A Feasibility Study for the Eradication of Rodents from Tristan da Cunha

Derek Brown

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Prepared by Derek Brown
Pest Eradication Consultant,
128b Redwood St, Blenheim, New Zealand.
E: derek.brown@xtra.co.nz

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Executive Summary

The establishment of ship rats and house mice has had a major impact on the biodiversity of Tristan da Cunha, and these rodent species appear to be having a continued effect on many remaining native species of flora and fauna. Rodents also have major effects on the lifestyle, agriculture and economy of the Tristan Islanders.

This study concludes that the eradication of rodents is likely to have significant ecological, financial and social benefits for the island, far greater than any practical level of ongoing control.

The eradication of rats and mice from Tristan appears technically feasible, but presents significant challenges, with an unprecedented combination of difficulties. There is no guarantee that eradication will be successful for either or both species, but with appropriate focus on precursor activities, planning and implementation, the prospects for successful eradication appear to be very high for rats and good, but with a lower expectation of success, for mice. If successful, it would be the largest island from which either ship rats or mice, or the two in combination, have been eradicated.

The only eradication method proven to be effective for islands of this size is the aerial broadcast of cereal-based pellets containing the anticoagulant toxin brodifacoum. Helicopters using specially designed bait-sowing buckets and Differential GPS navigation systems would have to be used to ensure total coverage of the island. No other toxins or alternative methods such as trapping, pathogens or genetic modification are recommended, as they have not been proven effective in eradications of rodents from islands, and as such have significant added risk of failure or unforeseen consequences.

There are major issues relating to potential effects on the human inhabitants of the island, on their livestock, and on several important wildlife species. Before an eradication operation can commence, all these issues must be resolved, mitigated, or the potential effects accepted by the relevant stakeholders. Acceptance by the islanders in particular of the potential consequences, and the mitigation actions required, is critical to the planning for rodent eradication.

Several issues need to be resolved by the islanders and their government before an eradication operation could take place. In particular, anthropogenic food resources for commensal rodents decrease the prospect for a successful eradication, and need to be reduced.

There would be no value in attempting rodent eradication if the prospect for subsequent re-introduction was high. Therefore, stringent rodent quarantine measures would need to implemented and maintained in the long-term to minimise the chances of re-invasion and to protect the ecological and socio-economic gains made. Tristan's isolation and other factors make it one of the most suitable of inhabited islands for which a suitably stringent quarantine system could be established. The Tristan government and its people need to recognise that improving and maintaining quarantine procedures is a fundamental precursor to an eradication attempt.

It is virtually impossible to derive an accurate cost from a feasibility study without the benefit of detailed operational planning. However, a very preliminary estimate of costs of an eradication operation on Tristan is in the order of £2 million GBP.

Contents

1. Background

Tristan da Cunha is an extremely isolated island in the South Atlantic Ocean. It is approximately 9,850 ha in area, and rises to an altitude of 2,060 metres. More detailed information on the physical characteristics, flora and fauna of Tristan can be found in Angel & Cooper (2006) and Tristan NRD/RSPB (2006).

House mice *Mus musculus* were introduced to Tristan sometime before 1873, probably as a result of whaling or sealing activities. Ship rats *Rattus rattus* (also known as black rats,) arrived on Tristan da Cunha with the grounding of the ship *Henry B. Paul* in 1882. By 1885, they had spread over the entire island, and reached such numbers as to be causing major effects on the subsistence lifestyle of the islanders.

The Tristan da Cunha and Gough group of islands is a recognised centre of endemism. The Territory has at least 60 endemic plant species (136 sub-species), and 40 species (75 sub-species) of animals, including six endemic land bird species, and four endemic and one near-endemic seabird species (Angel & Cooper, 2006). The Tristan group of islands (comprising Tristan da Cunha, Inaccessible, Nightingale, Middle and Stoltenhoff, but excluding Gough, which is separately classified) is classified as an Endemic Bird Area (EBA). The main island of Tristan da Cunha holds at least 20 fern and 34 flowering plant taxa considered to be endemic to the island. Four of the 62 known invertebrate taxa are considered endemic (Rothwell 2005).

