term scientific research on seabirds.

The protection of conservation values and the long-term research programmes on New Island are largely due to the vision and dedication of a pioneering Falklands conservationist Ian Strange, and to the continuing commitment of many scientists, especially Petra Quillfeldt and Paulo Catry and their teams.

The NICT is a UK-registered charity, with eight Trustees based in the UK and the Falkland Islands. These Trustees also act as the governing Directors of NICT as a Limited Company. This Board of Trustees is responsible for controlling the management and administration of the charity, monitoring its income, expenditure, investments, property and other assets, operating to strict regulations laid down by the Charity Commission. Alongside this, Ian and Maria Strange and daughter Georgina have helped to take care of all aspects of running the island from day to day, except for the 2013 winter season when temporary caretakers were resident on the island. Georgina based on New Island for the duration of the six months each year that the reserve is operation.

Parts of the objectives of the Trust relevant to island restoration and the potential eradication of pest species are:

- "To maintain and preserve for the benefit of the public the natural habitat and natural resources of New Island"; and
- "To secure the protection and preservation of the natural habitat, flora and fauna and environment for the protection of wildlife and landscape…"

3.5 Climate

No long-term climate records are available for New Island, but those kept over some recent years indicate that the island is slightly sunnier and warmer than the principal weather recording stations at Stanley and Mount Pleasant on East Falkland.

The Falkland Islands have a cool temperate oceanic climate, dominated by westerly winds. The annual mean maximum temperature is c. 10°C and the annual mean minimum temperature is c. 3°C. The temperature range is from 25°C to -10°C.

Strong winds are frequent throughout the year and reach gale force, more often in summer than winter. Westerlies are the most common winds, and the prevailing wind direction falls in a broad arc from south-southwest to north-northwest for 70% of the time. There is no significant seasonal variation in wind direction and strong winds are frequent throughout the year. The mean wind speed at Stanley is 16 knots. The wind is less than Force 5 (17 knots) for 60% of the time, between Force 6 (22 knots) and Force 7 (33 knots) for 20-25% of the time, and Gale Force 8+ (>34 knots) for 5% - 8% of the time during the September to May period, and for 12% of the time in June through August.

Annual rainfall is low because the Falkland Islands are situated in the lee of South America. The low-lying nature of the islands also prevents the widespread occurrence of relief rainfall. Areas on the eastern coast of the main islands tend to have higher annual rainfall than those on the western coasts. Stanley and Port Howard both have around 630 mm per annum, which is greater than on westerly islands such as New Island, where records collected from 1998-2006 showed it has even lower average rainfall, with a mean of 454mm. This is consistent with other western islands such as Beaver Island which can only receive c.200-300mm per year (L. Poncet *pers. comm*.). Most rainfall is in the winter months, but significant rain episodes can occur any time.

Average monthly rainfall in Stanley peaks in December and January (c.70 mm per month), and drops to a minimum in September-October (c.37 mm).

4 THE TARGET SPECIES, IMPACTS AND BENEFITS OF ERADICATION

4.1 Target Species

Ship rat (*Rattus rattus*)

New Island is the only known island in the Falkland Islands confirmed to have the ship rat or black rat (*Rattus rattus*) species present (though if rats are present on Landsend Bluff and possibly other islands offshore of New Island it is likely they also are ship rats and originated from New Island). Circumstantial evidence suggests they were possibly introduced to New Island during the whaling period between 1906 and 1916 (Strange 2007), but they may have well been present much earlier, coinciding with the arrival of the first sealers or whalers. The source of the ship rats is not known, but collection of DNA material from rats prior to any eradication attempt would be recommended as per eradication best practice, and would enable a genetic signature to be obtained.

As with *R. norvegicus* in other areas of the Falklands, ship rats on New Island appear to be in very low densities in open short pasture and heath vegetation, which afford little if any protective cover and relatively little food resources. Rats on New Island are recorded as most common in association with gorse, tussac and buildings (Strange 2007), with steeper rocky areas also well utilised (pers obs). Density is highly variable according to habitat, but nowhere do rats appear particularly numerous compared to many islands.

The food resources (particularly seabirds) on New Island are highly seasonal, and the ship rats (without any arboreal vegetation as refuge sites) would be highly vulnerable to predation by feral cats and avian predators. As a consequence, it appears greatest densities occur in taller vegetation or steeper rocky habitats where cats and raptors cannot so easily access or stalk their prey. Quillfeldt et al. (2008) showed just a 0-2.7% trap catch rate in the open diddle-dee areas, and a success rate of 0.5 -7.2% in the limited gorse habitat on the island.

Some local control efforts have been made over recent years on New Island to reduce rat numbers in sensitive areas (I. Strange pers comm). This has included use of bromodialone (Tom Cat 2 blox™, active ingredient .005% bromadiolone) and possibly diphacinone, anticoagulant toxins similar to any that would be used for eradication projects, but the quantities used in the past are unknown to the author. This prior use of toxins should not be a major issue with regard to use of similar bait for eradication purposes, but if planning proceeds towards eradication the type of toxins used for control and the extent of their use would need to be re-considered in the lead-up period.

House mouse (*Mus musculus*)

Analysis of genetic allotypes (Hardouin et al. 2010) indicate a very close relationship between the mice of New Island and those present on East Falkland (more so than with mice found on West Falkland), suggesting the New Island mice originated from there or at least shared a very similar point of origin. However, sample sizes were very small so it is not clear how confident these results are. They both have strong affinity with haplotypes found on Grande Terre on the Kerguelen Islands, indicating a common source from which these populations originated.

Mice are widespread over New Island, but most common in areas with tussac and gorse cover. A trapping event in 2002 caught 204 mice (and 157 rats) in 4270 trap nights (Strange 2007).

Quillfeldt et al. (2008) showed mice had just a 0.2-22.2% trap catch rate in the open diddle-dee (heath) areas, and a success rate of 1.4-19.8% in the limited gorse habitat on the island. This compares to a 2012 study on Steeple Jason (Rexer-Huber et al. 2012) where kill trapping rates over all habitats was c.16%, with highest rate of c.24% in coastal tussac, and lowest (c.2%) in the rocky montane area.

Breeding cycles have not been intensively studied on New Island, but is presumed to be consistent with information from other subantarctic islands where there is typically a hiatus in breeding activity through the winter months. Breeding on Steeple Jason Island appears to commence in late August for a few females and into September for most (Rexer-Huber et al. 2012), and but this is based on a limited temporal sample.

No prior attempts to control or eradicate mice from New Island or areas within it have occurred. Toxic (anticoagulant) baits are known to have been used on the island, but in relatively small quantities in discrete areas, so the mice should be naïve to baits and toxins.

Feral cat (*Felis catus*)

Domestic cats were introduced some time before 1925, to combat the spread of rats. It is likely more were introduced in the 1960's with the specific intent to control thin-billed prion numbers (for agricultural reasons).

The cat population on New Island is low, with less than 50 cats estimated (Strange 2007), while Bell (1995) records the cats as being "*in relatively small numbers*" and Catry et al (2007) suggested 30-160 cats.

The highest densities of cats are found around the settlement area, where the gorse thickets create a relatively high density of rabbits and rodents. Cat density appears very low elsewhere, and is almost certainly tied to concentrations of rabbits. Some seasonal movements would be expected to target seasonal food resources.

Limited information suggests kittens are most often produced in November-December.

Cats were shot in the 1970's but this was ceased when it was realised rabbits were their main prey (Strange 2007).

Rabbit (unconfirmed species)

The species of rabbit on New Island has yet to be formally identified, and with at least two introduction events known (one prior to 1814, one in the 1820's (Strange 2007) there could feasibly be at least two forms or indeed could be a mix of both.

Strange (2007) identifies the species as a cottontail rabbit *Sylvilagus* sp, possibly the eastern cottontail *S. floridanus*, but a single specimen taken from the island was identified by the British Museum as the European rabbit *Oryctolagus cuniculus* (Woods and Woods 2006), and Bell (1995) suspected the species to be a domestic breed of European rabbit. This study cannot ascertain which is correct, but DNA sampling could provide indisputable results.

Rabbits are spread over the entire island, but appear highly variable in density according to habitat, and may vary widely from year to year. Bell (1995) reported them as "*in considerable numbers*". Highest concentrations occur near the settlement, where short grass predominates and gorse bushes offer some protective cover. They are also in higher densities near the airstrip and South Hill, but appear absent or in very low densities in many portions of the island, particularly the northern end. A survey by Dr Paulo Catry in 2004 found 10 survey squares of 500m x 500m (25ha) had between 9 and 27 rabbits each (equating to relatively low maximum densities of ~1 rabbit/ha) , while 9 squares had between 4-8 rabbits, but the majority of the island had 0-4 rabbits per survey square (Strange 2007).

4.2 Impacts of the Invasive Mammals

<u>Collective Impacts</u>

Invaded ecosystems present complex management issues. Raymond et al. (2011) suggest this problem is exacerbated in many situations by a lack of knowledge about the ecosystem, but consider that delaying conservation action to collect further data and so reduce such uncertainty is often either impractical or inadvisable. Their study showed the complex interrelationships of invasive animals and native species on Macquarie Island, which has a number of similar species to New Island (e.g. albatross, penguin, burrowing seabirds). Their modeling conclusions strongly supported the simultaneous eradication of all three pest species there, as simulated eradications of only one or two generally suggested continued impacts on the island's native biota. The results also provided support for the anticipated positive outcomes of the project, with predicted recoveries of tall tussock vegetation, and burrow- and surface-nesting seabirds.

Strange (2007) presents the case for the unique invasive mammal situation on New Island and ask some important questions:

- exactly what effect are the introduced mammals having on New Island's native species?
- what is the degree of impact?
- are these populations regulated by each other?
- are the present controls sufficient?

These questions are attempted to be addressed within this study.

It has been argued (e.g. Quillfeldt et al 2008) that the suite of alien mammals on New Island has reached some form of equilibrium with native species such as the thin-billed prion. It is accepted that the situation on New Island is unique within the Falklands and indeed has few comparable scenarios anywhere in the world.

The strongly seasonal availability of seabirds (or chicks, eggs or carrion of such) and equally seasonal dearth of rich food resources in non-breeding periods probably severely limits the populations of the predatory mammals. The sheer number of prions means that the limited number of predators cannot utilise much more than a tiny percentage of their population, and expansion of predator populations are curbed by relatively severe shortages of food resources in winter seasons, and this may be accentuated by the modified vegetation of the island, particularly the relative lack of tussac. The high variability of density of the mammals across the habitat types on New Island add to the complexity of the situation.

However, the equilibrium (if it indeed truly exists) has been with the wildlife that has survived, and does not take account of species that are largely excluded from New Island because of the presence of the alien mammals, such as Cobb's wren, smaller seabird species such as sooty shearwaters, and possibly diving petrels and storm petrels, and perhaps some larger-bodied invertebrates such as camel crickets *Parudenus falklandicus*.

A commonly used argument by opponents of eradication projects is that for some sites there is no credible evidence of detrimental effects by rats or other invasives on native plants or animals, but such evidence is virtually impossible to obtain 'in hindsight' at locations where invasive mammals have already eradicated the most vulnerable native species or reduced them to critically low numbers (Towns et al. 2006). On the other hand, there are numerous global examples that have identified effects of invasive mammals. The perceived need for further research should not be seen as an excuse for inaction if important native species are threatened. Research should always guide management action if possible, but the lack of such should not be a reason simply not to undertake management based on the best information currently available.

Removal of grazing livestock has initiated a slow but steady recovery of vegetation (e.g. Quillfeldt et al 2008), and this will favour expansion of rats and mice as swards of taller grass establish and extensive bare ground areas are recolonized by flora. Research on New Island has recognized that cats and rodents might have future harmful effects if external factors depressed the prion population or allow a significant population growth of predators on New Island (Catry et al. 2007).

Potential changes at sea (food chain cycles and availability, global warming, etc.) may have an impact on seabird populations and any such changes that negatively affect New Island's seabirds may tip the balance in favour of predators. While it is highly unlikely that local extinctions of species such as thin-billed prions could occur in the foreseeable future, any predator-prey imbalance could see exponential and catastrophic declines in prion populations, and tip more precarious populations such as that of the white-chinned petrel and sooty shearwater 'over the edge'.

Strange and Strange (2013) suggested "*the eradication of feral cats would seem like a favourable option, but we cannot predict the subsequent effect of this on the populations of rabbits, rats and mice without further research being undertaken first*". This is a logical argument and one with which this study is in total agreement – cats alone should not be eradicated due to the risk of unforeseen consequences of 'prey release' as occurred on Macquarie Island, with considerable environmental damage. However, the logical response to this is simply to target all four invasive mammals at once. The Stranges' subsequent argument is that "*the eradication of these further three invasive mammal species may not have the desired effect either – these species support our valuable buzzard, owl and crested caracara populations. With such a high proportion of striated caracaras on the island competing with these other species for food, buzzards, owls and the crested caracara rely on the small mammals – a source that the striated caracara cannot exploit easily*". However, the native owls, hawks and caracara of the Falklands exist in good numbers on rodent free islands, and each species is clearly not reliant on these for survival in the Falklands. An unnaturally high population of predators may also have serious impact on some native prey species.

It is quite probable that some species currently utilise rodents as a significant source of prey on New Island. Eradication of mammals would undoubtedly cause some rebalancing of populations of various native predators, but this could be argued as returning things closer to a more natural balance. As in almost all island restoration projects the author has been involved in, the removal of 'unnatural' factors such as introduced predators will allow a more natural scenario to evolve. Sometimes this takes a little time to fully manifest, but it is extremely unlikely, based on all pest eradication projects conducted to date, that any native (avian) predator would be at risk at a population level from removal of the mammals as a food source. Populations of all native predators are likely to persist (albeit in adjusted but more natural numbers) and would shift their focus to the predicted increase and recovery of natural (native) food resources such as large-bodied invertebrates and small birds.

<u>Rats</u>

Ship rats are widely recognised as a significant invasive species, and listed in "One Hundred of the World's Worst Invasive Alien Species" (Lowe et al. 2000), and in a risk assessment of invasive animals in the Falklands this species had the highest ranking (Whitehead 2008).

While ship rats are typically smaller than the Norway rats present throughout much of the Falkland Islands, their conservation impact has been shown to be significant on a global scale (Towns et al. 2006), and in the author's view their potential effects in the Falklands are likely to be as severe as those *of R. norvegicus* for all but the larger species of seabirds.

Quillfeldt et al. (2008) argue that the ship rat is less "*ferocious*" than the Norway rat, and Strange and Strange (2013) state the "*black [ship]rat does not have the same effect on small ground-nesting birds as the* *brown rat*" but both statements are made without convincing evidence, and are probably based erroneously on the peculiar situation on New Island, where habitat issues, highly seasonal food resources, current absence or near-absence of the most vulnerable species, and cat predation restrict the actual damage the ship rat population can (currently) do there. While the ship rat is usually slightly smaller in size than the Norway rat prevalent through the rest of the Falklands, there is very little difference in their detrimental effect on most species. The only exception of relevance in the Falklands appears to be that the slightly larger Norway rats can potentially target larger-bodied seabirds (e.g. larger petrels and shearwaters) and their eggs more successfully, otherwise the relative impacts of the two rat species are hard to distinguish based on all documented evidence to date. Ship rats are known from many global studies to have caused significant harm to a range of species including invertebrates, plants, and a wide range of birds including seabirds such as shearwaters, prions, and terns (e.g. Towns et al. 2006, Moors and Atkinson 1984). In the largely treeless Falklands, both rat species would have significant effect on many ground-dwelling species, while the ship rat could actually in some circumstances be more harmful, with its known greater agility and climbing ability placing cliff-dwelling or tree- and shrub-nesting species at greater risk.

A recent study within the Falklands (Tabak et al. 2013) showed that presence or abundance of some passerine species are strongly affected by rat presence, in particularly the Cobb's wren and tussacbird, while the black-chinned siskin, grass wren, white-bridled finch and Falklands thrush appear affected to a lesser degree. Three passerine species, the long-tailed meadowlark, Falkland pipit and dark-faced ground tyrant are seemingly unaffected by rat presence. While this study focused on islands with Norway rats, the author strongly believes that, on an island-by-island basis, there would be no significant difference in the effects of ship rat or Norway rat on such species.

Reports such as Woods and Morrison (2010) and Poncet and Passfield (*in prep*) have shown the beneficial effects on populations of passerine species of the removal of rats from islands in the Falklands.

St Clair et al. (2011) found camel crickets on islands within the Falklands were up to an order of magnitude more abundant on rat-free islands than on rat-infested or recently rat-eradicated islands. Camel cricket populations recovered after rat eradication, and their results demonstrated severe suppression of a superabundant and large-bodied island endemic invertebrate by invasive rodents, and its prompt recovery after rodent eradication. Crickets would if available form a significant prey item for a range of bird species.

Levels of predation of thin-billed prions by rats on New Island are highly variable, with higher rat numbers and predation events likely in areas close to dense vegetation such as tussac (Catry et al. 2006), while predation events are rarer in the open grassy sites. While predation may be locally severe, the overall effect is minimal due to the seasonal 'swamping' of the rat population by the vast influx of prions, and without similar food resources to maintain the rats through the non-seabird seasons, the rat population cannot expand to take advantage of this almost limitless but seasonal food supply. Ship rats have existed on New Island for at least 100 years and possibly much longer, but their impact upon the world's largest population of the thin-billed prion currently appears to be small because of this.

Research has been conducted of the diet of the black rat on New Island during the summer months when seabirds are breeding. Although rat diet varied with the habitat in which they were caught, vegetation was the important component, followed by animal matter, insects and insect larvae (Quillfeldt et al. 2008).

On a visit to New Island in 2000, DB noted a researcher documenting that 7 of 12 thin-billed prion chicks in a study site were killed within two nights, possibly the result of a single rat. Once the suspected rat was trapped, the predation event ceased. This shows that a single rat can do significant local harm to prion nesting success, and were events such as this to become more commonplace or widespread, the balance between prion and rat populations could dramatically shift over time.

The absence of breeding populations of Cobb's wren and the greatly reduced abundance of tussacbird on New Island is likely directly related to predation, but also complicated by loss of habitat. It is considered most likely that New Island is a current 'population sink' for these species, and observations of these species on the island result largely from supplementation or dispersal (of ultimately doomed individuals) from neighbouring islands.

Similarly, the absence of some species such as Magellanic snipe (*Gallinago paraguaiae magellanica*), and surprisingly low estimated populations (Strange 2007) of white-bridled finch, black-chinned siskin and grass wren is considered related mainly to predation by invasive mammals, but may also be argued by some as being accentuated to some degree by relative lack of habitat.

The presence of rats on islands in the Falklands has been clearly shown to cause "*severe suppression*" of camel cricket populations (St Clair et al. 2011). Along with the drastic reduction of tussac habitat, it is considered that the presence of rodents on New Island will have significantly repressed or potentially extirpated populations of some invertebrate species, such as the larger-bodied taxa such as camel crickets, which are known to be an important food item for a range of bird species. Further research is warranted, but it is predicted that comparisons between comparable vegetation types or habitats on New Island and some relatively pristine adjacent island (e.g. Beef, Saddle, Coffin) would show a significant difference in diversity or abundance of some invertebrate species. A dramatic increase in camel crickets has occurred on Top Island since rat eradication (S. Poncet pers. comm.).

<u>Mice</u>

The impact of introduced mice on indigenous biota and natural ecosystems is often less pronounced or obvious as that for larger pest species such as commensal species of rats (*Rattus* spp.). However, house mice have been identified as a significant threat to ecosystems and species on both temperate and subantarctic southern hemisphere islands. They are widely recognised as a significant invasive species, and are listed in "One Hundred of the World's Worst Invasive Alien Species" (Lowe et al. 2000).

House mice are known to predate chicks and/or eggs of albatrosses, burrowing petrels and ground-nesting passerines on Gough Island, Tristan da Cunha (Cuthbert et al. 2013, Cuthbert and Hilton 2004, Wanless *et al.* 2007), and are likely to cause ecosystem-wide changes in nutrient cycling through predation of invertebrates and plants (Smith and Steenkamp 1990, Marris 2000, Phiri *et al.* 2009). These impacts are thought to be most severe where mice are the sole introduced rodent species (Wanless *et al.* 2007, Angel *et al.* 2009), and actual effects on New Island may be considerably less than would otherwise be expected due to competition, predation and population suppression by rats and cats.