Tristan da Cunha is the only island in the Tristan group where breeding sooty shearwater *Puffinus griseus* (IUCN 'near threatened'), grey petrel *Procellaria cinerea* (IUCN 'near threatened'), Atlantic petrel *Pterodroma incerta* (IUCN 'vulnerable') and great-winged petrel *Pterodroma macroptera* are thought to occur (Angel & Cooper 2006; BirdLife International 2006).

This feasibility study was carried out between 29 August and 27 October 2005. Tristan da Cunha was visited in the period 15 September to 6 October.

2. The Nature of the Problem

2.1. CONSERVATION IMPACT OF RODENTS

The past, present and future impact of rodents on the biota of the Territory of Tristan da Cunha are extensively discussed in Angel & Cooper (2006), which accompanies this feasibility study. Here, I summarise these impacts.

It is the conclusion of this study and that of the associated Review of Impacts (Angel & Cooper 2006), that seabird populations on Tristan have been greatly reduced by the presence of rats over the last 120 years. Richardson (1984) suggests 'the greatest present threat from introduced species to the birds of the group comes from the black rat *Rattus rattus*'. Tristan NRD/RSPB (2006) note that 'it appears that the numbers of petrels and shearwaters have dramatically declined on Tristan' because of predation from rodents and the formerly present cat population. Although there is little hard scientific data to support this view, evidence from elsewhere around the world and anecdotal evidence from the island itself provide convincing support for this argument. Mackay (1963) recorded that 'nightbirds' [possibly referring specifically to prions but perhaps to all nocturnally active seabirds] were 'getting scarce on Tristan by the 1920s'. Similarly Hagen (1952) reported the 'black eaglet [great-winged petrel] inhabited Tristan in great numbers' in the past, but 'the rats …have disparaged birdlife to only a fractional part of what it once has been'. Others support this general view, with Wace & Holdgate (1976) stating that 'rats remain the biggest single threat, accounting for the paucity of smaller seabirds on the main island' and that 'the Atlantic and great-winged petrels both suffer losses on Tristan from rats'.

Richardson (1984) suggested that 'Tristan supports [in 1972] an estimated 40,000 breeding pairs of seabirds' but calculated that if it had a similar density of breeding pairs to that found on the other islands of the group it would have harboured around 15 million pairs. While Richardson himself acknowledged the imprecision of his estimates, the scale of the difference (over two orders of magnitude) is strongly indicative of the impact of rodents (and, formerly cats) on the seabird colonies of Tristan. Richardson went on to state that 'rats are responsible for a high mortality amongst the chicks of greatwinged, Atlantic and soft-plumaged petrels [*Pterodroma mollis*] and broad-billed prions [*Pachyptila vittata*]' and that 'the impoverished numbers or absence on Tristan of little shearwaters [*Puffinus assimilis*], Kerguelen petrels [*Lugensa brevirostris*], storm-petrels [Hydrobatidae] and diving-petrels [Pelecanoididae] are probably due to the presence of rats'.

During this study, firm evidence of the impact of rats was detected at remnant colonies of broad-billed prions and of an unknown petrel species. Freshly rat-predated eggs of prions were found in two colonies located within small caves, while similar but older eggshell fragments were found in several burrows (possibly belonging to Atlantic petrels) on a ridge above the settlement plain. Predation of prion eggs continued after this study (A Rothwell pers comm.), and it was

apparent that breeding success of these remnant colonies would be virtually nil as a result.

It is probable that the seabird colonies that remain on Tristan are the scattered remnants of once extensive colonies of burrowing species. Their continued survival on Tristan in the face of ongoing rat predation is tenuous at best, and may only have lasted this long due to immigration from the neighbouring islands, where the populations are much larger and unaffected by rodents.

It can take many years for rats to have a noticeable effect on populations of some seabird species.. Vast seabird colonies can maintain a large population for many years by sheer weight of numbers – the rats simply cannot breed or eat fast enough to have an immediately obvious impact. Declines in seabird populations may therefore be gradual at first, then becomes exponential as the predator-prey balance shifts. The absence of such a plentiful resource in periods of the year when seabirds are not breeding can place severe constraints on the size of rodent populations and therefore limit their impact on seabirds. However, the likely former abundance of winter (such as Atlantic petrel and grey petrel) and late-winter (such as broad-billed prion) breeding seabirds may have provided rats with reliable year-round food sources in certain locations.

It is the view of this study that unless intensive control or eradication of rodents occurs, most remnant populations of burrowing seabirds will disappear within the foreseeable future. This will be a major biodiversity loss, as Tristan itself is the only known breeding site within the Tristan group of islands for at least four species of seabirds. Natural recolonisation of these species from the nearest remaining populations (on Gough, or even further afield in the case of sooty shearwater) would be unlikely, at least in the short to medium term, and could not occur unless rat impacts were drastically reduced.

The Antarctic tern *Sterna vittata* and the brown noddy *Anous stolidus* appear to breed only on the presumably rat-free Hardy Rocks and on near-vertical rock faces on the adjacent coast of Tristan itself, where rat predation may be restricted by access to the nest sites. Any spread or recovery of these species is almost certainly constricted by rat predation.

The Tristan thrush *Nesocichla eremita* (locally known as the 'starchy') is endemic to the Tristan group, and is almost certainly affected by rat predation. With no tall native trees on the island, thrush nests have to be constructed on or near the ground, making them highly vulnerable to rat predation. The relative scarcity of thrushes on Tristan in comparison to its almost super-abundance on the rodent-free nearby islands of Nightingale and Inaccessible (P Ryan pers comm.) is strongly indicative of the effects of rodent predation on this species. There is limited information on numbers of thrushes on Tristan itself, but that which is available appears to indicate a decline in numbers. Elliott (1957) recorded a few hundred pairs in 1950-51, while Richardson thought there were only 40-60 pairs by 1972-74.

An endemic flightless moth (unknown species) still persists in some areas of the island, but its distribution and abundance is unclear (P Tyler pers. comm.). The rarity of sightings combined with the abundance of rodents means the moth is probably very rare. The invertebrates of

Tristan have been poorly studied - many other invertebrate species may already have been extirpated by rodents, while others (possibly many yet to be discovered or classified) may persist in greatly reduced populations.

There may be unseen effects on vegetation. For example, Ryan & Glass (2001) considered that buntings and thrushes 'probably play an important role in seed dispersal, particularly of *Nertera depressa* and *Empetrum rubrum*'. The absence of buntings and the reduced population of thrushes may be altering natural seed dispersal and vegetative patterns. It is also very likely that changes in terrestrial ecology are occurring through the vast reduction in seabird numbers, and consequent reduction in input of guano, and effect on soils and drainage patterns.

Tristan is the only island in the Territory that harbours a rat population, and is the only island in the Tristan group (i.e. excluding Gough) that has house mice. Perhaps the most significant threat posed to biodiversity in the Tristan da Cunha group is the potential for rodents to be accidentally transported to the nearby rodent-free islands of Inaccessible and Nightingale.

Should rodents ever reach these islands, the consequences would be enormous, including:

- The probable extinction of the endemic Inaccessible rail *Atlantisia rogersi*
- The possible extinction of the two endemic bunting species (Grosbeak bunting *Nesospiza wilkinsi* and Tristan bunting *Nesospiza acunhae*)
- A major reduction in populations of island-specific subspecies of the Tristan thrush
- The probable extirpation of local populations of smaller seabirds such storm-petrels and diving-petrels if rats arrive, and significant reduction of populations if mice arrive
- A major reduction and possible eventual extirpation of many burrowing seabird populations, including the endemic spectacled petrel *Procellaria conspicillata* of Inaccessible Island
- The possible extinction of island-endemic invertebrates.

The Tristan Islanders are highly conscious of the risk of introduction of rodents to these islands, and trips to the islands are undertaken with due care. Nevertheless, the increasing demand for visits, and the increased ease of reaching them with modern powerboats, means that Tristan itself is considered to be the most likely source of any rodent invasion.

2.2. SOCIAL AND ECONOMIC IMPACTS OF RODENTS

For most Tristan inhabitants, the primary reason for seeking rodent eradication from Tristan is not conservation-related, but focuses on the rodents' effects on their everyday lives.