Recently work on Steeple Jason showed that storm petrel burrows were rare in areas where mice were most abundant, and work on Gough has shown a far more widespread effect of mice on a range of seabird species than previously documented (Cuthbert et al. 2013). The Steeple Jason result may in part reflect different habitat requirements or preferences between the species, but may also indicate a generally inverse relationship between population densities of storm petrels and mice. Camera traps there also recorded predation events on ground-nesting white-bridled finches and it is likely that mice predate eggs and chicks of other passerines on the island (Bolton and Stanbury 2010, 2011).

Direct comparisons can be made, and obvious effects inferred. The biota of Steeple Jason Island where mice are the only invasive mammal present can be compared to mouse-free islands in the Falklands, particularly the other islands in the Jason group. The abundance of species such as Cobb's wren, camel crickets and small seabirds such as Wilson's (*Oceanites oceanicus*) and grey-backed storm-petrels (*Garrodia nereis*) on the rodent-free Jason islands is noticeable compared with the paucity or complete absence of such species on Steeple Jason. Rough estimates of abundance of storm-petrels were made on Steeple Jason and nearby and rodent-free Grand Jason (Bolton and Stanbury 2010), and although data were limited they seemed to indicate an approximately ten-fold larger population on the mouse-free Grand Jason.

Some anecdotal evidence obtained during trapping by Dr. Alex Jones in 2005 on Steeple and Grand Jason Islands found a much higher density and variety of insects on mouse-free Grand Jason, which suggests that on Steeple Jason mice consume significant quantities of invertebrates, and suppress or eliminate some species.

The large-bodied camel cricket is perhaps a prime example of the effects of mice, being absent from Steeple Jason Island but occurring on neighbouring mouse-free Grand Jason (Woods and Woods 1997, Bolton and Stanbury 2011), and on other rodent-free islands in the area. The presence of rats on islands in the Falklands has been clearly shown to cause "*severe suppression*" of camel cricket populations (St Clair et al. 2011), and the available evidence suggests this also translates to presence of mice.

Such differences are supported from research elsewhere - striking differences in invertebrate fauna were demonstrated between Marion Island and the mice-free Prince Edward Islands (Crafford and Scholtz 1987). At the same sites Chown and Smith (1993) demonstrated substantial differences between plant and insect communities, which were mentioned as a likely role in the decrease of the lesser sheathbill (*Chionis minor*) on Marion Island (Huyser et al. 2000). On Gough Island in the South Atlantic, mice are potentially threatening the populations of two native moth species due to their predation on caterpillars (Jones et al. 2002). Similar impacts of mice on invertebrate communities have been recorded on the Antipodes Islands, contrasting the main Antipodes Island (with mice) and the adjacent mouse-free Bollon's Island. Mice may be responsible for the extinction of two invertebrate species there (Marris 2000, Russell 2012).

The diet of house mice in environments similar to the Falklands is reasonably well documented. On Guillou Island in the sub-Antarctic Kerguelen archipelago earthworms, caterpillars, weevils, seeds and flowers were identified (Le Roux et al. 2002), and at Marion island, diet components and their quantities were evaluated (Smith et al. 2002).

A New Zealand study (Williams et al. 2000) showed that mice destroy all seed they eat, and do not act as seed dispersers. This may have multi-level effects within an island ecosystem – for example, competing with natural seed-dispersing agents such as passerines, limiting the natural seeding of favoured plants, and consequential alteration in relative abundance of plant species and therefore even habitat types within certain ecosystems.

Some damage has been observed to adult plants as well as seeds. Phiri et al. (2009) reported cushion bog (*Azorella* sp.) being damaged by mouse burrows. *Azorella* species are a significant component of the New Island vegetation.

While it is clear that former grazing and fire are largely responsible for the dramatic decline in tussac cover of the island, it is quite feasible that mice are inhibiting its recovery through consumption of seeds. However, no direct scientific comparison is currently available between rodent-inhabited and rodent-free islands in the Falklands.

Feral Cats

The feral cat is another of the "One Hundred World's Worst Invasive Alien Species". The relatively small numbers of feral cats on New Island is probably determined by the strong seasonality of key and relatively easily hunted food resources such as seabirds and young rabbits.

Matias and Catry (2007) present evidence that cats by themselves may have an overall positive effect on the New Island environment, by controlling rabbit and ship rat numbers, thereby reducing the effect of these species on burrowing seabirds in particular. They calculated that for each prion a cat killed, it also killed 1.1-1.9 rats. This study agrees that the cats may have a generally positive effect on New Island in potentially controlling rabbit and rodent numbers, but may have specific negative effects (such as on white-chinned petrels, sooty shearwater and South American terns) that also need to be considered.

Analysis of 373 cat scats in the austral summers of 2004/05 and 2005/06 (Matias and Catry 2007) showed rabbits (in 43.7% of all samples), rats (31.6%) mice (37.5%) and prions (c.21%) were clearly the major components of diets of cats. Lesser quantities of other bird species were recorded (e.g. Falkland thrush in <2% of scats, unidentified passerine remains in 4.3%, unidentified bird remains in 7.5%). Cats were calculated to kill between 1,500 and 11,000 prions per year, equating to less than 1% of the population, and significantly less than the 40,000 per year estimated to be taken by the natural predators, skua and striated caracara.

There is some evidence of cat predation of white-chinned petrel chicks on New Island, but the very limited evidence to date (Matias and Catry 2007) suggests a fledging rate of 44-48%, comparable with success rates at South Georgia (Hall 1987, Berrow et al. 2000). While it has been stated that "*there is no evidence of a long-term change*" to the petrel population on New Island, the colony has only been known since 1972, and information is limited. This suggests cat predation is currently not severe, but the petrel colony is so small that predation when coupled with environmental and external factors could push the colony into an unrecoverable position. It may also be that cats preferentially prey on smaller and 'easier' prey such as rodents and prions. The natural long life of adult white-chinned petrels may mean that negative effects on productivity may have a delay factor of many years, even decades, so dependence on scant and 'snap-shot' evidence is risky, especially when it is known that rats and cats have a known negative effect on the species and similar species elsewhere (e.g. Jouventin et al. 2003, Moors and Atkinson 1984, Taylor 2000). The island managers must decide an appropriate course of action, but information is unclear on the current threat to the petrels from cats. In the author's opinion, the vulnerability and local importance of the New Island colony would suggest some further research and/or management measures need to be taken as a relatively high priority, to ensure as far as is practical the continued existence of the colony. Use of motion-sensitive cameras or other monitoring techniques outside petrel burrows is recommended to help determine current levels of predation. A 'do-nothing' approach is arguable based on the limited information currently available but is highly risky. (See Section 5 for further discussion on possible options).

Rabbits

Rabbits compete with thin-billed prions for burrows (Quiilfeldt et al 2008), and possibly by extrapolation also with white-chinned petrels, sooty shearwaters and other burrow-using seabirds. Disturbance of nesting birds and alteration of vegetation round burrows are also potentially harmful effects.

They have a considerable effect on vegetation and affect soil stability (Bell 1995), and may well be having significant effect on vegetation recovery (including rate of recovery, species diversity and habitat type) in at least some local areas of the island. Local information on ecological effects of rabbits is limited, but it is conceivable that they could restrict the abundance of some more palatable native plant species, lower the natural recovery of denser grasslands and key species such as tussac, and reduce available vegetative or seed productivity to invertebrates or birds.

The presence of rabbits may appreciably influence cat numbers on the island, by providing a large-bodied prey to see the cats through otherwise relative scarcity of food resources in the non-breeding season for seabirds.

The rapid increase in rabbit numbers following successful cat eradication on Macquarie Island caused major ecological damage, including significant loss and almost complete collapse of tall tussock and herb communities with a flow-on effect of abandonment of such areas as nesting habitat for a range of burrowing seabirds. Through their close grazing of vegetation around burrow entrances, rabbits also made seabird chicks more vulnerable to avian predators such as skuas (Parks and Wildlife et al. 2007). Rabbits there also contributed significantly to soil erosion and had effects through vegetation modification on the diversity, distribution and abundance of a range of invertebrate species. The case of Macquarie Island demonstrates both the effects of rabbits and the dangers of eliminating one invasive species (in this case, cats) without considering the effect of this on the remaining invasive species.

Table 2. Notable species on New Island and the likely effects of invasive mammals

[EN = IUCN Endangered, VU = Vulnerable, NT = Near Threatened, ACAP = listed species under ACAP agreement]

Species	*IUCN status/ ACAP spp.*	*Breeding (✓)*	*Estimated population*	*Effect of alien mammals*
Species probably formerly present or thought may have once to have been present:				
Cobb's wren	VU			Present on nearby Coffin, Saddle, Beef, and possibly others, but absent as breeders on New Island, largely due to predation by rats, mice and cats, though some may suggest lack of habitat also has an effect. Rabbits may cause habitat alteration and could inhibit recovery of preferred coastal tussac habitat.
Wilson's storm petrel				Highly vulnerable to cat and rat predation, and possibly to mice. Rabbits may cause habitat alteration and could limit tussac habitat recovery. May be present on some nearby pest-free islands but this is not confirmed
Grey-backed storm petrel				
Common diving petrel				
Camel cricket				May persist on New Island in severely reduced numbers, due to rodent predation and possible tussac habitat loss. Probably common on the pest-free tussac islands nearby.
Species Currently Present:				
Gentoo penguin	NT	✓	6,650 pr (IBA)	No likely effect
Southern rockhopper penguin	VU	✓	13,400 pr	Possible minor predation of chicks by cats. No likely effect by rodents or rabbits
Magellanic penguin	NT	✓	>3,700pairs	No likely effect
Black-browed albatross	EN ACAP	✓	12,000 pr	No observed effect of rodents but a remote possibility of change in predatory behaviour as per Gough Island
Southern giant petrel	NT ACAP	✓	50prs*	No likely effect (colony may have shifted to Ship Island?)
Thin-billed prion		✓	2 million pairs	Predation of chicks and eggs by rats, predation of adults and chicks by cats. Burrow competition by rabbits

Species	*IUCN status/ ACAP*	*Breeding (✓)*	*Estimated population*	*Effect of Alien Mammals*
White-chinned petrel	VU ACAP	✓	<20pairs (IBA data) 26 pairs on New Island (Reid et al. 2007).	Predation of chicks and possibly adults by cats. Predation of chicks and possibly eggs by rats Possible burrow competition and nesting disturbance by rabbits but there may be little or no overlap in current distribution between the species on New Is.
Sooty shearwater	NT	✓	Very scarce	
Rock shag		✓	<100 pr	Likely predation of chicks by cats. Rat predation possible on chicks but probably not significant No likely effect of mice or rabbits
King/Imperial shag		✓	>4,500	
Black-crowned night heron		✓	<10 pr	
Upland goose		✓	200-400 pr (est. from south end only)	
Kelp goose		✓	<100 pr	
Ruddy-headed goose		✓	c.6 breeding pairs (south end), non-breeding popn c.100	
Falkland steamer duck		✓	>30 pairs	No known effect
Speckled teal		✓	2-3 pr	Likely predation of eggs or ducklings by cats and rats. No likely effect of mice or rabbits
Crested duck		✓	<10 pr (from S end only)	
Turkey vulture		✓	?	No likely effect. Rabbits may be a food source for hawks.
Red-backed hawk		✓	3 pr (in southern end)	
Striated caracara	NT	✓	c.85 pairs	Possible minor effect through competition for some smaller seabird prey species by cats and rat. Rabbits are a possible beneficial food resource.
Crested caracara		Possible breeding	<10	Rodents are a possible beneficial food resource.

Species	***IUCN status***	***Breeding (✓)***	***Estimated population***	***Effect of Alien Mammals***
Peregrine falcon		✓	c.6pr	Possible minor effect of cats and rats through suppression of some passerine species and smaller seabird prey.
Blackish oystercatcher		✓	16 pr	Chicks and eggs would be vulnerable to cats and rats. May also be vulnerable to mice.
Magellanic oystercatcher		✓	30 pr (southern area)	
Two-banded plover		✓	25-40 pr	
Falkland skua		✓	>400pr	Possible minor effect through competition and/or suppression of smaller seabird prey. Mammals may alter skua-caracara relationship in favour of caracara?
Dolphin gull		✓	100-200 pr?	Chicks would be vulnerable to cats especially, but also to rats. No likely effect of rabbits or mice.
Kelp gull		✓	c.135 pr	
South American tern		✓	Variable, rare	Adults, chicks and eggs vulnerable to cats. Chicks and eggs highly vulnerable to rats, and possibly to mice. Population probably severely reduced.
Short-eared owl		✓	3-4pr	Possible positive impact through rodents as prey. Possible negative effect via reduction of key avian prey species. Habitat recovery could be inhibited by rabbits?
Barn owl		visitor		Possible positive impact through rodents as prey.
Tussacbird		✓	<10 pairs	Present and common on Beef, Coffin and Saddle. Population appears severely repressed on New by predation by cats and rodents.
Dark-faced ground tyrant		✓	Widespread and common	Probable predation of nests and chicks by cats, and suppression of population. Effect of rats and mice possible, but probably not significant. Rabbits may cause habitat alteration
Falkland pipit		✓	widespread	
Long-tailed meadowlark		✓	Widespread but patchy	
Grass wren		✓	uncommon	Probable predation of nests and chicks. Likely suppression of population by cats, rats and mice. Rabbits may cause habitat alteration
Falkland thrush		✓	widespread	

White bridled finch		✓	Uncommon <10 pr	
Black-chinned siskin		✓	20-40 birds	
Invertebrate species				Varied effect. Likely to be most significant on larger-bodied invertebrates
Plant species				Unknown and likely to be widely varied. Some plant associations are likely to be altered by rodent consumption of seeds, flowers, vegetation of some species. Rabbits likely to impact certain palatable species and may alter or inhibit general vegetation recovery.

4.3 Benefits and Possible Downsides of Eradication

The eradication of introduced mammals from New Island would be a costly undertaking, with some element of risk associated with various permutations of possible outcomes, and to potential levels of temporary impacts on non-target species.

Some stakeholders question the ecological value of potential eradications, and have stated "*of these alien introductions, none is considered to be a serious threat to native species*" (IBA New Island information). While this may be true for many species in the New Island circumstances, it is a bold statement with respect to the tenuous situation on New Island for white-chinned petrel, and perhaps also to other species such as sooty shearwater and terns, and also fails to recognize the damage already done - the most vulnerable species have probably already gone.

There is a possibility that New Island has some pest-sensitive species present largely due to immigration from neighbouring pest-free islands, and that it is actually a 'population sink' for some species, where productivity does not match losses from predation or other factors, and the populations are maintained only by immigration from more productive pest-free sites nearby. Further research would be needed to demonstrate the situation on New Island for species such as Falkland thrush, black-chinned siskin, white-bridled finch and tussacbird, speckled teal, South American tern, and possibly even for species such as the short-eared owl, which is most commonly found on tussac islands (Woods and Woods 1997).

Researchers and scientist s involved with New Island acknowledge that "*ideally all introduced taxa should be removed from the island*" (Strange 2007) and "*the eradication of rodents from the island would potentially make more habitat available to the thin-billed prion and other ground nesting birds*" (Quillfeldt et al. 2008).

However, some scientific papers and other documentation associated with New Island suggest that firstly, the introduced predator-native prey relationship has reached some form of equilibrium on New Island, and secondly, that no further local extinctions will occur. Certainly there is evidence that the effects of the suite of introduced mammals on New Island is much less than could be expected on most islands based on a vast accumulation of scientific evidence from elsewhere. This reflects the almost unique situation on New Island, with a strongly seasonal seabird presence and relatively severe shortage of food resources at other times of year, and interactions between the introduced mammals to some extent limiting the effect of others. The formerly seriously overgrazed vegetation means habitat alteration has undoubtedly also had an effect on reduction of some species that cannot in hindsight be separated from effect of predators. It is likely that both had a major effect on some species, and any restoration programme would need to address both issues to achieve maximum potential. Soil erosion is a serious issue on New Island (Upson 2011) and "*natural colonization is not however happening fast enough across the island as a whole and therefore soil erosion is a significant concern; there is an urgent need for large-scale restoration projects*", so the former cessation of grazing and the possible future removal of rabbits and rodents may also need to be linked with wider habitat restoration actions for all potential benefits to accrue.

This approach assumes that the 'status quo' will remain in perpetuity, but it is the author's view that this cannot be guaranteed and is in fact unlikely over the longer term. The planned control of gorse (or alternatively its gradual expansion), the relatively recent removal of stock and the subsequent slow and on-going recovery of vegetation or effects of on-going soil erosion are likely to have already set in motion a change of environmental circumstances, and other wider environmental issues may also promote changes in the current 'equilibrium'. These changes may take many years to manifest fully, but could have significant and even profound effects on the overall ecological situation.

For example:

- the recovery of denser vegetation (taller native grasses, the native shrub *Hebe elliptica* (boxwood), and non-grazed swards of introduced grasses) will probably favour the geographical spread and overall abundance of rodents. Denser vegetative cover may also make predation on them by cats and avian predators potentially less significant overall. An expansion of population and range of rodents and their overall effect on native species could be predicted to increase as vegetation slowly recovers.

- It is possible that cat numbers could naturally decrease as thicker vegetation makes hunting opportunities more difficult. It is known that feral cats on subantarctic Campbell Island naturally died out (despite the continued presence of rodent populations and other food sources) as the likely consequence of vegetation recovery following removal of the feral sheep population there – it is presumed the denser vegetation reduced hunting success or made travel in cold wet conditions more challenging (Brown and Theobald 1999).

- The planned control or removal of gorse and the gradual encroachment of taller grasses into their preferred short grass habitat is likely to have an effect on the rabbit population, which are known to use these areas for feeding and in the case of gorse for refuge from cat (and avian) predation. Any reduction in rabbit population caused by gorse control or taller grass regeneration would potentially have impact on the cat population too, as cats may rely heavily on rabbits at critical times of year when few other food resources are available.

New Island in itself also cannot be considered as a standalone island. The continued presence of rodents on the island poses longer-term biosecurity risks to other islands in the New Island group and to the wider Falklands that are currently mouse- or ship rat-free. Eradicating ship rats from New Island would greatly reduce this biosecurity threat.

The key benefits of eradicating ship rats, house mice, feral cats and rabbits from New Island are considered to include:

- Returning New Island some way back towards its natural state, free of all introduced mammals.
- Clearing the entire New Island group of islands (an important IBA) of all invasive mammals.
- Removing the potential for ship rats to establish in other locations within the Falklands from this single known local source.
- Eliminating the possibility of the delicate 'equilibrium' in predator-prey relationships shifting in favour of predators because of changed environmental circumstances (e.g. the continuing recovery of natural vegetation following sheep removal, global climate change or food-chain issues for the seabirds).
- Allowing the recovery of suppressed or remnant populations of pest-vulnerable species and/or the re-colonisation of the island from neighbouring islands. Species most likely to benefit include:
  - South American terns, and possibly various gull, duck, and wader species
  - white-chinned petrel
  - Wilson's and grey-backed storm petrel, common diving petrel and sooty shearwater
  - small terrestrial bird species, especially the Cobb's wren and tussacbird, but probably many passerine species.
  - a currently undefinable range of invertebrate species but almost certainly including the camel cricket and other larger bodied species.
  - recovery of natural vegetation communities free of unnatural influences.
- Eliminating the long-term possibility of rats or mice evolving predatory behaviour toward larger seabirds such as albatross on New Island (as exhibited on Gough Island) that could further threaten albatross and other seabird species.
- Another significant step in acquiring expertise and experience in eradication of invasive mammals from cool temperate climate islands in general, and as a means of furthering local Falkland Island skills and capacity-building.

Not all changes could be positive however, and Strange (2007) rightly warns of the possible negative consequences of eradication of one or more invasive mammals.

Some key negative aspects of potential eradication are considered to be:

Possible Negative Consequence	Possible Counter-argument
The high cost of any eradication project, and potential impact on funding for other important local and UKOT projects	Likely to be externally sourced and not likely to affect the NICT bottom line. Funding agencies should in theory prioritise projects based on relative

	urgency and cost-benefit.
Risk of partial failure (one or more mammal species surviving any eradication attempt) altering the ecological balance negatively.	Best practice and adequate resourcing will maximise prospects for success for all target species, but risks would need to be accepted. Repeat attempts at eradication are possible (at added cost), with high prospect for success.
Risk to some non-target species through use of toxins or traps.	Effects and risks may be temporarily significant for some species, but scenarios are largely predictable based on experience, and somewhat manageable. Effects will be short-term, and in most cases are likely to be off-set by longer-term gains. Such options would also need to be used for control purposes.
The potential loss of New Island's unique situation within the Falklands – the only island with this particular suite of introduced predators, offering a 'point of difference' for research opportunities on the invasive species.	An acknowledged negative aspect, but must be counterbalanced by the desirability of restoration of the natural environment, and also the research opportunities created by an invasive mammal-free IBA.
A possible interruption or added variable, or loss of some options for long-term research programmes	Providing new research opportunities to measure ecological changes as a result of any eradication.