The growing of potatoes as a staple food crop is a fundamental aspect of Tristan life. Every family on Tristan prides itself on its ability to grow sufficient potatoes to be self-sufficient in this food year-round. Rats in particular cause major problems for stored potatoes. Seed-potato stores are often damaged by rats, and the sizeable quantities of seed-potatoes required for each year's crop have to be held in rodent-

proof wire cages. Similarly, potatoes for consumption are usually stored in sheds within the settlement, and are prone to rat feeding damage and to contamination through soiling from rat urine and faeces. Poor potato yield years are often exacerbated by an increased level of rat damage (A Green pers comm.), both possibly linked to the same climatic factors.

Rats are known to dig up and eat or damage newly planted seed-potatoes in spring. Numerous accounts were received of the losses sustained in other crop-raising efforts, e.g. pumpkin seed being eaten after planting, tomatoes being consumed on the plants before ripening, developing corn cobs being stripped of kernels and whole stored pumpkin being eaten into. Rats are also known to take hens' eggs.

Rodents can find their way into many of the buildings, which are often old and constructed of local materials such as volcanic rock that rodents find easy to climb, and they are able to find shelter within the crevices. Some larger buildings (such as the supermarket) are of 'composite' construction, being the result of amalgamation of several earlier buildings. Often this leads to poor 'rodent-proofing'. Rodent damage to goods in the supermarket warehouse has been regular, such as chewing the plastic tops off bottles of cooking oil and other liquids, making them unsaleable. The school has reported continual problems with rodent infestation, with the school hall having to be closed for a time so that the rats could be poisoned. Mice are frequently found within the classrooms (A Green pers comm.).

Rats pose an as yet unquantified risk to human health on the island. People on Tristan are in general concerned about the potential for rats to spread disease. Many for example take care to wipe the tops of all cans of drink in case rats have urinated over them while in the rat-infested storage areas. Reports from neighbouring islands such as St Helena of illnesses and a death occurring from rat-borne diseases were often brought up. It is unknown whether rats or mice on Tristan carry any such diseases. During this study, a supermarket worker was bitten by a rat while shifting stores in the warehouse, causing an injury requiring immediate treatment with antibiotics and several days off work. The apparently poorly functioning septic tank system for sewage creates a potential health risk, in that rodents may feed in and around the outlet, which is in close proximity to the settlement, and may act as vectors for diseases to be spread back into the village.

An annual 'Ratting Day' occurs as part of the Tristan culture, ostensibly to reduce the numbers and impacts of rodents, although its effects in this regard appear to be limited. Most of the island's menfolk take part in teams, using dogs, traps and digging implements to either trap rats or to extract them from their nests. Numbers of rats caught have varied between 150 and 2,700 rats for years where information is available.

The Agriculture Department is responsible for rodent control around the settlement and also undertakes control at the Potato Patches. Apparently, two person-weeks every three months is allocated to spreading rodent poison around these two areas. With the cost of the bait, this amounts to an annual cost of near £2,000 GBP. No bait-stations are used (due to perceived cost of commercial bait-stations), with bait instead being placed in crevices in the rock walls. Bait is also

distributed at no charge to individuals undertaking control of rodents in and around their own homes. However, this level of control appears to be having little obvious effect on rodent populations within the settlement. Christopherson (1940) reported 'an army of rats' in the settlement in summer months, and current inhabitants report that rodents are a particular problem in February and March, presumably as the population peaks near the end of the breeding season and food resources begin to diminish.

The island is currently heavily reliant on the crayfish fishery for its economic survival. Development of other industries is seen as an important step to securing the future of the island in case of any downturn in the fishing industry. Less than 1% of the current annual income is derived from eco-tourism (Tristan Treasury Department figures), but it is a growing industry with substantial potential as a significant economic resource for the island. The landing of tourists off cruise ships is heavily weather reliant on any of the Tristan islands, but the existing wharf facilities on the main island of Tristan itself are more conducive to regular visits. Each tourist landed is charged a landing fee (currently £10 per person), and if travelling to view wildlife or head up to the higher altitudes of the island will also pay a daily guide fee. Therefore, it is considered that restoring some of the island's biodiversity, especially the endemic species keenly sought-after by birders, would be a significant added attraction for many visitors.

3. Relevant documents and agreements

3.1. DOCUMENTS SUPPORTING ERADICATION OR CONTROL

A variety of documents contain relevant policies and objectives that either directly or tacitly support the eradication of rodents:

Environment Charter for Tristan da Cunha

Contains several relevant 'Guiding Principles', most notably:

7. '*to safeguard and restore native species, habitats and landscape features, and control or eradicate invasive species*'.

In addition:

1. '*to recognise that all people need a healthy environment for their well-being and livelihood*'
5. '*to aim for solutions which benefit both the environment and development*' and
8. '*to encourage activities and technologies that benefit the environment*'.

Among the Tristan da Cunha government's commitments in the Charter is:

2. '*ensure the protection and restoration of key habitats, species and landscape features….and attempt the control and eradication of invasive species*'.

Tristan da Cunha Biodiversity Action Plan

Has as top-level Objective 4: '*the impact of invasive alien species [is] reduced or eliminated*' with the following activities identified:

4.3 '*Prevent the transfer of alien species between islands of the Tristan group*'

4.5 '*Introduced rodents are controlled or eradicated on Tristan and Gough*'

Agreement on the Conservation of Albatrosses and Petrels (ACAP)

The Agreement's Article III 'General Conservation Measures' includes the following clause:

1. In furtherance of their obligation to take measures to achieve and maintain a favourable conservation status for albatrosses and petrels, the Parties, having regard to Article XIII, shall:

a) '*conserve and, where feasible and appropriate, restore those habitats which are of importance to albatrosses and petrels*'

b) '*eliminate or control non-native species detrimental to albatrosses and petrels*'.

Annex 2, the Action Plan, contains the following species conservation objectives:

1.4.2 '*take measures to the extent feasible to control and where possible eradicate non-native taxa of animals and plants, or hybrids thereof, that are, or may be, detrimental to populations of albatrosses and petrels*'.

It also contains the following habitat conservation and restoration objectives:

2.2.1 '*Where feasible, the Parties shall give protection to the breeding sites of albatrosses and petrels…For all such*

protected areas, the Parties shall endeavour to… take other actions which maintain and enhance the conservation status of the species, including…the minimisation or elimination of damage by introduced non-native animals, plants, hybrids or disease-causing organisms'.

The following species on Annex 1 of ACAP are thought currently to occur on Tristan da Cunha:: sooty albatross *Phoebetria fusca*, Atlantic yellow-nosed albatross *Diomedea chlororhynchos*, grey petrel. It is thought probable that two further species, Tristan albatross *Diomedea dabennena* and Southern giant-petrel *Macronectes giganteus* formerly occurred but are now extirpated (Hilton et al. 2000).

Convention on Biological Diversity (CBD)

The Conference of the Parties has recognised invasive alien species as one of the 'cross-cutting issues' for the Convention. Article 8, 'in-situ conservation' contains the following paragraphs:

8f) Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies

8h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.

The eighth Conference of the Parties (COP8), in decision V/8 (6) 'Urges Parties, other Governments and relevant bodies to give priority to the development and implementation of alien invasive species strategies and action plans; and (8) '*Urges Parties, other Governments and relevant bodies, such as the Global Invasive Species Programme, in their work on alien invasive species, to give priority attention to geographically and evolutionarily isolated ecosystems, and to use the ecosystem approach and precautionary and biogeographical approaches, as appropriate*'.

In decision IV/1 C, COP8 (3) '*Invites Parties to develop countrydriven projects at national, regional, subregionall and international levels to address the issue of alien species*' and (4) '*Invites the Parties to address the issue of alien species for the conservation and sustainable use of biological diversity and to incorporate such activities into their national strategies, programmes and action plans*'.

Inaccessible Island Management Plan

Contains policies to restrict the potential for introduction of pest species to the island, eg rat-free certification required for all ships visiting the island. In practice these policies should apply to ships and boats departing for Inaccessible from Tristan itself.

3.2. DOCUMENTS POTENTIALLY RESTRICTING ERADICATION

The Tristan da Cunha Conservation Ordinance of 2006 has a section that potentially restricts the probable technique for rodent eradication:

'*3. (1) No person shall willfully within Tristan da Cunha except with a permit-*

(b) spread, discharge or dump any noxious material except within a building or in a place approved by the Administrator for the disposal of such material;

spread by spray or by any other means any insecticide, herbicide or any other type of pesticide except within a building, tent or

garden or areas used for agricultural or horticultural purposes and except within the Settlement of Edinburgh in the Main Island for public health purposes.'