5. MANAGEMENT OPTIONS TO REDUCE IMPACTS OF INVASIVE MAMMALS

It is believed that three broad alternatives exist with respect to the presence of invasive mammals on New Island:

1. Maintaining the status quo, i.e. managing the island much as it has been over the last decade or more.
2. Enhanced control options to specifically address key conservation issues over the whole island or specific portions of it.
3. Eradication of some or all of the invasive species.

5.1. The 'Status Quo' Option

A 'status quo' approach may maintain the current situation, and whatever effects rodents, rabbits and cats may have on the ecosystems and species of New Island will continue in perpetuity. Some specific management actions (such as rodent or cat control, or associated gorse control) may be targeted at colonies of certain key species or other specific locations.

The status quo could be considered acceptable in the shorter-term, while further research and planning is conducted. While rodents and/or cats are probably responsible for the local extirpation of Cobb's wren, beyond the possible exception of the white-chinned petrel and sooty shearwater, the impacts of rodents and cats currently do not appear to immediately threaten any further avian species with local extinction or any damage beyond the various species' natural ability to recover.

Some recent changes, e.g. the recovery (post-grazing) of some grass species appear in recent years to have benefited some passerine species such as the Falklands thrush, long-tailed meadowlark and white-bridled finch (Strange 2007), but it is unclear but probably unlikely whether populations of such species are at a level comparable to pest-free islands. Hall et al. (2002) demonstrate that rat presence is clearly the most important factor (overriding potential complicators such as habitat modification) in predicting passerine presence and abundance in the Falklands.

However, the changing circumstances on the island (especially the recovery of vegetation post-grazing) mean the degree of on-going threat to some native species posed by invasive mammals is unclear. Further shifts in predator-prey relationships are predicted as these changes continue. It is therefore a distinct possibility that effects may get progressively worse (and in the worst case scenario exponentially worse) as the populations of smaller seabird species potentially decline and the proportionality of the seabird and invasive mammal populations change in favour of the predators.

As an example of unexpected consequence of change, grey-faced petrels co-existed with rats for a number of years on Whale Island in New Zealand, with a fledging rate of 29-47%. However, rabbits were introduced to the island c.1968 and the resultant change in food web interactions influenced greater rat predation on the petrels, and petrel productivity fell to virtually nothing for a period of years between 1972 and 1977.

Fledging success rates in later years was highly variable and correlated with the degree of rat and rabbit control undertaken (Imber *et al.* 2000). Following eradication of both the rabbits and rats in 1987, petrel fledging success was consistently high and increased steadily to 52% in 1994 (the last year of the study).

Advantages of a 'status quo' approach include:

- No extra financial cost or risk
- Unique research opportunities of New Island are maintained
- Ability to take advantage of more cost-effective or 'safer' rodent eradication or control options that may potentially become available in future

Disadvantages include:

- Continued effect of alien mammals on species and ecosystems on the island
- Potential negative reaction to perceived inaction of managers toward restoring the island
- Potential increase of severity or range of predation or competition of mammal species over more of the island
- Risk of accidental transfer or natural colonisation to neighbouring pest free islands

➢ **This study concludes that a 'status quo' option can be considered as a valid temporary option, while further monitoring, research, or preparatory work for eradication, is being carried out. The one key species currently known to be threatened with imminent local extinction or major short-term effects (the white-chinned petrel) could be temporarily protected to some degree by site-specific management. However, the 'status quo' scenario is less desirable as a long-term option, as it excludes the most pest-sensitive species that were probably present in the past, and probably allows continued suppression of populations of others. Predicted environmental changes may alter species interrelationships and effects of pest species may become more pronounced.**

5.2. The 'Sustained Control' Option

Some control of rodents around seabird nesting areas has been undertaken since 1990, using a combination of traps and toxins. Trapping has also been used for indexing of rodent abundance and research into diets.

Cats were shot in the 1970's but this was ceased when it was realised rabbits were their main prey (Strange 2007), and that they were "*also declining naturally*".

Control options are often not practical for remote and uninhabited islands, as the measures by which significant positive results would accumulate would need to be island-wide and would need to be maintained for as long as the positive benefits were required, i.e. in perpetuity.

Long-term solutions and/or localised control are possible on New Island, but could be difficult to implement and/or sustain at a level required to ensure aims of the control work are being achieved. A regular 'pest control' staff input on the island would be required at least over summer months, and this would be a necessary first step to enable the sustained baiting or trapping required to protect the seabird colonies and other vulnerable species/ecosystems over the extended breeding season.

White –chinned petrel protection options

The priority objectives for any long-term control measures would perhaps be to protect the white-chinned petrel colony, remnant sooty shearwater breeders and perhaps selected prion colonies from cats in particular, but also rats. The actual effect of cat or rat predation on white-chinned petrels may need to be clarified, and some research, such as use of motion-sensitive cameras positioned outside of burrows could provide clearer evidence of any predation on petrel chicks by invasive mammals.

Management personnel on the island have controlled rodents around geographically small sites, but site-specific cat control is considerably more challenging, given the known propensity of feral cats to often travel very large distances (many kilometres) in a single night. To achieve effective control of cats at the white-chinned petrel site, the control measures would need to be on-going, and widespread enough to target all cats likely to visit the colony as part of their home range, effectively meaning much of the island, and therefore much of the cat population. It is difficult to predict whether predation at the petrel colony is the result of just a very few cats deliberately targeting the area, or a wider more opportunistic predation by a larger number of cats. If the former, the removal of these few individuals may result in immediate but temporary benefits, as these home ranges would quickly be filled by other cats.

It is most likely cats would most often target (or have success in predating) chicks and fledglings rather than the more aggressive adult birds. Predation possibly peaks when larger chicks come out of their burrows in preparation for fledging, but this could be established by monitoring of any predated carcasses, and the seasonality of predation events. If so, control options may only need to be focused in a relatively small window of time.

Shooting of cats in the vicinity of the colony may be the most ‘site-specific’ and species-specific control option, but would be incredibly labour-intensive to prevent cat predation over every night, even just during the most vulnerable stages of the breeding cycle.

Other control options, such as fences to exclude or deter cats have their own issues (cost, on-going inspection and maintenance, the known risk on New Island of other wildlife being trapped or entangled in the fence, etc.). It is possible that netting fences with a seasonally activated electric outrigger or top wire could deter most cats, but would be difficult to erect and maintain their effectiveness (i.e. cat-proof nature). Pest-proof fences of the type used in New Zealand are extremely expensive to build, and would be likely to suffer significant wind damage at such sites while being a potential serious impediment to flying seabirds.

The various kill or leg-hold trapping or toxic baiting options available also have serious risks to non-target species. It would be difficult to find or present a bait type that does not hold attraction and risk to some native (non-target) species. Cage traps need to be baited to draw cats in, and therefore present a risk to caracara and other species which could injure or stress themselves before being able to be released. Apart from shooting, it is difficult to see a safe, cost-efficient and sustainable control measure around the petrel colony. Without more detailed knowledge of the petrel colony environment, it is difficult for this study to suggest further avenues for investigation.

Pros and Cons of Sustained Control

Unlike eradication, targeted control efforts can focus on a few key areas, and can be adjusted to some degree according to resources available and level of control desired. However, the degree of benefit achieved is highly dependent on the effectiveness and scope of the control regimes.

It is currently unclear what measures are necessary on New Island to ensure on-site issues such as predation are reduced to levels that create negligible effect on productivity and population recovery of species such as white-chinned petrel, or what beneficial effect this might have on the population in view of likely continuing off-site factors (possible fisheries by-catch, environmental changes, etc.). Regardless, management to protect threatened species should be undertaken wherever practical options exist to address each issue.

One major disadvantage of this scenario is that control must be on-going for any long-term benefits to accrue. Any relaxation in effort would mean slippage in terms of any conservation gains already made – rodent and cat populations in control areas will quickly recover through enhanced productivity and/or through immigration from adjoining areas. Costs would therefore need to be on-going, while actual conservation gains may be limited due to the practical constraints likely to be faced in terms of potential area able to be covered by control measures or the overall amount of effort that is sustainable over extended time periods.

As control measures have to be maintained 'in perpetuity', it means a continued input of toxins (if poison baits are to be used) into the environment over time, and the toxins used are very similar or identical to those used in eradication. In a situation such as New Island, it is considered almost essential that such rodenticides would have to be used to achieve the level of control desired. Traps are by comparison highly labour intensive, requiring servicing every day, are relatively costly, and rodents often learn to avoid them. If traps are utilised, there will be an on-going risk of non-target capture. Associated with the repeated use of toxins are potential non-target effects, which although less severe than for an eradication, are also on-going. In the long-term, non-target effects are potentially cumulatively greater than that for a one-off application of bait as in an eradication attempt.

Advantages of sustained control can be said to include:

- Ability to focus on specific areas (e.g. white-chinned petrel colony or prion colonies in tussac areas) as required.
- Can be flexible and responsive to changing conditions, varying budgets, etc.
- Usually significantly less initial cost than eradication, and in this case could be several orders of magnitude less, but costs would need to be sustained over a much longer time period.
- Possible to use a wider range of methods – some less potent toxins or traps not appropriate for eradication can be used for control.
- The degree of precision required for control (as compared to eradication) is not so important – managers retain the flexibility to 'make mistakes' and learn and adjust control measures over time.
- May slow or stem the rate of decline of some species – provides more time for improvement or development of longer-term options.

Disadvantages are:

- Very labour-intensive – would require long periods of staffing on the island and around the colony sites which could have its own environmental impact.

- Usually less effective than eradication – some predators will almost always 'get past' any control measures and continue to do harm, albeit on a reduced level.
- Efforts must be on-going to have sustained long-term effects, and based on experience the funding, skilled staff and motivation for this are often hard to maintain.
- Individual animals within predator populations can survive negative experiences with control measures and learn to avoid certain control techniques, with likely increase in cost or loss of efficiency in control over time.
- Environmental effects such as from input of toxins into the environment, or use of traps, or disturbance to wildlife will be on-going, creating a more prolonged but lesser risk (cf. eradication) to vulnerable non-target species.
- Control would be most beneficial to most species during their breeding season, potentially creating conflict between necessary control measures for mice and potential disturbance to wildlife.
- Likely continued inability of most wildlife species affected by mammals (especially those outside the 'controlled' areas) to recover natural populations.

➢ **It is considered that long-term control of alien mammal pests on New Island is potentially feasible for site-specific locations such as the white-chinned petrel colony and some prion colonies, but while undoubtedly cheaper than eradication it is more costly over time per unit area protected, is difficult to maintain in perpetuity, is not practical over all of the island, potentially introduces toxins into the environment over a long time period, and is relatively inefficient in terms of level of protection afforded cf. eradication. It may however be enough to aid protection and lower the vulnerability of a few of the most sensitive species such as white-chinned petrel, but would not allow recovery of species outside the control area on the island, or currently unable to re-establish on New Island.**

5.3. The Eradication Option

The only feasible and proven method for the eradication of rodents from large islands that is currently available is the use of cereal-based pellets containing an anticoagulant poison, the most commonly used variant is brodifacoum, with others such as diphacinone, bromodialone and flocoumafen also being less extensively used. This bait is distributed by one of three means; spread from helicopters guided by GPS (Global Positioning System) navigation systems to ensure comprehensive bait spread over the entire island, or distributed by hand or set out in bait stations). These options are discussed in more detail in Section 6.3.

The vast majority of aerial eradication campaigns to date have been achieved using two particular brands of bait, PestOff 20R™ made by Animal Control Products in New Zealand, or Brodifacoum 25W™ or 25D™ made by Bell Labs in the USA (or their prior equivalents). These baits, containing 20-25 ppm (0.002%-0.0025%) brodifacoum, have proved to be highly acceptable to insular populations of rodents. The success rate for eradications using these baits has been high, especially so on temperate islands, and the eradication of rodents from islands is now a well-established and proven conservation management action worldwide (Howald et al. 2007).

The options of using other forms of toxin and/or bait has considerable added risk in that they have yet to be regularly proven in large-scale rodent eradications, especially for mice. Some toxin options such as diphacinone have had considerable success against rats (including on islands in the Falklands) and for mice on a few small islands as well, but mice have a much higher tolerance to this toxin (Fisher 2005, Eason and Ogilvie 2009). Diphacinone has a lower risk than brodifacoum to non-target species and "*those planning an eradication attempt might choose brodifacoum with arguably higher chances of success but accept or mitigate its non-target risks, or diphacinone with arguably a higher chance of failure but with lower non-target risks*" (Parkes et al. 2011). If alternative toxins were to be used or even considered, they should be extensively trialled and tested on smaller islands before being employed in an expensive operation on a large island such as New Island. The potential effect of the more potent brodifacoum on other target species (rabbits and cats) would further support preferential use of this toxin here.

Other methods as used for 'control', such as traps, are simply not effective in achieving eradication on an island of this size. The ability of rodents to learn and become averse to traps is well known (e.g. Crowcroft and Jeffers 1961, Hurst and Berreen 1985), and consequently a proportion of the population will avoid traps and repopulate the island. Only two eradications of rodents from islands have been recorded or are known using traps as the primary method, and these were both very small islands (0.8ha and 14ha, Howald et al. 2007).

Other potential options such as pathogens, immunocontraception or genetic engineering have yet to be fully developed, and importantly have not been field-tested or proven for eradication purposes. They are currently theoretical options only. Such options, if indeed they ever become available, may be many years away.

Eradication is a high cost and relatively high-risk option. However, its potential reward is also extremely high. Complete eradication could provide a long-term solution to many conservation needs on New Island.

The major potential disadvantage is the cost required to undertake an eradication, and also the absolute distinction between success (which cannot be guaranteed) and failure – there is no 'in-between' result. As a consequence, eradication operations must be meticulously planned and implemented to maximise the chances for success.

Another 'disadvantage' is the requirement for heightened pest quarantine measures to be implemented – if the rodents especially have been removed, it would obviously be extremely important to take measures to ensure they do not return.

Key advantages of an eradication effort are:

- Usually a concentrated 'one-off' effort
- The target species are potentially removed from entire island, so benefits are island-wide
- Significant and sustained conservation gains – recovery or expansion of seabird, passerine and other wildlife or plant populations

Disadvantages include:

- High cost, but over a short time frame
- Risk of partial failure (one or more target species not eradicated) or complete failure (no species

successfully eradicated) and the potential ecological consequences of this

- Likely and potential risk to individuals of some species and to a much lesser extent populations of some non-target species
- Requires sustained and high quality quarantine measures to prevent re-introduction of rodents and to protect the investment.

➢ **This feasibility study has found no obvious impediment or issue that would automatically preclude the possibility of a successful eradication of all four introduced mammal species on New Island. However, further investigation is required to answer some key questions and address some key issues, and at this stage it appears appropriate to continue research and planning if eradication is the desired course of action. If eradication is proposed, it is strongly recommended that all four mammal species should be targeted for eradication concurrently, and not on a one-by-one basis.**

6. CAN ERADICATION BE ACHIEVED?

6.1. Achievability

Invasive pest eradication from islands has in the past few decades become an extremely important conservation management tool, with rats successfully removed from hundreds of islands, cats and rabbits from over 100 each, and mice from approximately 49 (Island Conservation 2012). The likely achievability of eradicating invasive mammals from New Island is assessed here. In Section 6.7, the implications of possible failure or partial failure are discussed.

Ship rats

Ship rats have been removed from a number of large islands around the world (e.g. Macquarie (12,800ha), Taukihepa (900ha), Rangitoto-Moutapu (3,842ha), Hermite (1,022ha), and St Paul (700ha)). There have been a small number of failures but these largely derive from the more challenging tropical situations or from earlier operations where 'best practice' implementation was not achieved. Howald et al. (2007) recorded that to that date 174 eradication operations had been conducted against ship rats with a 92% success rate. Comparisons have shown ship rats are no more difficult to remove from islands than other species of rat, such as the Norway rat (*R. norvegicus*) or the Pacific rat (*R. exulans*).

Eradication success rates for ship rats on temperate climate islands is greater than this, and is very close to 100% where it is known that natural reinvasion is not possible and the implementation has largely followed best practice procedures.

Some appreciable technical challenges presented by New Island, such as steep cliffs, rock crevices and sea-caves have all been experienced and overcome in previous successful rat eradications. Methodology such as deflector buckets, which direct bait-casting in a certain location only, have been used to place bait inside caves and on very steep slopes with reliable success.

Mice

To late 2012, a total of 77 islands had been the focus of mouse eradication efforts (Island Conservation 2012), with 49 of 70 islands (70%) of these being confirmed successful, with another 7 (11%) still to be confirmed. [Note corrections have been made to information presented in the database by author of this report on the basis of or incorrect data or unrecorded new data].

Earlier attempts (prior to 2007) at mouse eradication had considerably lower success rates (62%) than operations for the various rat species (>90%, MacKay et al. 2007), but success rates for mouse eradications have improved in the last few years, largely due to the input from the Island Eradication Advisory Group (IEAG) of New Zealand's Department of Conservation. Since 2007, the success rate worldwide is 91% for mice (McKay 2011). It appears that where operations have occurred using experienced personnel and following now-established rodent eradication 'best practice', the success rates are very high. Griffiths and Towns (2008) showed that 10 out of 10 mouse eradication operations (e.g. Pomona and Rona, Adele, Tonga and Fisherman's Islands in New Zealand) undertaken by the New Zealand Department of Conservation using IEAG advice and following best practice guidelines had been successful. Subsequent to their review, several other operations using the same approach have been successful, with no apparent failures (though incursions or re-invasions have occurred in some instances).

More recently, the acquired experience and knowledge has allowed successful removal from appreciably larger islands, especially the 3,842ha Rangitoto-Motutapu project in New Zealand (Griffiths et al. *in prep*), making the co-joined islands the largest area yet to be entirely cleared of mice. Other large islands recently successfully completed include 1183ha Coal Island and 262ha Pomona Island in southern New Zealand. Results for the Macquarie Island (12,785ha) project are pending.

Mouse eradication on several other very large islands are currently also under evaluation or in planning, including Antipodes (2,025ha) in New Zealand, Floreana (17,000ha) in the Galapagos, and portions of South Georgia Island.

Reasons for failures of operations can be varied, but for a number of earlier operations it is apparent that what is now considered best practice was not followed, including inadequate bait spread to reach all mouse home ranges, bait stations set too far apart, poor planning or inexperience within the management team, and inappropriate choice of toxin or bait type. On a few islands (e.g. Mokoia and Te Haupa Islands in New Zealand) successful eradications were eventually made where prior attempts had met with failure.

Where mice are the sole rodent species present success rates may be slightly higher, possibly due to a theory that where multiple rodent species occur, competitive exclusion or altered behaviour of mice reduces the likelihood of all mice being able or willing to access toxic doses of bait. A strategy would need to be developed for any project on New Island to specifically cater for the possibility of any less than universal bait acceptance of mice that may derive from any rat influence on mice behaviour. This issue has been successfully addressed in multi-species eradications (e.g. Macquarie, Rangitoto-Motutapu) by baiting methodology (two or more applications of bait, with appropriate interval between bait drops).

The challenges around mouse eradication are thought to mainly relate to their biology: in comparison to rats, mice have smaller home ranges, are less likely to cache bait pellets, and may require higher toxin doses relative to body weight to cause mortality (Phillips 2010, Cuthbert et al. 2011b). Island restoration programmes worldwide are continuing to investigate the impact of mice and undertaking research on how best to eradicate mice.

No mouse eradications have yet occurred in the Falklands, largely due to relative lack of islands where they are present, and the initial priorities and feasibilities. However, approximately 60 islands within the Falklands have successfully had Norway rats eradicated from them (Poncet et al. 2010, Poncet 2011, 2012), up to the size of First Passage Island (750ha), all using the relatively more labour intensive methods of bait stations or hand-broadcasting bait. Whilst initially led by New Zealand experts, local capacity and expertise are well-developed and all the most recent projects have been undertaken using solely local expertise and labour.