Baiting over much of the island appears to contravene this section.

In addition, section 4. (1) states that '*All native organisms within Tristan da Cunha are hereby declared to be protected species and no person shall, except with a permit, or a Fishing Licence, and in accordance with the terms thereof, willfully kill, capture, molest, disturb, hold in captivity, destroy, cut down, uproot, remove or collect for any purpose any native organism*'. This means that expected non-target impacts and captive holding of native species may be restricted.

However, section 6 (1) states that '*The Administrator in Council may issue a permit in writing to authorise a person named in the permit to do anything forbidden by this Ordinance, but only if there is or appears to be no other satisfactory course of action and only if the issuing of a permit is consistent with the Agreement on the Conservation of Albatrosses and Petrels, including Article III (General Conservation Measures) and any future amendments to that Agreement*'.

Effectively this means that if the Administrator and Island council are in support of the operation, the issue of a permit from the Administrator will remove all legislative obstacles for such an operation.

The new Conservation Ordinance makes allowance for improved quarantine measures, including prohibiting the transfer of indigenous biota between islands in the group without permit.

4. Options for reducing rodent impacts

4.1. DO NOTHING (MAINTAIN THE STATUS QUO)

If the current situation continues, it can be expected that conservation values of Tristan will continue to decline (see Angel & Cooper 2006 for a full discussion). It is expected that populations of most burrowing seabirds including the 'vulnerable' Atlantic petrel and 'near threatened' grey petrel and sooty shearwater will dwindle further towards extirpation (with the possibility that continuous immigration from other islands indefinitely maintains a remnant). It is possible that the Tristan thrush population will continue to decline. Wider effects on native invertebrates and vegetation are unclear.

Rodents will continue to be a major agricultural and domestic nuisance and a potential health risk.

They will also continue to pose an appreciable risk to the ecological values of the neighbouring rodent-free islands.

The only major advantage of this scenario is that it has no additional cost.

This study concludes that this is not an acceptable option, either for the residents of the island or for the protection of the island's native wildlife species.

Advantages	Disadvantages
Little or no cost - the 'easy' option	Current effects on human population, agriculture and ecological values will continue
Potential to make use of developing rodent control technology at some stage in the future, at possibly reduced cost compared to existing methods	Likely eventual extirpation of several seabird species and decline/extirpation of other native biota
No major changes in island pest quarantine regime required	Continued risk of rodent introduction to Inaccessible and Nightingale Islands

4.2. IMPROVED CONTROL

Substantial scope exists for improving and/or expanding rodent control, both within and around the settlement and for conservation purposes.

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

One disadvantage of this scenario is that control must be ongoing for any long-term benefits to accrue. Any relaxation in effort would mean rapid loss of any gains already made – rodent populations in control areas will quickly recover through enhanced productivity and/or immigration from adjoining areas.

Control operations are, by definition, ongoing. If poison baits were used, as they probably would be, there would be a continuous input of toxins into the environment over an extended period.

Associated with this are potential non-target effects, which although far less acute than for an eradication, are also ongoing. In the long-term, such cumulative effects are potentially greater than those for a one-off application of bait as in an eradication attempt.

While financial and non-target costs are therefore ongoing and long-term, the benefits achieved would be limited by practical constraints on the area over which control operations could take place.

Advantages	Disadvantages
Significantly lower initial cost than eradication	Costs ongoing, and likely to be largely borne by local government or individuals
Control can be targeted at specific high priority areas	Efforts must be ongoing to have long-term effects
Flexibility to alter regimes as required or as affordable	Continual, long-term input of toxins into the environment
Improvements in quarantine not so critical as for eradication	Only achievable in very limited areas
	Likely continued decline of most rodent-affected species

4.3. ERADICATION

The only currently available, feasible and proven means for eradication of rodents from large islands is the use of aerially-sown cereal-based pellets containing a second generation anticoagulant rodenticide poison, such as brodifacoum. The bait is spread from helicopters guided by DGPS (Differential Global Positioning System) navigation systems, to ensure comprehensive bait spread over the entire island.