Although relatively large, New Island is within the size range of islands successfully treated for mice, and as a cool temperate island with apparent cessation of mouse breeding in winter months, the situation appears reasonably straightforward, though rabbit and rat populations may add some complexity to baiting regimes.

A particular challenge on New Island would be pockets of vegetation on very steep faces and cliffs where some mice may eke out a living. This may be further accentuated by possible evasion behaviour by mice in the New Island situation to avoid predation by cats or rats. It may present some challenges for ensuring bait is distributed to any possible mouse home range on these areas, but this is yet to be an issue, with a number of successful mouse eradication projects with similar but perhaps not as extensive environments.

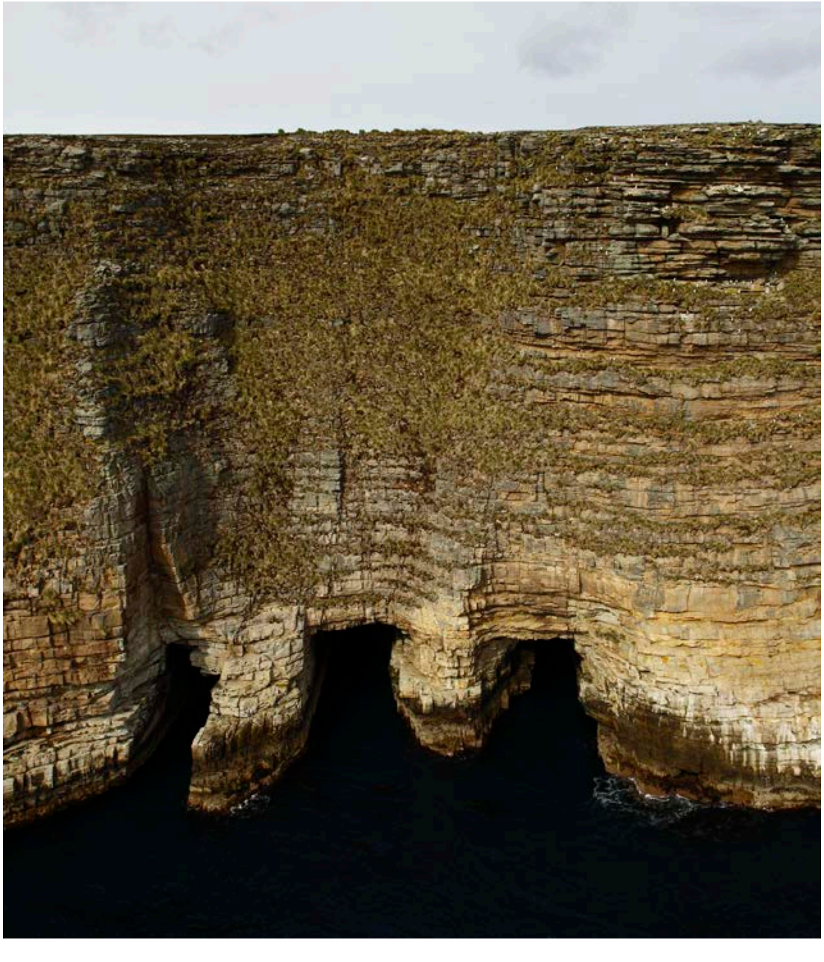

Photo 2. Tall vegetated cliffs and sea caves on the western side of New Island add challenge to any possible rodent eradication but do not preclude success. *(Photo courtesy of I. Strange)*

The prospect for successful mouse eradication on New Island is considered to be high (appreciably higher than the overall historic c.70% and 91% (post-2007) success rates achieved in mouse eradications thus far, and perhaps closer to the 'no-failure' recent results from New Zealand operations undertaken by DOC or by practitioners following best practice methodology as developed over many years of experience by the New

Zealand Department of Conservation (Broome et al 2010). But, as with all eradications, success cannot be guaranteed, and risks on New Island are elevated because of the complex interrelationships of the introduced species and also the extent of the vegetated cliff areas.

Feral Cats

Feral cats have been successfully eradicated from a large number of islands worldwide, including some very large, remote and challenging sites including Marion Island (South African subantarctic 29,000ha), Macquarie Island (Australian 12,800ha), San Nicolas (USA, 6,147ha), Faure (Australia 5,241ha) and Rangitoto-Motutapu (New Zealand 3,842ha).

Cats were eradicated during the 1980s and 1990s from several islands within the Falklands including Beaver (4,856ha), Bleaker (2070ha), West Point (1255ha) and 5150ha Speedwell Island (Otley et al. 2008), so the local ability for eradication has also been well demonstrated on sizeable islands.

The DIISE (Database of Island Invasive Species Eradications, Island Conservation 2012) lists 130 eradication operations against cats, of which 106 (87%) were successful where outcome is currently known. Five projects are 'outcome unknown' at the current time. Of the 19 recorded failed attempts on 14 islands, six were subsequently re-attempted with a successful outcome while a re-attempt is underway on one other island.

The New Zealand Department of Conservation has recently developed a draft 'best practice' document for eradication of feral cats from islands (Broome et al. *in prep*), and adherence to the recommendations acquired through years of collective experience will no doubt considerable improve prospects of success well above the current documented success rate. There have been no islands in New Zealand where cat eradication has not (eventually) been successful, and all recent operations (post-1997) have been successful on first attempt.

The open nature of the vegetation of New Island, and a predicted behaviour (as seen on other islands) of cats to make extensive use of vehicle and walking tracks for travel both lend themselves to a relatively straightforward operation for the size of the island. The cliff areas may present some minor issues but it is predicted any cats using such areas would need to venture onto flatter ground for hunting and travelling. Some methods (e.g. traps baited with meat or fish) may not be suitable for New Island with the presence of avian scavengers and predators, or may need some adaptation to lower their risk.

With application of best practice and the cumulative global experience, appreciably larger islands successfully targeted around the world, and several relevant local cat eradications achieved, there is no reason to believe cat eradication on New Island would not be successful if undertaken in a properly resourced and professional manner.

Rabbits

Rabbit eradication has been achieved on a large number of islands worldwide, largely using toxic baits very similar or identical to those used for rodent eradication for the removal of the vast bulk of the population.

In some cases, this bait distribution has been enough to eradicate the entire rabbit population, but for most cases, follow-up work (e.g. hunting, trapping) has been required to target a few individuals which survive the baiting.

Some of the larger islands for which rabbit eradication has occurred include Guadalupe (26,194ha, Mexico), St Paul (1,028ha, French Indian Ocean territory), Deserta Grande (1,200ha, Portugal), Norfolk Island (Australia, 3,958ha) Enderby (Auckland Island group, south of New Zealand, 710ha), and Rangitoto-Motutapu (temperate NZ islands, 3,842ha). Macquarie Island (12,800ha) in the Australian subantarctic region still has a project underway but indications for success are very positive at this stage.

The DIISE (Island Conservation 2012) records 117 rabbit eradications worldwide. Of these 87 (86% of those with known outcome) have been confirmed successful. A further 16 have outcome being confirmed or currently unknown, while 14 recorded attempts failed. Of these 14 failed attempts, 11 were on islands where a subsequent eradication attempt was successful.

New Island would be one of the larger cooler-climate islands targeted for rabbit eradication, and while appearing eminently feasible, the resources required to ensure success should not be underestimated. The last few rabbits can through experience develop strong anti-hunting or anti-bait behaviour and can provide a disproportionate and time-consuming effort to target.

A New Zealand best practice document for eradication of rabbits from islands has been developed (Broome and Brown 2010), and if any rabbit eradication on New Island is undertaken according to best practice principles by skilled and dedicated staff with adequate resources, there is little reason to suggest why it would fail.

6.2. Is Keeping New Island Free of Invasive Mammals Sustainable?

Eradication is only to be considered where the benefits of the eradication operation can be realistically maintained over the long-term, and ideally in perpetuity, i.e. the re-invasion of the target species and other invasive species can be reduced to extremely low levels through implementation of effective biosecurity programmes.

New Island and its associated off-lying islands with rodents are many kilometres from the nearest landmasses that have rodents (Beaver and Weddell Islands), and it is inconceivable in current circumstances that rodents could naturally recolonize the island, and this is further borne out by the observation that the Norway rats present on those islands have not established on New Island or any of its satellite islands. Similarly it is not conceivable for rabbits or cats to naturally re-establish.

The most likely mechanism for pest mammals to re-invade New Island is through accidental transport of rats or mice, or deliberate introduction of other species to the island or it's nearest neighbouring islands via human means.

A range of possible 'pathways' by which rodents could be transported to the island exist, and include (in no particular order):

- Scientific parties
- Tourists and tourist vessels
- Local service boats, aircraft and recreational vessels
- Shipwreck at or near the island
- Illegal visits (foreign yachts, fishing vessels, unauthorised landings)

All permitted visitors to the island must read the "Code of Practice for Visitors" (Annex 10, in Strange 2007) though this does not have biosecurity protocols within it. The NICT publication "New Island Falkland Islands - A South Atlantic Wildlife Sanctuary" (Strange 2007) contains sections on non-native species, biosecurity and visitor policies, with some broad management objectives, but no specific biosecurity procedures or protocols.

Biosecurity has been addressed in a scientific workshop focussed on New Island (NICT 2013) and a review of a number of improvements to the biosecurity regime was recommended. These include review of and formalisation of existing procedures, specific measures for different avenues of entry to the island, improved preparedness for contingency situations, and wider legislative and communication goals.

Some biosecurity measures do currently occur on New Island, such as the opening of packages within closed rooms, and current biosecurity measures are generally considered good (NICT 2013). However, the author of this study has little knowledge on the quality or reliability of on-site quarantine procedures in place for these visits and strongly recommends the suggested biosecurity recommendations (as per NICT 2013) procedures are put in place, if not already in effect, to further enhance the current efforts. A key recommendation from the scientific workshop on New Island (NICT 2013) was to "*Develop a biosecurity protocol for visitors to and practices at New Island, to minimize risk of introduction and establishment of alien species. Press for enactment and implementation of biosecurity legislation by FIG*". This recommended action is heartily endorsed by the author.

It is known that visiting tourist ships belong to the International Association of Antarctica Tour Operators (IAATO) and follow established IAATO biosecurity measures, so each tourist ship calling at New Island should have its own routines, but this should be verified and supplemented by on-site procedures. Similar on-island procedures need to be put in place for visitation by other means, and scientists, managers and other regular visitors should not be excluded from such quarantine procedures.

Scientific visits typically originate from within the Falklands, and usually consist of local agents or overseas researchers conducting albatross, penguin and other wildlife or flora monitoring and research. The number of visits per year over the past decade or so is unknown to the author of this report, but is limited by accommodation availability, and presumably the island's owners (NICT) retain this information.
Access has in the past and may again in the future be largely by small fixed wing planes operated by FIGAS. Currently it is usually by flights to neighbouring islands (Beaver) and a charter vessel from there to New Island, or occasionally via military or military-contract helicopters which typically originate from Mount Pleasant or Stanley. The island's accommodation can cater for several independent parties, possibly up to 12 people at any time. They generally occur in the months of September to April with the island largely being closed up in winter months.

Day tourism occurs on a limited basis, usually direct from expedition-type ships. Land-based tourism has occurred in the past but is not longer conducted due to competing and overriding demands from researchers for limited accommodation. Boat-landings on New Island are reliant on good weather, though a range of landing points can be selected according to conditions. These are via small inflatable boats, and this tends to limit both the number of likely landings and the amount of equipment brought ashore, which reduces the overall risk of accidental transportation of rodents or other pest species amongst equipment. Each tour company should follow IAATO biosecurity protocols, but it is again highly recommended some basic on-site verification methods and supplementary biosecurity procedures are developed and implemented.

The current suite of invasive mammals on New Island may reduce the priority of a site-specific biosecurity plan, but to prevent the possible introduction of other potentially harmful invasive species, a formal biosecurity plan or protocols should be developed. This study is unable to comment on the levels and consistency of current biosecurity measures, but it is known that mice for example have been recently recorded reaching currently pest-free islands in the Falklands (e.g. George Island and Sea Lion Island, S. Poncet pers. comm.), so a very real risk exists. Development of a plan aids greatly in setting protocols and the desired levels of compliance. Such a plan should be prepared as soon as possible, and recommended actions implemented as soon as practicable, and ideally these protocols should be in operation and well-tested before an eradication attempt.

Table 2. Invasive Pathways

Species	Source	Pathway	Risk Severity	Prevention Strategy
Rattus norvegicus, mice, cats	Falklands (e.g. East or West Falkland, Beaver, Weddell).	On local tourist, charter or supply boats, or local aircraft, military vessels from Mare Harbour or in supplies.	Low (if suitable biosecurity measures are undertaken)	Follow established biosecurity procedures and permit systems. Develop a site-specific New Island Biosecurity Plan
R. norvegicus, *R. rattus*, mice, cats	On vessels from foreign locations	Ocean-going tour vessels, fishing vessels.	Low	

No island can be made totally secure from potential rodent reinvasion, as some circumstances (such as illegal visits or shipwrecks) are beyond the control of managers. However, many potential pathways can be effectively managed, and with the implementation and maintenance of strict biosecurity protocols, the 'security' of New Island from reintroduction of rodents or other invasive mammals appears very high in comparison to many islands that have been the focus of rodent eradications.

Factors that greatly advantage New Island include its relative isolation, only seasonal human presence, the absence of grazing/farm animals, the 'wet' landing conditions for most sea-borne visitors, the restricted and vetted access conditions, and existing biosecurity awareness amongst the management team. Risk of reinvasion is a serious management issue, but is not considered a significant detracting factor in this situation when assessing eradication feasibility.

6.3. Technical Approach for an Eradication

Overall Strategy

Because of the complexities of the invasive mammal situation on New Island, and also for cost-effectiveness, it would be strongly recommended that if eradication was considered for rodents, rabbits and cats on New Island, that the eradications are attempted concurrently or at least in a tightly time-constrained and planned sequence. This would follow the framework successfully employed for multi-species operations such as Rangitoto and Motutapu Islands (rats, mice, rabbits, cats, stoats and hedgehogs), Macquarie Island (rodents and rabbits), and Raoul and Mayor Islands (rats and cats).

The most efficient and proven method is to primarily target the rodents, via a thorough island-wide distribution of highly palatable baits, in two or more separate bait-sowing events 7-21 days apart. This is very likely to remove the entire rodent population and in all probability would dramatically reduce the rabbit and cat populations too. Within a month of the last baiting, 'mop-up' methods (e.g. use of detection devices, hunting, trapping, alternative toxins, use of trained detecting dogs) would then be employed to detect and target the surviving rabbits and cats. The length of the mop-up period can be highly variable, depending on number of animals surviving, the intensity of the follow-up measures, the skills of the field team and any constraints on possible control methods (e.g. risk to non-target species).

Eradication Methods

<u>Rodents</u>

Currently, the only consistently proven method for eradication of rodents from large-sized islands is the use of anticoagulant toxins presented in highly palatable baits which are spread comprehensively and systematically over the entire treatment area. For an island with the size and terrain of New Island this would most practically involve an aerial broadcast of bait from a helicopter, where bait pellets containing brodifacoum are spread along GPS-guided flight-lines. Use of hand broadcast or bait stations are feasible for portions of New Island, but would be enormously labour-intensive, and some areas, especially steep cliff areas and virtually inaccessible sites such as Landsend Bluff would need to be targeted using aerial means.

Other techniques such as trapping are simply not practical for an island the size of New Island, and as some individual rodents in many populations either tend to avoid or learn to avoid traps, will only achieve some level of control for as long as it is maintained, but will not achieve eradication. While there is much talk and some research into potential pathogens or rodent-specific diseases, none have yet shown any ability to *eradicate* entire rodent populations, and cannot currently be considered a suitable eradication technique.

Several options have been suggested as alternatives for rodent eradication including genetic engineering, species-specific pathogens, immunosterilants, etc. While there may be potential for new techniques to be developed and field-tested in future, none have yet been proven effective for eradication. It would be extremely risky and potentially costly to attempt novel techniques on an island the size of New Island without extensive field-trialling elsewhere first. The Falklands does have the advantage that if any such method is ready to be field-tested, a range of similar but smaller islands are potentially available as 'test sites'.

For the foreseeable future, use of anticoagulant toxins is the only feasible rodent eradication option available.

Cats

Cats have been a secondary target of a number of eradication programmes initially targeting rodents (e.g Mayor, Rangitoto-Motutapu, Raoul, and Motuihe Islands in New Zealand), and a proportion of the population will succumb to secondary poisoning through ingestion of poisoned rodents or rabbits. The proportion of cats that will succumb to secondary poisoning has ranged widely in reported operations from possibly as little as 10% up to 100% of the cat population, with most tending strongly towards >50%.

Stand-alone cat eradications have also been achieved (e.g. Little Barrier, Macquarie and Marion Islands) using alternative toxins, trapping and hunting, but for cost-efficiency reasons the best option would be to target surviving cats immediately after a rodent baiting operation.

Well-tested options include night-hunting using spotlights and silenced rifles (on foot or on ATV-type vehicles), alternative toxins, leg-hold traps and to a lesser extent kill- and live-capture traps. Some constraints on use (and potentially efficiency) of some options would be needed to reduce risk to non-target species.

The New Zealand Department of Conservation have developed an unpublished draft 'best practice' for the eradication of cats, and there is a wealth of global experience to call upon.

The use of cat-detecting dogs has been developed with great success by the New Zealand Department of Conservation, and use of such dogs could dramatically improve efficiency of detection of remaining cats on New Island after any baiting operation. However, the cost and logistical difficulties of getting such dogs and their handlers to the Falklands could make it cost-prohibitive.

Rabbits

Rabbits are highly susceptible to the toxins used in rodent baits, and as demonstrated in a number of previous eradication projects, a very high percentage of them would most probably succumb through consumption of the rodent bait. This percentage can be varied and has been in one or two instances been <50%, but it is known that these operations were primarily against rats and mice, and insufficient bait rates were used to allow all rabbits access to bait. Kill rates of rabbits via consumption of the rodent baits in most previous rabbit-only or multi-species eradications has been 90%-plus, and can be as high as 100% (Broome and Brown 2010), but this should not be relied upon. In almost all cases, a small percentage of the population will survive, and these – giving the well-known propensity for rabbits to breed – need to be urgently targeted immediately following the manifestation of effects of the bait applications. Options include spot-poisoning with alternative toxins and alternative baits, hunting by day or using spotlights at night with silenced small-calibre rifles, 'ambush' hunting at known sites, burrow gassing, soft 'entangling' netting or hard 'funnelling' netting around burrows or gorse suspected to hold rabbits, leg-hold trapping and snares. Experimental use of night-vision equipment by camouflaged hunters has been used to great effect in New Zealand, but the equipment is costly and problematic to obtain. Some 'best practice' or alternative techniques may not be suitable or would require some constraints for use on New Island where some non-target species would be vulnerable.

A best practice document for rabbit eradication has been developed by the New Zealand Department of Conservation (Broome and Brown 2010) for use on New Zealand islands but which is largely applicable in most situations, and provides advice collated from numerous experts on the best strategies for rabbit eradication.

The introduction of specific pathogens such as rabbit haemorrhagic disease (RHD) has been used as a prior 'knockdown' technique in some operations (Cabbage Tree Island, Macquarie Island, Rangitoto-Motutapu). Prior poisoning (using an alternative toxin such as pindone and possibly also alternative forms of bait) is possible to target any concentrated area of rabbits before the main baiting, to reduce overall quantities of brodifacoum-containing bait required. Both of these options could be seriously considered for use on New Island immediately prior to a rodent baiting operation, as the carcasses of rabbits killed by these methods would present lower or no risk to predators or scavengers.

Specially trained dogs are being employed to detect and help mop up the last few rabbits on Macquarie Island, and were also utilised on Rangitoto-Motutapu. It is possible that such dogs could also be used for any New Island operation, as they are extremely efficient (compared to human searchers) at detecting sign and location of remaining rabbits, but again the difficulty and cost of getting such dogs to the Falklands could be problematic.

Habitat management could also be considered – it seems rabbits on New Island are reliant to some extent on gorse cover to afford protection from cats (and avian predators). Reduction of gorse cover would be recommended to prevent its further spread on the island, while benefiting any rabbit mop-up measures required in an eradication attempt.

Toxin Options

The only repeatedly proven technique currently available eradication of rodents from islands is the presentation of highly palatable cereal-based baits containing an anticoagulant toxin. These relatively slow-acting toxins mean that rodents feed on bait and acquire lethal doses before any possible ill-effects or subsequent bait-avoidance can occur, as there is usually a lag period of 3-5 days between exposure and the onset of clinical signs (Eason and Wickstrom 2001).

Other toxin types have been attempted (e.g. 1080/sodium monofluoroacetate, and strychnine) but have been unsuccessful for eradicating rodents.

A variety of anticoagulant toxins are available, from 'first-generation' types such as warfarin, pindone and diphacinone, to the now far more widely used and more potent 'second-generation' versions such as brodifacoum, floucomafen and bromodialone. All six toxins mentioned here have been successful in eradicating rats from islands, and are the only known successful toxins (or any method) to achieve eradication of mice (McKay et al. 2007).

Brodifacoum has been by far the most widely used toxin in successful mouse eradications (Howald et al. 2007, McKay et al. 2007), being used in 80% of all mouse eradication attempts, and a similar rate for rat eradications. Coupled with its relative potency for mice (Cuthbert et al. 2011), and its relatively well-known and predictable effects on other species, this fact makes it the most logical first choice for toxin type on New Island. Parkes et al. (2011) state that precedence and logic show brodifacoum is the rodenticide of choice if non-target impacts are acceptable or can be practically mitigated. Other second-generation anticoagulants such as floucomafen, difenacoum and bromodialone have similar toxicological properties with no advantages over brodifacoum (Eason et al. 2001, 2002) and while a few operations have been successful using these toxins, they offer no obvious benefit over brodifacoum (e.g. would generate likely similar non-target effects) and have a considerably lesser pool of accumulated information.

Diphacinone has an advantage in being less potent and therefore less risky to many non-target types of wildlife, but this must be treated with caution as evidence from eradication field situations is limited. It has been used successfully in eradication of rats from several islands in the Falklands, and could well be used for that purpose here, but mice are significantly more resistant to this toxin than are rats (Fisher, 2005) and require repeated doses over several days for acquisition of lethal doses, compared with brodifacoum which is potentially lethal after a single dose (Parkes et al. 2011). It is feasible that a two-application baiting strategy (as per best practice) could utilise diphacinone in at least one application (to primarily target rats) while one uses the more potent and reliable brodifcaoum in the second application to target mice (and rabbits). However, risks to non-target species would probably be just as appreciable (but potentially just over a slightly lesser timeframe), while there may be added risks and costs to the operation through to separate types of bait having to be purchased, and the potential lower efficacy of diphacinone against rats and rabbits (and its secondary effect on cats).

Only one eradication of mice has previously been attempted using diphacinone, which resulted in failure, in contrast to brodifacoum which has 26 aerial operations with 65% success for mice (up to 100% for 'best practice' operations implemented by DOC), and 21 ground operations with 48% success (Parkes et al. 2011). Diphacinone may be a suitable option to target mice but almost certainly would require higher baiting rates and possibly an extended baiting period (potentially more repeat applications) to allow for the multiple feeds desirable, and would create a higher but currently unquantifiable extra risk of operational failure due to its relative lower toxicity to mice. A similar situation exists for warfarin and other less potent first-generation anticoagulants such as pindone, coumatetrylyl and chlorophacinone.

No other toxins have been extensively used for eradication of mice, and relevant information is quite often also lacking on actual effects on non-target species, due to lack of field trials and accumulated experience.

A possible option in the longer term is the use of cholecalciferol which has the advantage of lower toxicity to birds, and particularly if mixed with coumatetralyl or diphacinone may be an alternative to brodifacoum (Eason and Ogilvie 2009). Such options are being investigated currently. However, this is untested in eradication situations and would necessitate numerous smaller scale field trials before any large scale use could be recommended, though if developments of such baits occur they should be given due consideration. It would also potentially require reformulation of baits or toxin registration, a complex and potentially extremely costly legal process.

- **This study's current recommendation would be to use bait pellets containing brodifacoum as this is the most proven and widely used toxin for eradicating mice and other rodents, and would have reduce beneficial knockdown of rabbit and/or cat populations. This toxin would have risks to non-target species, and this would need to be planned for and where possible mitigated. Use of other**

toxins would heighten risk of failure. New options may become available in future but could not be considered until reliably field-tested, with a considerable time delay factor involved.

Bait Application Options

Best practice for eradication of rodents has been developed over many years of experience. Broome et al. (2010) have developed a 'best practice' protocol that has largely been developed from experience of previous rat eradication projects. It applies to mice as well, but on the basis of acknowledged lower (though still appreciable) levels of experience.

Three broad options exist to enable bait to be presented to all individual mice over the entire island. These are:

Aerial – using helicopters carrying specifically designed under-slung bait spreading buckets to spread bait pellets at pre-determined baiting rates out along parallel GPS-guided transect lines across the entire island. This is by far the most commonly used technique for larger islands, but requires the potentially challenging task of sourcing and financing a suitable helicopter and pilot. Experienced pilots guided by GPS-tracking can ensure thorough coverage of the treatment area, and this can be verified by GIS analysis of the sowing pattern. Intentional overlaps between swathes of bait also ensure coverage is comprehensive, with no gaps. In effect, the quality of coverage relies on one key individual, the pilot. The largest island successfully treated by this method for rats is Campbell Island (11,300ha), with Macquarie Island (12,800ha) looking very positive but awaiting official confirmation of success. The largest island successfully treated for mice is currently Rangitoto/Motutapu (3,842ha) but again Macquarie Island (with mice) awaits confirmation of success.

For aerial application or hand-broadcasting, best practice would suggest at least two separate bait applications occur, with 7-10 days between applications. There has been some discussion (e.g. McKay 2011) about extending the ideal period between bait drops to more than 10 days but this has yet to be adopted into best practice.

Aerial baiting using a single helicopter and experienced pilot could cover the entire island in 2-4 days per application (based on a proven ability to sow a minimum of ~1 tonnes of bait per hour and usually appreciably more, and the expected maximum of c. 32 tonnes of bait required per application). At least four ground staff would be required to load each bucket-load of bait. After each application the team could depart the island.

Hand broadcast - This technique effectively mimics the spread of bait by aerial means, but uses people walking across marked transect lines, or GPS points, spreading measured quantities of bait over measured distances. It is a proven technique (including on many islands in the Falklands) but obviously has considerably higher labour input than aerial baiting. First Passage Island (750ha) in the Falklands has been successfully treated for rats (Poncet 2011), and it is the largest island achieved to date using this method for rats. First Passage Island is flat, relatively very narrow (a major advantage logistically), and motorbikes and ATV's could be used to support the operation, making it relatively straightforward. Technically it may be feasible to carry out an operation on New Island using this technique over most but critically not all of the land area, but it would be a major undertaking. It would need to be supplemented by aerial means here for the cliff areas, defeating much of the potential cost-saving benefits. It relies heavily on a very fit and dedicated field team, and an error or shortcoming by any single operator could potentially result in failure.

The target animals here include mice and not just rats and this accentuates the difficulty, with the need for significantly higher intensity and accuracy in spreading baits. It is feasible to do larger islands using this technique but it has been not been commonly used outside the Falklands as it is best suited to open, non-forested islands.

Bait Stations – Bait stations require huge labour resources over a period of many weeks to set out, maintain and service. There is a critical need to ensure that bait stations are set out in a grid pattern, and at a suitable density over the entire island to ensure every single mouse or rat has access to them. Areas of steep cliff would preclude the installation or servicing of bait stations in many locations on New Island and such areas would only be able to be covered by site-specific aerial-broadcast using helicopters, effectively negating any possible cost-saving aspects of use of bait stations or non-helicopter methods.

While theoretically possible for accessible areas on an island the size of New Island, (and it has been accomplished for rats on 500ha Staats Island in the Falklands; Poncet 2012) the use of bait stations is by far the most labour-intensive of the three methods. Poncet (2012) reported that Staats was by far the most difficult of any rat eradication undertaken to date in the Falklands, and cited the selection of the bait station option as one of the principle reasons. Targeting mice for eradication rather than just rats would require at least a sixteen-fold increase in density of bait stations as that used on Staats, with a resultant many-times multiplication of the effort per hectare. Between c.32,000 to c.50,000 bait stations would be required to cover New Island at a desired grid density (maximum of 25m x 25m grid spacing, and ideally a 20m x 20m grid), a truly massive logistical undertaking that infrastructure on New Island simply could not support. The largest rat eradication using this method is Langara Island (3,105ha) in British Columbia, Canada. This eradication took a team of over 60 people several months to complete (Taylor et al. 2000), even with the much lower density of c.1 station per hectare, as opposed to the 25 per hectare recommended here for mice. The largest island this technique has been successfully used for to eradicate mice is Flat Island (253ha) in Mauritius.

The perceived advantage of bait stations are that overall, less bait per hectare tends to be used (it is replaced in stations only ‘as required’, and less is lost to the elements or non-target species consumption). Another advantage is that rodent presence/activity can be scientifically monitored by the disappearance of baits from each station. Some non-target take is reduced through their inability or reluctance to enter tunnels and access the bait. However, some non-target species will still do so, especially if they can see the bait within the station or learn that it is there (some passerines and caracara would be expected to be candidates for this behaviour on New Island). Design of bait stations is problematic, insofar as designs that minimise non-target access may also deter entry by rats or mice, a highly undesirable and potentially disastrous effect. Bait stations do not appear to appreciably reduce secondary poisoning risk – dead or dying rodents are still available to predators or scavengers (see Section 6.6 for more detailed discussion).

Bait stations have numerous downsides, such as potential neophobia by individual rodents towards such ‘structures’, the possibility of exclusion of some individual mice from stations by dominant rats, and the fact that bait is only presented at bait stations, meaning intervals between bait stations need to be small enough to encompass even the smallest home range of a mouse (cf. the wider and more ‘even’ distribution of bait from aerial and hand broadcast methods). Bait station operations usually take much longer to implement than the other methods, as it appears dominant individuals restrict access to bait by subservient animals, meaning bait needs to be repeatedly replenished to ensure that as the dominant individuals die off there is sufficient bait for all remaining individuals to receive a lethal dose.

From past eradication work, bait stations have been relatively successful in eradicating rodents, achieving eradication in 48% of attempts on mice (McKay 2011), but efforts have largely been restricted to small islands (the largest yet achieved for mice by this method being 253ha). Best practice (Broome et al. 2011) states use of bait stations should only be considered when the aerial and hand-broadcast methods are for whatever reason not practical.

For the New Island situation, the use of bait stations would also mean rabbits would not have access to the bait, with any resultant rabbit eradication starting 'from square one' rather than benefiting from the sizeable knock-down of rabbit population expected from broadcasted rodent bait.

While technically possible to use this technique, New Island is much larger than the largest island treated by this method, has some areas either dangerous to access by humans or in effect inaccessible, and the logistics involved make this option largely impractical.

- **It is considered that an aerial broadcast of bait is the most feasible and perhaps the only practical method for spreading bait over the entirety of New Island and has the highest likelihood of success. Hand-broadcasting or bait stations could not adequately or safely cover the cliff areas.**

Bait Type and Quantity

Only two recommended sources of bait are currently available – PestOff™ bait from Animal Control Products (ACP) in New Zealand, and Brodifacoum 25 Conservation™ (in two formulations, for wet environments 25-W and dry environments, 25-D) from Bell Labs in the USA. Both companies have manufactured high quality bait that has been successful in numerous eradication operations worldwide. They can produce bait pellets in several standard diameters, weight, and hardness to suit particular situations.

Previous operations in the Falklands have used relatively low bait rates compared to many other eradication operations around the world, with <4kg/ha being used to successfully eradicate Norway rats from some islands using hand-broadcast methods (i.e. mimicking an aerial broadcast strategy), even on relatively high rodent density islands with dense tussac.

Rexer-Huber et al. (2012) conducted bait acceptance trials on Steeple Jason using non-toxic PestOff bait with the biomarker pyranine, and found that bait application quantities of c.8kg/ha for each of the two applications would be sufficient to ensure all individual mice would be able to access a lethal dose of toxin and would mimic the recommended application rates in the best practice document (Broome et al. 2011).

However, there are three mammals on New Island (along with a range of native bird species) that would take appreciable quantities of bait, so caution is required on using evidence from single-species eradication projects. The rabbits especially could have significant localised impact on bait consumption, and it is absolutely critical that all individuals of all target species have access to potentially lethal amounts of bait. Current estimated rabbit densities are not high enough to trigger supplemental bait rates above best practice recommendations (Broome and Brown 2010) but the density estimates should be revisited closer to any possible eradication timeframe. However, the suggested bait rates here are conservatively higher (10kg/ha per application) in the absence of detailed knowledge. These rates potentially could be lowered, or lowered in certain areas of the island, if further knowledge becomes available on rabbit and rodent density and distribution. Bait uptake trials (using non-toxic bait with biomarkers) may be desirable to define bait rates in view of the range and abundance of bait-consuming species on New Island, and to further clarify risk to non-target species.

Further work may be required on the best option for accounting for variable rabbit density over the island, which could include: pre-operational knock-down of rabbit numbers using hunting or the release of a rabbit-specific pathogen such as RHD; a pre-baiting in localised high rabbit density areas with an alternative toxin such as pindone; or a variable baiting density or additional treatments to cater for higher density rabbit areas.

However, it is known that for many areas on New Island rat and mouse densities are relatively very low, and growing knowledge of rodent ecology on New Island and across the Falklands suggests rodents can be in extremely low densities and almost absent from certain habitats such as dwarf shrub heath (diddledee) areas. On New Island significant areas of heath, eroded ground and feldmark for instance would require relatively little bait, but it would be exceedingly dangerous to make any reduction in bait quantity or coverage without strong on-site evidence to support it.

Therefore, while bait rates would be more appropriately determined in an operational plan, and clearly warrant further investigation, early planning estimates would suggest:

- 2 applications of 10 kg/ha over a 2240ha treatment area (plus any smaller islands with rat or mouse presence, currently 2 islands of total max. area of 16ha) = 45,120 kilograms
- coastline buffer treatment (c.85km of coast x 80m wide swath = c.680ha @ 10kg/ha = 6,800kg x 2 applications = 13,600kg with possible additional swathes on some western cliff areas, making a total of ~ 15,000kg
- Special treatment or re-treatment areas of high density rabbit areas, estimated additional rate of 10kg/ha over 250ha = 2,500kg
- Special treatment areas (caves, any inland slopes of over 50°, shipwrecks, residential areas and within buildings) = c.100kg

➢ 45,120 + 15,000 + 2,500 + 100 = 62,720kg + c.15% contingency = 72,128 kg (c.73 tonnes)

A coastline buffer is essential in aerial operations (and highly recommended for hand-broadcasting too) in order to ensure no gaps occur at the end of each cross-island baiting transect. The pilot must make a conscious decision when to stop sowing bait - too soon and there's a gap, too late and bait enters the sea and is wasted. At the 40-50 knot speeds the helicopter typically works at, a split-second difference can mean a significant area of ground. The end of transects are an inherent but known weakness in the aerial sowing method, and therefore it is highly recommended that a 'round-the-shoreline' run is carried out to cover any potential gaps. Coincidentally, the highest densities of rodents often occur in this zone, so it's an added surety that bait rates are adequate.

On occasion, a third application of bait has been recommended in rodent eradication projects, in situations where more than one species of rodent is present (e.g. Rangitoto/Motutapu), with the possibility that one species (e.g. a rat) may preclude another (e.g. mice or a smaller rat species) from accessing bait in the initial applications. It is not considered that a third drop would be required here, though extra bait may be sown in in one or both applications in specific areas of known higher rabbit density.

Prior to any bait ordering, the island's precise size (along with off-shore stacks and islands to be included in the treatment area) should be calculated accurately using GIS technology. Previous operations have occasionally shown that stated island sizes can be at considerable variance from the actual size, and this has significant implications for bait quantity requirements.

Timing

Successful rodent eradications have been conducted at various times of year, but recommended best practice for rodent eradication (Broome et al. 2011) is to target the rodent population when natural food resources are at their lowest (to accentuate the appeal of the bait), and when they are not breeding (to avoid any potential alteration in 'normal' feeding or foraging behaviour by pregnant or lactating females or their dependent young). Typically rodent breeding and food resources are strongly linked, and in temperate climate islands there is usually a hiatus in breeding through the cooler winter months. Studies of mice on Steeple Jason indicated that mice were breeding in August near the end of the Austral winter, although it is likely that breeding had only recently commenced (Rexer-Huber et al. 2012). Confirming if mice are not breeding in June or July would be useful for fine-tuning the timing of any operation.

Consideration also needs to be given to non-target species issues, such as avoiding the disturbance of nesting or moulting colonies of sensitive species, or timing to avoid the presence of seasonal users of the island (see further discussion, Section 6.6).

Extreme weather in winter months can (as for South Georgia Island) dictate that eradication work take place at a more practical time of year, but it is considered that the winter climate of New Island is not so extreme as to pose any significant restriction on eradication activities. Virtually all the successful rat eradications that have occurred in the Falklands have taken place in winter and early spring months (Miller 2008, Poncet et al. 2010).

The Steeple Jason Management Plan (Falklands Conservation 2009) provides a comparable and useful seasonal chronology of most species occurring on New Island that potentially could be affected by helicopters and/or ground staff. Penguin and giant petrel colonies in particular may be affected by disturbance, and to a much lesser extent so may nesting albatross and their fledgling young. Penguin moult usually ends in mid-April, and black-browed albatross chicks depart late in the same month, the last of the 'seasonal' colonial breeders to vacate the island, though some non-breeders of several species (e.g. gentoo penguin) may remain throughout the year. Thin-billed prions return to breeding grounds in September, and young are generally fledged by late February, so this period of high food availability to rodents and cats needs to be avoided.

Ideal timing would be between the departure of fledged chicks from prion, albatross, penguin and petrel colonies, and their return in spring for the next breeding season, which from available evidence seems to largely coincide with the onset of breeding of rodents in the Falklands, at around the end of August/beginning of September. Therefore the target period should ideally be between early May and end of August of any given year. To avoid the possibility of annual variations prolonging or initiating an early start to the breeding cycle in any given year, the 'shoulder periods' should be avoided if practical. The months of June-July are therefore the most suitable and recommended months for broadcasting of bait in eradication attempt, with the following month or two critical for follow-up for rabbit control in particular before any survivors can recoup population losses incurred from the baiting.

Logistics

Practical aspects of an eradication project for rodents, rabbits and cats would typically be provided in an Operational Plan. However, some brief consideration needs to be given here of the logistics of conducting an operation at such a relatively remote site.

If an aerial spread of bait is undertaken, then a helicopter could get to the island in around an hour from the main airfields in the Falklands, and could be based temporarily on the island or a nearby island such as Beaver Island (which already has an airstrip, established communications, emergency equipment, etc.) for the 2-3 days required for each of two bait spreads recommended by best practice.

Bait and fuel and possibly general supplies would need to be delivered to the island by a sea-going vessel capable of carrying at least 40 tonnes of supplies per application. If a landing craft-type vessel such as the Concordia Bay is used, bait and other supplies could be driven off into storage on New Island at any time close to the intended date of baiting. The Concordia Bay currently operates on a six-weekly schedule. Alternatively a large helicopter or smaller boat could deliver bait and fuel in increments but this would be a far more costly undertaking.

Staff involved in the operation could possibly stay at the established accommodation on the island, or could utilise their own portable accommodation (as used on South Georgia) or could stay in tents at least overnight during aerial baiting operations. For the much more extended periods of accommodation required for rabbit and cat mop-up operations some temporary accommodation options (tents) may be required at times to enable efficient coverage in more remote portions of the island. If scientific monitoring or captive holding of wildlife were to occur, this could also entail longer-term stays on the island.

Baiting in this situation would largely need to be by aerial spread, but some limited hand-broadcast or bait station operations may also occur, especially around houses or in any especially sensitive areas (though none are currently known). GPS tracking and analysis would occur to ensure comprehensive coverage, and this ideally occurs on-site, so that any gaps can be immediately identified and rectified.

6.4. Is Eradication Socially Acceptable?

Eradication of invasive mammals from islands is a conservation tool that has become increasingly important over the past three decades as experience and advancements in technology has demonstrated what can be achieved, with eradication taking place on increasingly larger islands and in more complex scenarios (multiple species eradications, commensal environments, etc.). Because of the nature of the work, there is often opposition to eradication projects, sometimes on the basis of disbelief that it can work, but often - more legitimately - on possible environmental concerns.

However, the Falkland Islands community and government are well-accustomed to rodent eradications using anticoagulant toxins, and have been very supportive of the 60 or so rat eradication projects on small islands within the Falklands carried out since 2001. The positive conservation results of eradications have been demonstrated on a number of these islands (e.g. Poncet et al. 2010).

There may be some valid argument that removal of the unique assemblage of alien mammals would reduce the distinctiveness of the New Island environment within the Falklands, and to some extent reduce the research possibilities inherent in this current differentiation.

There may also be some debate about the relative merit and priority of eradication of these animals from New Island (i.e. could the high cost and relative high risk of a possible eradication project here be better spent in conservation terms on some other high priority work in the Falklands?).

There is the potential for some emotive reaction amongst the wider public to the suggestion of killing 'cute' species such as rabbits and cats, and this would need to be addressed with an appropriate public information and project management policy. The more pragmatic conservation community see the value and need for such work.

It is almost certain that there would be some negative effect on some non-target species, and this is potentially a major issue. Whilst those involved at ground level on eradication projects have to be pragmatic about short-term effects on non-target species, others often more detached from the eradication process (e.g. advocates for particular species) can sometimes express concern that non-target species may be affected. This is covered in more detail in section 6.6.

Local residents and organisations are likely to be involved in any eradication project on the Falklands. It is probable that Falkland-based personnel would be involved in planning, permitting, transport, accommodation, logistics, fieldwork and scientific monitoring. A core of experience in rodent eradication and remote island work has developed in the Falklands, and it is recommended that as many suitably skilled locals are employed as possible to fulfil roles within any eradication operation that may develop. Eradication work provides small-scale but valuable employment opportunities over winter months.

A key issue to resolve is the relative roles of the various agencies if an eradication project were to proceed. An eradication project on New Island (and some of its associated nearby islands) may involve several different agencies (i.e. NICT, RSPB, Falkland Islands Government, and Falklands Conservation, amongst others). Various aspects of any operation, including technical management, finances, staff selection and management, non-target species mitigation, and scientific monitoring (amongst other issues) all need to be considered, and responsibilities agreed upon and assigned. An operational plan should clearly spell out individual and organisational responsibilities and the decision-making processes.

A list of potential key stakeholders is found in Appendix 1.

6.5 Is Eradication Politically and Legally Acceptable?

New Island Conservation Trust

It is considered that consent from the NICT's Trustees and management will be required as a prerequisite. Eradications are not 'magic bullets' that instantly solve all issues without any downside - all eradication attempts have some operational risk and some potentially negative environmental effects associated with the likely operational methods. NICT will need to be fully cognisant of these risks and potential effects, and would need to help develop and approve in advance all mitigation measures whilst also being fully aware that some short-term negative effects may occur in order to reach the potential longer term and greater positive effect.

Permission for the operational teams to land and to be accommodated on the island would need to be obtained from NICT, as would special permission to undertake the baiting activities. An eradication operation would desirably occur at a time of year when visits to the island are not normally conducted.

FIG Consents and Approvals

Authority to breach flying regulations over New Island would be required. The area is currently 'red-zoned', with flying under 1500 feet prohibited, to protect nesting seabirds from undue disturbance. As eradication work would sensibly occur over winter months when colonial nesting albatross, penguin and petrels are not present, the low-flying restrictions should not be an issue (N. Rendell pers comm).

Any proposed eradication project will need to be submitted to the FIG Environmental Planning Department and to its Environment Committee for approval.

There have been no legal constraints on prior rat eradication projects in the Falklands, and the situation although on a larger scale seems similar here.

It is recommended that any eradication proposal should be independently reviewed by internationally regarded eradication experts such as the New Zealand Department of Conservation's Island Eradication Advisory Group, to ensure all aspects of any operation have been considered and planned for.

Aviation permits and clearances

It would be a matter of courtesy to engage with the head of Civil Aviation in the Falklands regarding use of civilian helicopters for any eradication work. The FIG Environmental Planning Department has indicated they may be able to conduct or assist in this role for Steeple Jason (N. Rendell pers. comm.) and therefore presumably here too.

Similarly, the Commander of British Forces South Atlantic Islands (CBFSAI) in the Falklands should be advised in advance of any intended operation, so that the military are aware of activities in that area that may include use of aircraft not normally present in the Falklands.

Flying in the UK Overseas Territories is currently regulated by Air Safety Support International Ltd (ASSI), a wholly owned subsidiary of the UK Civil Aviation Authority. ASSI ensures implementation of the Air Navigation (Overseas Territories) Order 2007. Standards to be met by civil aviation in the OTs are specified in Overseas Territories Aviation Requirements (OTARs) published by ASSI.

The helicopters would ideally be UK-registered, and consequently would be flown under UK Civil Aviation Authority (CAA) regulations,. However the implementation by ASSI of new EU regulations may alter the current situation and create some problems, especially for using pilots without UK/EU certification. It is possible that operations could be carried out under the register of a different country (e.g. New Zealand) but such issues would need careful consideration at the appropriate time.

The Project Manager would need to assume responsibility for ensuring that the helicopters and that all pilots used in the operation meet the pertinent regulations and have all necessary certificates.

On a practical level, any setting down or storage of helicopters on New Island will need to take account both of potential strong winds, but also of the potential for striated caracara to damage helicopter parts (M. Reeves pers. comm.). Any operational activity would need to develop appropriate protective measures.

6.6 Non-target Species and Environmental Issues

While details for many individual Falkland Island species are currently lacking, it is abundantly clear and openly acknowledged that a range of non-target species can and have been affected during rodent eradication projects. Other (non-target) mammals and certain genera or families of birds tend to be the most commonly affected non-target species, but the effect is highly variable according the general and site-specific nature of each species. Many are not affected at all, but others can receive toxic doses through ingestion of bait ('primary poisoning') or through predation or scavenging of dead, dying or sub-lethally affected prey ('secondary poisoning').

Broome et al. (2012) summarise the LD50's (the required dose to kill 50% of the population or 'the average' individual of the species) of brodifacoum for a range of pest animals, domestic stock, and wildlife. Rodents tend to have amongst the lowest resistance to anticoagulant toxins, hence their effectiveness in rodent control and eradication situations. From research, an average weight (160g) ship rat has a maximum LD50 of c. 0.73mg/kg (equating to <3 of the standard 2-gram bait pellets containing the standard 20 parts per million of brodifacoum); a mouse has an LD50 of c. 0.44 mg/kg of bodyweight (Cuthbert et al. 2011, equating to less than a quarter of a single pellet of bait). Rabbits (European) have an LD50 of 0.29mg/kg, meaning a 1.3kg rabbit would need to eat c.9 pellets. Cats have a much wider range of recorded LD50's (0.25-25mg/kg) but at the lowest reported value a 2.5kg cat would need to consume 16 baits (or the equivalent via rodents or rabbits that have recently eaten the bait).

As established examples, a small passerine like a dunnock or sparrow would need to consume 1-3 baits to acquire an LD50, a blackbird is thought to have to eat c.14 g of bait (approximately 7 baits), and a Canada goose 170 g (c.80 pellets), though it must be stressed that each species and individuals within it will have considerable variability in susceptibility.

While many eradication projects have some temporary and sometimes severe negative effects on some non-target species, in all documented cases the overall ecological benefits of a successful eradication far outstrip the negative effects. To the author's knowledge, no successful eradication project using anticoagulant toxins has caused any significant long-term negative effect on the island environments.

It is feasible that unforeseen negative effects may occur – e.g. removal of rodents may exacerbate weed establishment if the rodents have been targeting seed or seedlings of such plants. This has however, rarely been reported from eradication operations. On-going plant pest monitoring and control programmes are warranted on New Island and should be catered for in any overall restoration programme.

The removal of mammals may not immediately result in an increase in all species, and small seabirds particularly, as the current imbalance in predator-prey relationships for numerically less abundant species may continue via natural predator species (caracara, skua, owl, etc.) which may slow or inhibit recovery or re-establishment of seabird populations.

For more detailed information on risk to individual species, see the 'Non-target Species' sub-section, p 60.

Longevity of Toxin and its Potential Effects

Various trials have demonstrated that anticoagulant toxins remain potent within bait until the bait is broken down and microbial action can begin the organic breakdown of the toxin. It is therefore able to be said that the toxin would remain a risk to any potential consumer so long as the bait pellet remained as a recognisable entity.

In trials on Steeple Jason Island, Rexer-Huber et al. (2012) found that bait pellets lasted at least 2 ½ weeks post-baiting during their trials, and their observations had to end before they could determine overall time to complete disintegration. With the dry conditions prevalent in the Falklands it could be expected that pellets could last for perhaps several months, but would be highly dependent on a variety of contributing factors such as soil moisture, rainfall, invertebrate activity, and other continued 'non-target' take, as well as of course the quantity and type of bait applied in the first place. Rainfall and continued or repeated exposure to moisture appear to be the most significant issue in breaking down uneaten bait (and toxin) to a point where it is no longer attractive to wildlife, though in some situations disappearance of bait can be very rapid due to consumption by abundant non-target species such as crabs or ants (usually in more tropical situations), and to some degree in more temperate climates by species such as geese, as indicated by the Steeple Jason bait trials.

Choice of bait type may be important toward reducing longevity of potential effect. Some baits used for eradication work (e.g. that used on South Georgia) are specifically formulated to last a long time in wet conditions, while it would be more advantageous for the New Island situation (and elsewhere in the Falklands) for bait to disintegrate relatively quickly. This can be specified to bait manufacturers. In eradication pre-planning, some bait longevity trials may be warranted on New Island to determine which bait option is best suited for needs here.

Baiting rates need to accommodate 'worst-case' scenarios to ensure ALL individual rodents are targeted to maximise the chances of eradication, and best practice eradication planning relies on ensuring sufficient bait goes out to cater for expected worst case situations, meaning in most normal situations an over-supply of bait is achieved. A fine line needs to be trodden to ensure adequate bait is spread to maximise prospects of eradication, but without being excessive which would heighten risks of non-target species exposure.

Low rainfall on the Falklands means natural degradation of pellets will take several weeks and in some instances months to degrade to a state where it is no longer recognisable as a potential food item and is no longer potentially toxic to wildlife. Exactly how long that would be could only be determined by monitoring.

Effect on Soils, Water and Vegetation

As baits disintegrate, brodifacoum is absorbed and strongly bound in the soil. Once in soil, brodifacoum is slowly degraded over weeks to months. Soil type, temperature, and the presence of soil micro-organisms capable of degrading brodifacoum will all influence the degradation time (Broome et al. 2012).

Broome et al. (2012) review the documented studies of brodifacoum residue in soils. In most cases no residues could be detected even directly under decaying bait, while in other instances miniscule and insignificant concentrations were found. While residues may persist for some time (perhaps months) before degradation, there is negligible risk for accumulations of sufficient levels to cause any toxic effects in any soil dwelling or soil-consuming species.

Brodifacoum has a very low solubility in water. Numerous tests have occurred in prior eradications and all but one results could not detect any toxin at all, while one sample taken immediately beside a bait sitting in water showed a miniscule and barely detectable level, orders of magnitude below levels of concern (Broome et al. 2012). Leaching from soil into water is therefore unlikely to occur, and for similar reasons, plant uptake is also unlikely to occur.

There may be natural concerns over potential for contamination of water supplies for human or wildlife use, but in relation to anticoagulants these are emotively based and without foundation. In all prior documented eradication projects there have been no recorded issues related to contamination of water sources or subsequent human health effects. Some obvious mitigation actions can be taken to reduce any perceived risk or concern of island residents, such as temporary disconnection of guttering on roofs used for water collection, temporary covering of any water storage tanks, or temporary supply of bottled or bulk imported water for domestic consumption. A number of inhabited islands have been the focus of similar eradication projects, with no reported issues.

Effects on Marine Life

There is a possibility that relatively small amounts of bait would find its way into the marine environment, through bait sowing lines extending accidentally into the intertidal or coastal zones, being bounced off rocks during application, or later being moved by wind or animal movement downslope.

There is no evidence of marine invertebrates being affected by brodifacoum poisoning during rodent eradication projects. However, a few studies have found residues shortly after bait application, but these have quickly dropped to below the minimum detectable level, many magnitudes below levels where any toxic effect would occur. The rapid dilution and dispersal factor would almost certainly mean any significant effect would be extremely unlikely.

As an extreme case, in 2001 a truck crashed into the sea at Kaikoura, New Zealand, spilling 18 tonne of Pestoff 20R (20 mg/kg brodifacoum) cereal pellets (intended for use on the Campbell Island rat eradication) into the water. Measurable concentrations of brodifacoum were detected in seawater samples from the immediate location of the spill within 36 hours but after 9 days the concentrations were below the level of detection (0.02 µg/l). Two samples of seaweed/kelp taken from the immediate location 64 and 91 days after the spill did not detect brodifacoum residues (Primus et al. 2005).

A field trial was also conducted to examine the fate of cereal pellets dropped into the sea at Kapiti Island in New Zealand, and any consumption of these baits by fish (Empson and Miskelly 1999). Non-toxic baits disintegrated within 15 minutes and small reef fish species were observed eating the bait. In subsequent aquarium trials several reef fish species were fasted for 24 hours before being exposed to brodifacoum cereal pellets for 1 hour. The fish were moved to a clean tank and held for 23-31 days, then killed and analysed. Six of 24 triple-fins exposed to bait died, possibly from stress-related issues as none were observed eating bait and no residue was detected in their livers. Of 30 spotties, six ate toxic bait and one of these died of brodifacoum poisoning. Two other spotties died that had not been observed eating bait but did show clinical signs of poisoning. It is thought the poison was absorbed through gills or skin. This is unlikely to happen in the sea given wave action and dilution (Empson and Miskelly 1999).

Non-Target Species

A number of rat eradication projects (>60) have occurred in the Falklands since 2001. No appreciable non-target impact has been noted on any species by the project managers (e.g. SP, DB pers. obs.), though it must be acknowledged that often monitoring has not been detailed enough in many cases to detect levels of individual losses. However, all longer term monitoring and anecdotal observations have been unable to detect any long-term negative impact on any non-target species so far.

In some eradication work in the Falklands a different toxin (diphacinone) was used, in a different bait presentation, but many islands were treated with brodifacoum toxin in a similar or identical bait pellet to those currently available as the recommended best option. It is likely that some individuals of some non-target species were killed, but in all documented cases the losses were short-term and monitored populations have recovered or in some cases have expanded beyond pre-eradication levels.

Effect on black-browed albatross, giant petrel and penguins

Seasonal timing of any operation would be critical to avoid risk of disturbance to colony nesting penguins, giant petrel and albatross. Monitoring during helicopter baiting operations on various islands such as Campbell, Macquarie and South Georgia have shown no significant impact from the noise of the helicopter or falling bait, but each island has its own peculiar circumstances, and significant disturbance to such species has been reported in other situations. Avoidance of the breeding and moulting periods for these species will alleviate any major risk. Based on previous baiting operations, disturbance of non-breeding individuals still present at the island during an operation would be minor, temporary and insignificant.

An article by Ian Strange (July 2010 Penguin News) raises the possibility of residual toxins in soils affecting nesting albatross, penguins or cormorants. Such concern is commendable but completely unfounded. Many successful rodent eradication operations using precisely the same toxin have been on islands holding critically important populations of species such as royal, Gibson's, black-browed, Campbell Island and light-mantled sooty albatrosses, and yellow-eyed, rockhopper, gentoo, king and macaroni penguins with no negative effects observed despite often long-term monitoring. Similarly, no effects have been detected in previous eradication work in the Falklands, or for that matter on New Island itself where very similar toxins (e.g. bromodialone) with very similar course of physiological action have been used for rodent control measures. Anticoagulants are biologically broken down (albeit relatively slowly) and do not bio-accumulate like DDT or other toxins that may create a very long residual effect. In the author's view it is inconceivable that any seabird engaged in nest-building months after any baiting could acquire through contact or swallow enough bait residues to accumulate lethal or harmful doses.

Giant petrels were killed during the Macquarie Island pest eradication, and this was attributed to the secondary ingestion of toxin via numerous carcasses of large-bodied prey (rabbits dead from poisoning). A total of 591 rabbit carcasses were found above ground in specific searches compared to just 30 mouse and 11 rat carcasses found above ground (Macquarie Island Pest Eradication Newsletter No.8 July 2011). It is thought less likely that rats or mice would die above ground in sufficient quantity or biomass for a giant petrel or other large scavenger to accumulate a lethal dose, so the largest risk (as for Macquarie) would be from rabbit carcasses. The vast majority of the mortality was of northern giant petrels *Macronectes halli*, not the southern giant petrel as on New Island, and this is consistent with the different feeding strategies of the two species. It is estimated that 7.6% of the northern giant petrel population and 0.3% of the southern giant petrel population was killed as a result of the baiting operations on Macquarie Island (Broome et. al 2012). Targeting rodent eradication for winter months when the giant petrels are largely absent would further reduce any risk, as would collection and removal of rabbit carcasses as they are encountered). Some giant petrels may still be present in winter months, but in lower numbers than in breeding periods.

Burrow-nesting seabirds

Burrow-nesting seabirds (white-chinned petrels, thin-billed prions, and any shearwaters present) do not feed on land, and will not be at risk from ingestion of bait. As with albatrosses, it is remote in the extreme that any effect could accrue from contact with soils. No disturbance of burrow-nesting seabirds has been reported or observed from any eradication project apart from minor accidental damage to burrows from fieldworkers moving about the islands. Avoidance of the breeding season will alleviate any significant concerns, and any disturbance by helicopter or human activity would be minor and temporary.

Effect on striated caracara

The Falklands are the major stronghold for the IUCN 'Near Threatened' striated caracara. There are thought to be c.520 pairs over 77 islands within the Falklands (Woods 2007), and the population on New Island is highly significant, with estimates indicating a population of c.85 territorial pairs plus more than 100 non-territorial immature individuals, for the whole island (Strange 2007).

While striated caracara are known to have a curious nature and have been observed 'sampling' bait in prior eradication work in the Falklands, no deaths of caracara have been recorded from the several islands on which eradications occurred and where caracara were present (Sally Poncet pers. comm., DB pers. obs.).

In non-toxic bait trials on Steeple Jason, Rexer-Huber et al. (2012) found that 27% of individual striated caracara tested were positive for bio-marker dye, indicating they had either directly ingested bait or (less likely) acquired it through preying or scavenging on something that had eaten bait. Although caracaras showed little interest in bait when it was first spread, eighteen banded individuals were observed eating cereal baits (rate 12–46 baits per 10 min) on the third and fourth days post-baiting. Only 2 of 39 (5%) caracara presented with dead mice ate the offering. This suggests secondary poisoning by consuming dead rodents may be less of an issue than direct consumption of bait, but that both individually or collectively could present a significant risk to the caracara population on the island.

Secondary poisoning via a larger-bodied prey such as rabbits, upland or ruddy-headed geese could potentially be more of a risk than via eating rodents, if the geese themselves eat sufficient bait to cause mortality or weakness sufficient to invoke a caracara attack. The non-toxic bait trials on Steeple Jason showed some but not all geese ate bait pellets, but again it is unclear whether potentially lethal quantities of toxic bait would be eaten. This may be a key issue to be determined by further research. A dead goose is more likely to be eaten by a number of caracara in a 'feeding frenzy' rather than by a single bird or pair (M. Reeves pers. comm.), so the amount of toxin ingested by each caracara is probably limited per goose carcass, but would accumulate if more than one goose carcass was consumed. The goose population on New Island is relatively large (200-400 pairs of upland geese and ~100 ruddy-headed geese; Strange 2007) and geographically widespread, which suggests they are too numerous to be managed as a whole by options such as prior culling of upland geese or collecting carcasses or sick geese before caracara consume them, and although such actions would be practically difficult, they could have some benefit.

While birds have significantly higher tolerance to brodifacoum than rodents, the cautious conclusion to draw from available information is that a moderate to high proportion of the population of striated caracara on New Island would be at risk and could potentially succumb to unintentional poisoning. The site fidelity and seasonal movements of the New Island population (and populations on its neighbouring islands) is unclear, though some work on Steeple Jason is being conducted to help clarify the situation for that island (K Bildstein, M Reeves unpubl. data), which may be helpful for this situation too. Observations in 2012 suggest that it is possible that the entire summer breeding population on Steeple Jason may remain on the island throughout the winter, though the low overall proportion of sub-adult birds compared to adult and juvenile (first winter) birds suggests high mortality or emigration of many younger birds before or during the winter (Meiburg 2012). Banding and genetic sampling of 70 birds of all ages has also occurred on Steeple Jason. Re-sightings of these banded birds will be of use in future behavioural and demographic studies of striated caracaras, as well as studies of their very poorly-known movements between and among islands and island groups.

Options for management of striated caracara (or any other species considered significantly 'at risk') during possible invasive mammal eradication on New Island might include:

1. Accepting any potential losses and assume and predict that population recovery will occur through enhanced breeding of survivors and/or movement of birds from nearby presumably unaffected islands. Some mitigation could be attempted, e.g. by removing all carcasses (especially of large-bodied species such as rabbits or geese) as soon as they are found, to reduce risk of secondary poisoning to caracara and other scavengers.

2. Further research to identify possible means to further reduce potential impact (e.g. bait size and colour, toxin type, seasonal movements of birds, etc.)

3. Capture and captive holding of a proportion of the population.

Option 1 is the most frequently used option for most wildlife species in previous eradication operations. To the author's knowledge, only two small populations (<10 individuals) of a single non-target species (a rail species, the weka, *Gallirallus australis*) have been completely eliminated during an eradication operation on two small islands in New Zealand (Tawhitinui Island, Eason and Wickstrom 2001, and Allports Island, DB pers. obs.), out of more than 300 operations, while an unexpectedly severe mortality of bald eagles on Rat Island in Alaska nearly extirpated that population. Interestingly both of the NZ operations employed the bait station method, which did not prevent the inquisitive weka from manipulating the stations to extract bait.

Very high mortality of some non-target species has been known, particularly from highly vulnerable specific taxa such as rails and some raptors. If the population of striated caracara was depleted or in the worst case scenario extirpated, the island may be rapidly re-colonised by individuals from neighbouring islands. However, relying on survivors or colonisers to rebuild the population is a less desirable option in this situation, when the population of the non-target species is of very high conservation value, e.g. the island holds a significant proportion of the global population of a Near-Threatened species. This option may not be acceptable to some stakeholders because of the risk to this significant population, and/or because of the potential negative reaction of stakeholders, conservationists and the general public to 'knowingly' causing harm to a desirable species, even if the species may benefit over the longer term.

The vulnerability of striated caracara to toxins is not precisely known – while a subset of the population sampled or ate bait in Steeple Jason trials, it is not altogether clear how big a subset of that subset would be seriously affected by the toxin, or how much bait would be required for such effects to manifest. Past experience has shown raptors are vulnerable and significant losses of individuals have been reported in some operations (e.g. bald eagles in the Rat Island Alaskan operation), while apparently they have been unaffected in other operations. The most relevant information available for raptors is for the Australasian harrier (*Circus approximans*), which has an LD50 of 10 mg/kg. An 850 g harrier would need to ingest 425 g (c.200 pellets or the equivalent via primary consumers of bait) of the standard 2 ppm brodifacoum pellets for a 50% chance of a lethal dose, but this has occurred on scarce occasions (Broome et al. 2012). Striated caracara can consume up to 200 g of food in a single sitting (M. Reeves pers. comm). It would be erroneous to directly extrapolate the lethal dose for a striated caracara from such information, but it does provide a broad indication of the relative amount of bait that may need to be consumed. Such information needs to be treated with caution as available LD50 information is based on small sample sizes and can be variable according to species and circumstance.

The presumption is that some caracara will definitely be affected, but the proportion of the total population is harder to predict. The 2012 Steeple Jason trials indicated almost one-third of caracara tested showed evidence of bait consumption and this proportion was probably an underestimate (Rexer-Huber et al. 2012) but the trial with non-toxic pellets could not show what proportion of the birds consumed a potential *lethal* dose.

Some effort could be made to reduce the possibility of secondary poisoning to scavenging species such as caracara. As an example, dead rabbits poisoned during an eradication project on Macquarie Island were collected as soon as they were found by actively searching field-teams, in order to reduce chances of giant petrels scavenging the carcasses. This substantially reduced (but did not entirely eliminate) non-target losses in comparison to a previous eradication attempt the previous year (Macquarie Island Pest Eradication Newsletter 8, July 2011). On New Island it is presumed, on the basis of body size and the likely quantity of bait (and therefore toxin) to have been consumed, that larger-bodied species such as rabbits and geese would present the greatest risk for providing an avenue for secondary poisoning. As for Macquarie, a team could retrieve and bury carcasses to prevent access to them by caracara, or the rabbit population can be substantially reduced beforehand via some other control option such as RHD or pindone that is safer to non-target species. A more radical option could be to cull the population of upland geese (and possibly rabbits) on the island immediately before baiting to greatly reduce the possibility of this avenue of secondary poisoning to caracara. Upland geese are regularly hunted in the Falklands and while not a pleasant task, this option may be more socially 'acceptable' than knowingly putting caracara at risk. However, the actual effect of such actions in reducing mortality of caracara currently cannot be quantified, so it would be risky as a standalone option, but could for example be employed in conjunction with option 3, to attempt to protect some birds unable to be captured and protected that way.

Another potential option would be to provide alternative food (e.g. mutton carcasses) on nearby islands such as Coffin or Beef Islands, which may 'draw off' birds from New Island and satiate their appetites during the critical times for potential bait exposure on New Island. This could have consequences such as drawing striated caracara and other scavengers from further afield and potentially enticing them towards New Island, so the practicalities of this need to be considered further.

As caracara are likely to be relatively mobile, the adjacent landowners (Falkland Conservation and Beaver Island owners), as well as the FIG would need to be involved in any decision-making for mitigation options.

Option 2 (further research) is worthwhile and should be pursued wherever possible. However, it does not guarantee that any developments will provide any additional sureties against negative effects. Most alternative options will be relatively untested, so may have unforeseen negative effects through lack of prior field experience. Calling for further research may provide opportunity for gaining further insights but can also be used by opponents to cause procrastination and delays, which can create a demoralising effect and loss of project impetus. This needs to be balanced against the alternative possibility, of 'rushing' eradication without attempting to find solutions to potentially solvable issues and thereby causing possibly preventable environmental harm.

Option 3 (captive holding) has been used very successfully in several eradication operations, e.g. the Galapagos hawk in eradications in the Galapagos in 2011 and 2012, Henderson rail on Henderson Island in 2011, and bristle-thighed curlew on Palmyra atoll in 2011. It is a relatively expensive and time-consuming activity that has its own risks (possible failure to adapt to captivity, disease outbreaks, de-structuring of established territories, etc.), but when used has generally yielded positive outcomes and the captive individuals have been successfully released back into their own territories at a safe period after the baiting. The relative tameness and inquisitive nature of caracara means that capture of a number of individuals would appear to be relatively straightforward, and it is considered feasible that a moderate proportion of the population could be captured by a range of capture techniques, but it is highly unlikely all individuals could be captured, and the practicalities may dictate that only a pre-determined number or proportion of the population may be targeted for capture. The proportion of the population deemed necessary or desirable to capture and hold in captivity can be widely debated. In some prior operations it has been a combination of what is practical and what is desirable from a point of view of maintaining genetic diversity (e.g. the entire small population of Galapagos hawks (c.30) was able to be captured for operations on Rabida Island; DB pers. obs.) but only a genetically significant proportion of Henderson rails were held in captivity for the Henderson Island project (Brooke et al. 2011a). Options for holding could include temporary cages purpose-built on the island, as for Henderson Island in the Pacific and Pinzon Island in the Galapagos, or similar structures adjacent to but off-site from the treatment site (e.g. Rabida Island in the Galapagos). The possibility of ex-situ captive holding (e.g. in an off-island location where the avicultural staff may have a greater range of facilities, logistical support and transport options) could also be considered.

Other options such as translocation to other islands is unlikely to be worthy of consideration here, due to the caracara's flying ability – it is presumed they would quickly 'home' back to the island. It may also cause problems by disrupting established territories and hierarchies on both New Island and the receiving island (if it had a resident population already).

The current Darwin raptor project (2012- 2015), will produce a species action plan for striated caracaras. It is vital that there is a join-up between this FC-led project and any potential eradication project on New Island. The current policy is full protected status of striated caracara with no culling. In extreme circumstances licenses to cull birds maybe granted by FIG Executive Council. There needs to be clear agreement between the Darwin project and any possible eradication work on New Island, and good communications to prevent misunderstandings within the community and with local farmers/landowners (e.g. one project is working with farmers to understand conflicts in sheep farming and to reduce the perception of raptors as problematic and reinforce the 'no culling' policy whereas on the other hand conservationists are potentially agreeing to an acceptable loss of some of the population at New Island). There would need to be detailed dialogue between the projects and more understanding on how Falkland landowners will perceive secondary losses of the birds due to actions of conservationists.

Falkland Skua

As a predatory and scavenging bird, the skua may be affected by primary or secondary ingestion of toxin. They may eat bait directly or may ingest toxin through eating mice, rats, rabbits or small birds that have consumed bait. The skua population on Enderby Island south of New Zealand was severely reduced by secondary poisoning via consumption of rabbit carcasses during a summertime eradication project (Torr 2002), and a similar high mortality of skua has occurred on South Georgia (S. Poncet pers. comm.) where baiting has had to occur for operational reasons over the months when skua breeding occurs. Macquarie Island also had localised high mortality, of up to 40% of the breeding population (Broome et al 2012), due to high numbers of rabbit carcases as vectors for the toxin. Losses during eradication projects on other islands such as Campbell Island have been significantly lower, where most skua were seasonally absent over winter months.

It appears the summer breeding population of skua on or near New Island is typically ~400 pairs (Strange 2007). This species is migratory and unlikely to be present in winter months, and toxins and vectors for consumption would be absent or negligible by their return.

Sheathbill

Mortality of sheathbills has been noted in the South Georgia rat eradication operation, and may also be expected for any operation on New Island. As a non-breeding regular visitor in winter months it would be present on the island during the recommended window for baiting, and losses would be expected.

Short-eared owl

A very small population of the short-eared owl (estimated to be perhaps just 3-4 pairs on the southern half of the island, Strange 2007) and perhaps a similar number on the northern end, is present on New Island. The relative lack of smaller seabirds other than thin-billed prions on New Island, relative lack of cover and suitable habitat, and intense competition from other avian predators such as skua and caracara potentially means they may take proportionately more mice or rats as an alternative prey, and could be vulnerable to secondary poisoning as a result. Mice are a known component of short-eared owl diet on Steeple Jason (K. Rexer-Huber pers. comm.) and rats on other Falkland Islands (DB pers obs), and this would be predicted to be the same on New Island. Some short-eared owls were found dead after baiting operations on small islands in the Galapagos in 2011 (Will and Campbell 2011) indicating they are vulnerable to this type of toxin. Options are effectively the same as for caracara, though capture would be significantly harder to accomplish due to the wariness and behaviour of this species. Re-colonisation could be expected over time from neighbouring islands if the population was affected. Recovery of camel cricket and small seabird populations post-mammal eradication, in association with vegetation recovery, are likely to benefit this species in the longer term.

Other Raptors

Other species of raptor have been recorded from New Island, but in comparatively low numbers. A few turkey vultures are present, along with southern caracara and peregrine falcon. Susceptibility of raptors is relatively high in general, but relative risk to each species is unclear, as their local foraging behaviour and prey would determine such risks. While risks to individuals could be equal or higher than that for striated caracara, the relative importance of the New Island populations of these species is lower from a species conservation perspective.

Effect on passerines

Individual thrushes and tussacbirds were observed on Steeple Jason Island eating bio-marked cereal bait pellets and producing fluorescent faeces during non-toxic bait trials (Rexer-Huber et al. 2012), but it is unclear what proportion of the population actually took bait. Pyranine-positive faeces from other passerines was widespread, but could not be assigned to species with confidence. Based on experience from previous operations worldwide, it is likely that some individuals from a range of passerine species could be killed. However, if rodent and cat predation and/or competition were removed via a successful eradication, populations of most species would also be expected, based on past experience, to rapidly recover and in many cases quickly surpass the pre-eradication population level, and all anecdotal evidence from previous eradication work in the Falklands supports this, where long-term responses are either positive or neutral to removal of rodents, and no serious negative effect has yet been detected. In line with this, it is considered that all passerine species would either show a long-term positive benefit from eradication or a neutral result, and none would be negative in the long term.

Geese, ducks, gulls

Of the other avian species present on New Island the potentially most vulnerable include ducks, geese and gulls. Some upland geese were regularly observed consuming bait during the 2012 Steeple Jason trials, though oddly this behaviour was never noted on smaller islands in the Falklands treated between 2001 and 2012 (Sally Poncet pers. comm., DB pers. obs.) despite many possible encounters of bait by geese. However, bait take by geese on Steeple Jason was not observed until c.3 days after the baiting, so it is possible that the geese take some time to key in to the bait, and consequently bait-take by geese may have been under-reported from previous operations.

The risk to ruddy-headed geese would be presumed to be similar to upland geese, as though the bait trials in 2012 (Rexer-Huber et al. 2012) did not record this species as eating bait this may simply have been because of lower numbers present. It appears far less likely that kelp geese would be at any risk, due to their very different foraging behaviour.

There is limited information by which to assess the risk of goose mortality. The closest comparable species for which an LD50 has been established is the Canada goose, which would need to eat c.180g of pellets to acquire this dose. A goose keyed in to bait on New Island could potentially eat this amount of bait over the course of several days and therefore would be expected to be at risk of a lethal dose. Some mortality would be predicted, but the population would also be expected to recover relatively quickly in the next breeding season or via re-establishment from neighbouring islands.

Generalist species of ducks may be at some risk, as shown on South Georgia where a high proportion of the pintail (*Anas georgica*) population was affected (S. Poncet pers. comm.), and Rangitoto/Motutapu where mallard (*A. platyrhynchos*) and paradise shelduck (*Tadorna variegata*) had high mortality rates (Broome et al. 2012). In these and other cases, local populations recovered through enhanced productivity and possible immigration from nearby untreated areas. A similar possible effect could occur for the speckled teal, and possibly the crested duck on New Island.

Scavenging species such as kelp gulls are known to consume bait, and would if the opportunity presented itself would also eat dead or dying rodents and rabbits. Many individuals of that species are likely to be affected. Similarly, dolphin gulls are present, but their scavenging instincts are less well-known to the author. Individuals may be affected but it is unlikely that the population would suffer any long-term effect. Targeting baiting operations to winter months may reduce risk as non-breeding birds are expected to disperse widely.

Invertebrates

Invertebrates are highly unlikely to be affected on a significant scale. Broome *et al.* (2012) summarise research on invertebrate species. Brodifacoum (and other anticoagulants) has been perceived as lacking insecticidal properties because invertebrates do not possess the same blood clotting systems as vertebrates. However, other research reported that the enzymes brodifacoum binds to (carboxylase enzyme systems) are present in molluscs (i.e. *Conus*) and arthropods (i.e. *Drosophila*), suggesting invertebrate physiology may be affected by brodifacoum. Earth worms have been killed by excessively high brodifacoum doses (far higher than any concentrations likely in eradication scenarios) during laboratory trials, and there is some potential but challenged evidence of snails dying from brodifacoum poisoning in rat eradication operations in Seychelles and Mauritius (Gerlach and Florens 2000). In contrast, separate laboratory studies on locusts (Craddock 2003), slugs and carabid beetles (Bowie and Ross 2006) garden snails (Booth et al. 2003), weta (a large New Zealand camel cricket-like insect, Booth et al. 2001) and land crabs (Pain et al. 2000) could not detect any toxic effect and studies of snails, cockroaches and woodlice on Henderson Island again revealed no toxic effects (Brooke et al. 2011b; R. Cuthbert pers. obs.). A simulated bait station operation in New Zealand monitored ground-dwelling invertebrates by pitfall trapping, and found the relative numbers of invertebrates caught in the treatment and non-treatment areas one year after the poisoning were similar to those before poisoning (Broome et al. 2012).

Marine Mammals

Sea-lions, elephant seals and fur seals may experience some temporary disturbance from helicopter activity or human movement around the islands but it would be of minor and negligible consequence. Any eradication operations would preferably occur in winter months when pinnipeds are not breeding.

Other Species

Based on prior knowledge from previous operations in the Falklands and elsewhere around the world, it is unlikely that any other species not already discussed above will be significantly affected at a population level.

Human Health

It is extremely unlikely that human health will be at risk with use of anticoagulant rodenticides, especially if simple safety precautions procedures and established bait-handling protocols are followed. The most common exposure route is orally, which would require the consumption of relatively large quantities of bait, something that would be extremely unlikely in any eradication situation unless a deliberate self-harming act.

Inhalation of fine particles is a secondary means, and this may be more pertinent to eradication operations, where fine debris from bait pellets may form in bags of bait. Protective gloves and dust masks, outer clothing such as coveralls, and routine safety procedures such as washing of face and hands immediately after handling baits will be sufficient to minimise any perceived risk to those involved in bait loading or distribution. Risk to non-participants would be highly improbable.

No negative effects have been reported from the several hundred eradication projects conducted to date, including on islands that have human populations. There is a wide variation in susceptibility to brodifacoum among individuals. People suffering from anaemia or liver disease, or who are taking prescription anticoagulants are more susceptible. Brodifacoum is a slight skin irritant and a mild eye irritant. It is classified as non-mutagenic and unlikely to be carcinogenic.

The most likely toxin for potential use on New Island would be brodifacoum, with alternatives such as diphacinone also possible. These toxins are the same as found in commercial rodent baits sold in retail outlets and are widely available to the public, and previously used on New Island. Very similar products, with very similar effects (e.g. warfarin) are widely used for therapeutic treatment of heart conditions in humans.

Vitamin K1 provides an effective treatment for anticoagulant poisoning. However, due to the relatively short half-life of vitamin K1, and the very long half-life of brodifacoum, any treatment with vitamin K1 will need to be continued for an extended time (many months depending on the dose).

6.7 What if Eradication Fails?

If an eradication attempt fails, the implications may be of significance for both the island itself and for rodent eradications world-wide. It is possible that it may make it harder to successfully seek funds for a repeat attempt from similar funding sources. Any possible negative effects on non-target species would not be off-set by the greater long-term benefits accruing from a successful eradication, and could provide some substance for any ‘anti-eradication’ argument.

Any benefits from a reduction in rodent, rabbit and cat populations (rather than a complete eradication) would be very short term, predicted to be less than two years. Any temporary gains may also be offset by an irruption (temporary over-population spike) of mammal numbers before the population stabilises to a sustainable level.

Failure to achieve eradication would mean the current effects of these invasive mammals on species such as invertebrates, seabirds and passerines would continue, and could possibly increase in severity if environmental changes occur.

The consequences of eradicating some but not all of the invasive mammals are difficult to predict in the unique New Island scenario, but would undoubtedly affect the current equilibrium.

Failure to eradicate rats

Eradication of ship rats on temperate islands using best practice methodology has a very high probability of success. However, if the rabbits, cats and mice are eradicated but rats survive, it would be predicted that rat densities would increase significantly, with probable greater impact on those species vulnerable to rat predation. Thus a failure to eradicate rats only may result in possible improvement for species such as the white-chinned petrel, 'no change' for a number of native species, and possibly a worse situation for some species such as prions and some smaller ground-nesting birds.

It is also possible that with greater rat densities, the risk of invasion of those smaller islands close to New Island could increase, as frequency of attempts at immigration may be related to pressures on food resources on the 'home' island.

If rat eradication fails, given sufficient resources and willpower, a second attempt at eradication is possible within 2-3 years, and the limited available evidence suggests repeat attempts have no less a prospect of success.

Failure to eradicate mice

Of the four target species present, mice are probably the most difficult to eradicate, based on success rates for historic projects. The vegetated cliff areas pose some challenges for removal of mice on New Island. It is considered that the most likely outcome other than complete eradication of all four mammal species is the survival of mice.

Without the presence of rats or cats to limit their population, mice would be predicted to spread in range, relative density and abundance over the island. In certain habitats (e.g. tussac and improved grasslands) they could reach relatively high densities. While the effects of mice are restricted to a smaller range of prey species than for rats or cats (typically but not always the smaller-bodied species), their impacts can still be appreciable. Few local examples exist, but Steeple Jason provides the best guide as to what may occur, and it is clear that on that island mice reduce the abundance of some species (smaller seabirds such as diving petrels and storm petrels, some passerines, and large bodied invertebrates such as camel crickets). Some species (e.g. white-chinned petrel) would probably be unaffected by mice and therefore be in a better position to increase populations, while a few species, largely the avian predators (e.g. the short-eared owl) may benefit from greater prey abundance.

The presence of a dominant rodent species almost certainly adds to the difficulty of mouse eradication in that mouse behaviour will have adapted to minimising interactions with the rats. This may have an impact on the way that some mice initially react to bait distribution. However, baiting methodology can overcome this, as demonstrated on the successful Macquarie and Rangitoto-Motutapu eradication projects where rats and mice were simultaneously eradicated.

As for the rats, if mouse eradication fails, a second attempt at eradication is possible with no less a prospect of success, and if rats had been eradicated in the first attempt, the likelihood of mouse eradication in a separate later attempt is if anything likely to be higher.

Failure to eradicate rabbits

Based on success rates (close to 100%) of adequately funded and professionally implemented prior projects, it is very unlikely that eradication of rabbits would fail. However, poorly implemented measures could lead to hunting-, trap- or bait-averse individuals, and the difficulties in dealing with such animals could lead to a significant lengthening of time (and therefore cost) of the mop-up operation, with heightened risk of resources not being able to be sustained. However, even when this has occurred in previous projects, they eventually resulted in success through applied efforts by dedicated field staff.

However, if rabbits did survive and cats didn't, there could be an appreciable rabbit population expansion and potentially severe effects on vegetation (as witnessed on Macquarie Island), and increased competition with burrowing seabirds for burrows. Avian predators present on New Island such as hawks, skua and caracara could have some effect on rabbit density and could benefit numerically but this could have unforeseen effects on other species such as seabirds if seasonal predation levels increased as a result of expanded avian predator populations. Invertebrate diversity and abundance would be likely to increase if the predator mammals were removed, with flow-on benefits to insectivorous birds, but this may be offset to a degree by potential vegetation damage by an enlarged rabbit population.

Failure to eradicate cats

As with rabbits, it is the author's belief based on numerous documented cat eradication projects that, with sufficient resourcing and dedication, it is very unlikely that eradication of cats would fail. However, poorly implemented measures could lead to hunting-, trap- or bait-averse individuals, and the difficulties in dealing with such animals could lead to a significant lengthening of time (and therefore cost) of the mop-up operation, with heightened risk of resources not being able to be sustained to see eradication completed.

In the unlikely scenario of cats surviving but rabbits and rodents not surviving, cats could rely more heavily on seabird colonies for food, and in the short-term at least could have a more severe impact on the white-chinned petrel colony for example. However, the relative dearth of food resources in seasons when the seabirds are not present would have a major effect on the 'carrying capacity' of the island for cats. While unable to be proved, it is feasible that the small cat population on New Island is heavily reliant at certain times of year on the rodent and rabbit populations, and without them, the cat population would be so low as to be very vulnerable to chance natural events (e.g. a sex imbalance resulting in no offspring) and would also be far more vulnerable to on-going control efforts.

It is predicted that with additional funding (if required) cats could be targeted relatively easily in a separate cat-only eradication attempt if the initial effort failed.

Should an eradication project ever occur, it would be recommended that a sequential priority be placed on efforts for each species, with cats being targeted last within the wider single project (this fits with current best practice recommendations). This means consideration could be given to abandoning cat eradication if in the interim it became apparent that either rabbit or rodent eradication had or was going to fail.

Failure to eradicate two or more but not all the target species

This is perhaps the most difficult scenario to assess, as it is probable the current 'equilibrium' would be altered, but the various permutations are difficult to accurately assess. A scenario with rats and mice surviving would probably see similar affects as 'rats only' surviving. A 'cat and mouse only' or 'cat and rat only' survival scenario would probably see no benefit for white-chinned petrels or other seabirds or for a range of smaller landbirds, but the complexities of rabbit removal on vegetation recovery would also need to be factored in. A 'rabbit and cat survival only' scenario would not permit white-chinned petrel recovery and beyond some possible recovery of some invertebrate species would probably have few ecological benefits.

6.8 Capacity

It is worth assessing what staffing resources and skills would be required to conduct an eradication operation of this size and complexity in the Falklands. The following categories of staff would be required to conduct an eradication of invasive mammals from New Island:

- Project Manager (overall responsibility, budget and contract management, etc.)
- Operational Manager and Technical Adviser(s) (leading practical aspects of the operation)
- Scientific Monitoring (as required, but exact requirements would be dictated by stakeholders.)
- Pilot(s) and Helicopter Engineer (if an aerial operation was undertaken)
- GIS mapping expert (mapping, set-up and analysis of baiting lines, and hunter search grids)
- Bait loaders/Operational field staff for the rodent baiting (smaller numbers for an aerial operation, considerably larger numbers if ground-based operations were to occur)
- Skilled ground staff (hunters, trappers and possibly trained detection dogs and their handlers) for longer term rabbit and feral cat mop-up, and for rodent monitoring.
- Aviculturalist/veterinarian, and assistants for field-capture and aviculture (if captive holding of non-target species).
- Support personnel as required (logistics, drivers, cook, medic, etc.)

The Project Manager would probably be a person appointed from within and by the controlling agency (which in itself would be determined by agreements reached by key stakeholders). This person could also overlap with (i.e. take more than one role) in leading operational aspects or scientific monitoring.

Scientific monitoring staff could presumably be available from agencies involved (e.g. NICT or associated researchers) but could also be provided locally via other experienced agencies such as Falklands Conservation or Beaver Island Landcare.

Local rodent eradication expertise has grown significantly in the past decade, with a number of successful eradication projects within the Falklands being planned, led and implemented by locally-sourced personnel. This includes the largest island in the world (First Passage, 750ha) for which rat eradication has been accomplished using the hand-broadcast method. However, no eradication operations have yet been attempted in the Falklands using aerial application of bait, principally due to the lack of a suitable local helicopter and operator. However, some Falklands residents are involved in the on-going aerial-baiting rodent eradication work in South Georgia and are accumulating valuable experience in that technique.

There are a range of suitably outdoors-skilled practical people on the Falklands to assist with baiting, follow-up hunting, trapping or monitoring, or in provision of logistics. Similarly, there is an impressive range of skills and expertise available within the Falklands or outside researchers known to NICT for wildlife monitoring, and if necessary, capture of wildlife.

It is possible that at least one of the Project Manager and Technical Advisor(s) is a local, but appreciable expertise is available from New Zealand or elsewhere in the world, where an increasing number of people have gained experience in successful rodent, rabbit and cat eradication projects. Similarly, there is growing capability within the Falklands for skilled fieldworkers for the rabbit and cat ‘mop-up’ phase and rodent monitoring. As with the successful Patagonian fox eradication on Tea Island, expert overseas advice was sought to develop best practice and the operational strategy, but primarily local labour was used to undertake the work.

Several helicopter pilots vastly experienced in baiting operations are available in New Zealand, but expertise in this specific field is less developed elsewhere. If a helicopter and pilot were to be available via the South Georgia rat eradication project or shared with other projects within the Falklands, costs could be significantly reduced.

A specialist raptor expert (from the University of Minnesota Raptor Centre) was utilised in the Galapagos to care for the captive Galapagos hawks, with great success, while a similar avicultural expert (from the Royal Zoological Society of Scotland) was employed to successfully hold and release Henderson rails whilst baiting operations were conducted on the respective islands. Should capture and temporary holding of any species be deemed desirable, efforts should be made as early as possible to identify interested individuals and/or agencies with the relevant skills, interest, experience, and potential availability.

Of potentially enormous benefit to any possible project on New Island or elsewhere in the Falklands is the prior experience of the on-going South Georgia project, which has had to arrange and co-ordinate staff and logistics on a larger scale via the Falkland Islands. A great deal of benefit could accrue through liaison with the South Georgia management team to learn from their endeavours and potentially utilise equipment and resources if timing is favourable for this.

6.9 Preliminary Cost Estimations

Eradications are not cheap. However, if they are successful and followed by adequate biosecurity measures it is a one-off cost that has lasting benefits. Few if any people involved have said a successful eradication wasn't worth the financial cost.

The costs for a possible New Island project are extremely difficult to establish at this early phase, but would be expensive due to the necessity to use helicopters for bait spread. Much will depend on where the key equipment is sourced from, and confirmation of the preferred method of bait presentation and, if required, of the desired level and location of any captive-holding operations. The Falklands are remote, so some specialised equipment may not be readily available. Freight is costly and sometimes problematic, having to come all the way from the UK, or pass through other (South American) countries. Travel and accommodation costs for non-local personnel could also be significant.

No suitable helicopters of the types used for bait-spreading are currently available in the Falklands. However, three are in use for eradication work on South Georgia, and once that project concludes a helicopter and associated bait-spreading equipment could potentially be transported back to the Falklands if the South Georgia Heritage Trust (SGHT) project management would agree to the temporary hire or transfer of such equipment at a later date. The South Georgia project is due to conclude April/May 2015 and it is very unlikely that an eradication operation on New Island would be possible on that timescale. However, delays or extensions to the South Georgia project are possible, so contact with the managers of the South Georgia project would be desirable to see if lessons learned from the helicopter operation there can be applied to New Island, and whether timeframes fit for possible use of some ex-South Georgia equipment within the Falklands.

The cost of bringing a helicopter specifically down from the UK (based on information provided by Tony Martin, SGHT) is estimated to be at least £30,000 (c.US$50,000).

Potentially, if a helicopter were temporarily situated in the Falklands, the costs of freight, storage and maintenance could potentially be shared with other possible eradication or more general projects in the Falklands, reducing the cost to each project. Such possible projects include Steeple Jason, and potentially a range of other islands.

A very preliminary estimate of cost for a four-species eradication project is presented below in Table 3. As stated earlier, these figures should be treated with considerable caution – it is intended as a broad indicator of the magnitude of the cost only, and actual costs could vary significantly according to circumstances at the time, and options chosen for such aspects as wildlife mitigation, choice of eradication technique, and sources of equipment.

Table 3. Indicative Costs for a New Island Invasive Mammal Eradication Project

[All $ figures are US$. Indicative cost in GBP based on exchange rate of US$1 to £0.644 as at 28 August 2013. This table assumes a 'stand-alone' project, and significant cost savings could accrue if some costs were shared with other projects].

Item	Details	Estimated Cost (£)
Operational Planning Stage:		
Operational Plan	Contract for writing, 20 days	4,000
Consultations, meetings	Flights, accommodation etc. during planning.	7,000
Biosecurity Plan	10 days	2,000
Biosecurity implementation	Material costs – monitoring equipment, contingency trapping equipment, sealed plastic containers, etc.	500
Rat DNA collection	Done by island caretakers?	0?
Bait Longevity, Uptake and Biomarker trials		10,000?
Civil Aviation Regulations and helicopter issues	Chief Pilot to lead. Travel and time costs, fees, etc.	5,000?
Implementation Stage:		
Bait	2240ha at 2 applications x 10kg/ha, plus 84km of coast plus cliffs and small islands plus contingency = c.73 tonnes @$3750-$7500/tonne depending on the source.	176,000-353,000
Freight	? (10 x 20ft or 5 x 40ft shipping container from NZ or US) (including duties, Customs fees, etc.)	50,000
Bait Storage	Stanley and local storage site, several ?? weeks	??5,000??
Local Road and Boat Transport for bait	Fuel, bait to port of loading, and boat/barge to New Island loading/storage site	??10,000??
Pilot	US$600/day, up to 30 days	12,000
Helicopter Engineer	$600/day, up to 30 days	12,000
Op manager	$300/day, up to 120 days	23,000
Technical Adviser	$250/day, up to 30 days	5,000
Lead Scientist and monitoring staff	(covered by NICT?)	0?
Local baiting staff	$200/day average, GIS person, bait loaders (aerial baiting), c. 6 people for 20 days	16,000
International Flights, Local accommodation	Project manager or technical advisers, pilot, helicopter engineer 4+ people x 1 return flight plus up to 30 days accommodation.	13,000
Local flights (FIGAS	8-12 personnel, each with 2 return flights, £150	2,100 – 3,100

and/or Brintel?)	plus excess baggage fees.	
Local yacht charter for staff	Interisland to New Island x several trips (if necessary)	4,000????
Helicopter hire	(includes fuel, repositioning, storage, insurance, etc.) $2000/day, 40 days, plus hourly flying charges.	70,000
Helicopter transport UK to Falklands	(if required)	30,000
Wildlife mitigation	Possible capture and holding in captivity of striated caracara?? Aviculturist, capture and husbandry assistants, pen materials and construction, bird food, flights, accommodation and food for all avicultural staff, for c. 60 days.	50,000?
Rabbit and cat mop-up team leader/advisor	100 days @£125/day, plus airfares, accommodation.	15,000
Field supplies for mop-up teams	Food, accommodation contributions, hunting/trapping equipment, fuel and vehicle costs, etc.	10,000
Dog teams	Rodent-detecting dogs and handler, c.60 days, plus airfares, accommodation costs	15,000???
Mop-up, feral cats	4 people for 120 days, @£100/day plus airfares, accommodation costs	55,000
Mop-up, rabbits (may be same people as involved in cat mop-up, with some cost savings)	4 people for 120 days @£100/day plus airfares, accommodation costs.	55,000
Sub Total		666,600 – 844,600
Contingency (20%) (% could be substantially refined downward as costs are more accurately confirmed)		133,320 – 168,920
	Preliminary Estimated PROJECT TOTAL (approx.):	**£799,920 to 1,013,520**

7. CONCLUSION

The five fundamental prerequisites relating to prospects for successful eradication, as presented by Parkes (1990) and Bomford & O'Brian (1995) are:

1. All individuals can be put at risk by the eradication technique(s);
2. They can be killed at a rate exceeding their rate of increase at all densities;
3. The probability of the pest re-establishing is manageable to near zero;
4. The project is socially acceptable to the community involved;
5. Benefits of the project outweigh the costs.

The answer to the first two questions based on experience appears to be a 'yes', with very high prospects for success of rat, rabbit and cat eradication and a lower but still 'high' prospect for success for eradicating mice. The answer to Question 3 is a definite 'yes' for natural re-invasion, and with appropriate biosecurity measures being reliably implemented is also a manageable 'yes' for human-assisted re-invasion possibilities. The answer to question 4 cannot be answered by this study, and can only be answered by the key stakeholders themselves. Question 5 is somewhat subjective, and the case for New Island may be less clear-cut than for some other islands, and the estimated cost of conducting such an operation are significant, but in the author's opinion the answer is a qualified and subjective 'yes', but this assessment is effectively not part of the author's brief for this study.

The eradication of rats, mice, rabbits and feral cats from New Island is considered to be technically feasible, and if adequately resourced and undertaken in accordance with established best practice procedures, has a high chance of success. However, there is no guarantee that an eradication attempt would be successful for any or all of the target species, and while repeat efforts are possible, there would be appreciable cost factors and potentially some temporary imbalance as ecosystems and species adjust to any changes in invasive species status. Such an operation would have some element of conservation risk but so too would a reliance on the 'status quo' situation maintaining itself in perpetuity.

Successful eradication of invasive pest mammals from New Island would be of significant benefit to certain sectors of the native biota of the island, but would not automatically benefit all species, and a relative few may actually be disadvantaged, but overall eradication would allow recovery of many species and of natural ecosystem processes, and possible re-establishment of other species currently absent. It would also make the New Island 'archipelago' completely free of invasive mammalian species, and eliminate ship rats from the Falkland Islands, a significant achievement and status on a global scale.

It would be of appreciable value as a skills-building exercise for the Falklands, and for other UK Territories, and indeed would add appreciably on a global scale to skills and accumulation of knowledge for rodent, feral cat and rabbit eradication.

In addition to the primary issue of whether the project is feasible, the most important other issue in relation to implementation is the potential effect on non-target species and/or the potential adverse public reaction associated with such possibilities. The most significant risk appears to be for the striated caracara, a Near-Threatened species for which New Island has a significant proportion of the global population. Mitigation of the concerns related to this species is considered one of the most important issues to resolve in the planning process.

Logistical issues would be a practical problem, especially the sourcing and cost of a suitable helicopter. Although such issues could be potentially costly they are not insurmountable. The potential ability to 'tie in' with other local eradication projects (e.g. a potential mouse eradication project on Steeple Jason), particularly the possible sharing of a helicopter and associated equipment may be important in minimising realistic budgets for any operation on New Island.

Table 4. KEY POTENTIAL ISSUES

Issue	Recommendation
Debate about value of eradication (costs, benefits, risks) and possible alternative options (e.g. control at certain sites only)	NICT to make the decision, based on evidence presented in this study, their own experience and that of key stakeholders, and impartial advice from elsewhere.
Resistance among some stakeholders to use of toxins	Identify key concerns and provide with relevant information. Contacts with managers/stakeholders from previous operations to provide first-hand similar experience.
Debate over which toxin or eradication method to use.	Presentation of summary of existing information (this study) and further explanation and investigation where necessary.
Potential effect on striated caracara (primary or secondary poisoning, some risks from any traps used)	Further investigation on defining the risks. Possible investigation on alternative toxins in bait. Investigate further the possibility of captive holding, and related issues (who could do this, where, avicultural requirements, establishing the minimum % of population to be held, etc.) Collection of dead or dying geese and rabbits to reduce secondary poisoning risk, providing alternative food, or consideration of culling upland geese prior to baiting, to reduce that avenue of potential poisoning to caracara.
Potential disturbance to nesting, fledging or moulting penguins, albatross and giant petrels	If at all possible, limit the operational timing to non-breeding periods which would effectively remove the primary concern.
Potential effect on skua (secondary poisoning risk)	
Potential short-term effect on passerines, short-eared owl, geese, gulls, etc.	Pragmatically accept that individual losses will occur, but that affected populations will recover and in most cases expand when/if rodents and cats are removed. Wide and open consultation to inform and prepare stakeholders for expected non-target losses based on the wealth of experience from other eradication projects.
Availability of helicopters, appropriately skilled pilots and bait-spreading equipment in the	Consultations with other potential local eradication projects re possibilities of sharing use and costs of equipment and some personnel.

Falklands	If this is not possible investigate other options and open negotiations as soon as possible.
Long distance transport and storage of bait	Learn from the South Georgia operational experience, identify possible routes and options and required timeframe well in advance. Factor in contingencies for timing in any operational plan.
Inter-agency disagreements or lack of co-operation	Steering Committee established. In a pre-agreed MOU, ensure clear definition of respective roles, how and by who decisions are made, determining critical ‘tipping points’, etc. Operational Plan developed and approved by all parties to further define roles, responsibilities and decision-making process.

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Appendix 1. Potential Key Stakeholders.

Organisation	Name	Notes/comments
New Island Conservation Trust	Trustees	
	Ian Strange	Trust Founder, previous owner and long-term conservationist of New Island
Falkland Island Government	Nick Rendell	Environmental Planning Department, (includes responsibility for management of invasive plants programme); the voluntary process of submission of operational plans for rodent eradications goes through Nick who gives the permission.
		Environment Committee
	Bruce Wilks	FIG head of Civil Aviation / FIGAS
RSPB	Clare Stringer	Head of UK Overseas Territories Unit
Falklands Conservation	CEO (currently David Doxford)	Owners of Ship Island, Landsend Bluff islands, Cliff Knob Is.
	Micky Reeves	Raptor Project Officer
	Robin Woods	Striated caracara expert
Beaver Island LandCare	Sally Poncet	Local eradication expert, wildlife biologist
UK Armed Forces		Falklands Base Commander
BirdLife International		New Island is part of a BIrdLife IBA
South Georgia Heritage Trust	Tony Martin CEO (Alison Neil)	Potential provider of helicopters, equipment, personnel used in SG eradication. Experience of logistics through the Falklands
International Association of Antarctica Tour Operators (IAATO)	CEO (Kim Crosbie)	All tourist vessels visiting New Island are linked to this agency
British International Helicopters		Possible transport option for bait, fuel, personnel
Workboat Services Ltd	CEO (Adam Cockwell)	Inter-island service provider for bulk supplies
Department of Agriculture	Biosecurity Officer (currently awaiting new office)	Responsible for all national and international biosecurity procedures in the Falkland
Island Conservation		US-based conservation agency with significant rodent and cat eradication experience, and possible funding avenues.
IEAG		NZ-based eradication advisory board with many years of expertise. Potentially available as a peer review group.