The options of using alternative forms of toxin and/or bait have considerable added risk in that they have yet to be regularly proven in large-scale rodent eradications. If alternative toxins were to be used or even considered, they would have to be extensively tested on smaller islands before being employed in a very expensive operation on a large island such as Tristan.

Other methods used for control, such as traps, are not effective in achieving eradication, while ground-based baiting operations are completely impractical on an island the size and nature of Tristan. Eradication requires that all individuals in the target population are 'at risk' from the method employed – ground-based operations simply could not access the many rodents living in areas that are difficult or dangerous for humans to access.

Other potential options such as pathogens, immunosterilants or genetic engineering have yet to be fully developed, and importantly, have not been field-tested for effectiveness or proven safe for other species. 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. Only

complete eradication will provide a long-term solution to conservation needs and for a lasting solution to the agricultural and domestic problems caused by rodents.

The major potential disadvantage is the one-off 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. Consequently, 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 have been removed it would obviously be extremely important to take measures to ensure they do not return.

Advantages	Disadvantages
A one-off effort	High one-off cost
Rodents removed from entire island	Risk of failure, and consequences of this
Major conservation gains – recovery of seabirds, thrush and other wildlife populations, and ecosystem function	Risk of rats being eradicated but mice remaining
Significant agricultural and human health gains	Potential risk to humans, livestock and wildlife species during and after operation
Economic gains – opportunities in agriculture and eco-tourism.	Requires improvements in ongoing quarantine measures to protect the investment

4.4. THE PREFERRED OPTION

Clearly, eradication appears the most desirable option in terms of potential benefits for the island's wildlife and people. The status quo option is highly undesirable both from the conservation and the islanders' socio-ecnoomic viewpoint. Numerous comments received from islanders suggest the rodent problem is 'getting worse', but this may simply reflect an inadequacy in current control measures and/or a growing frustration towards the rodents as the islanders' way of life is otherwise improved and modernised.

4.5. BENEFITS OF A SUCCESSFUL ERADICATION

Anticipated outcomes of a successful eradication:

- Recovery of remaining burrowing seabird colonies
- Possible re-colonisation of Tristan by previously extirpated seabirds, especially smaller species such as diving-petrels and storm-petrels
- Recovery and expansion of Tristan thrush population
- Recovery and expansion of native invertebrate populations
- Possibility for re-introduction of a subspecies of Tristan bunting to the main island (upland birds from Inaccessible would probably be most

suitable and appropriate (P Ryan pers comm.)

- Agricultural opportunities – increased yields and a greater range of crops could be grown, leading to less reliance on imported goods and consequently, less risk of subsequent introduction of pest species
- Elimination of costs of current rodent control and rodent damage
- Reduced long-term input of poison into the environment
- Social and health benefits to the islanders

Potential negative effects of an eradication:

- Possible short-term health effects on humans, dogs, livestock and wildlife
- Possible increase in Gough moorhen *Gallinula comeri* population (perceived by islanders to be damaging to albatross nests)
- Possible increase in Tristan thrush population, resulting in some possible nuisance value in gardens through digging up seedlings or eating fruit
- Potential for increase in some pest invertebrate species
- Probable increase in mouse numbers and impacts, if mice are not eradicated along with the rats
- Possible tighter restrictions with regard to import of goods and how they are unloaded

4.6. WHAT IF AN ERADICATION FAILS?

If an eradication operation failed to eradicate either rodent species, there might be major implications for both the island itself and for rodent eradications world-wide. Support and funding for other ambitious operations might be less available after a failure on Tristan, and this might particularly affect sites which are likely to depend on similar sources of support (eg other UK Overseas Territories). It would be unlikely that another attempted eradication on Tristan would be funded within the foreseeable future.

Any benefits deriving from a reduction in rodent populations after a failed eradication operation (ie an operation that killed the vast majority of the population, but failed to remove the last individuals) would be very short-term, probably less than two years. Any temporary benefits that did accrue could well be offset by an irruption of rodent numbers as they recover from the setback: there might be a temporary population boom before the rodent population stabilises to a sustainable level. Such an irruption apparently occurred on Tristan in 1885, three years after rat arrival on the island, causing potato crop failures and undoubtedly also resulting in acute short-term effects on native wildlife.

If an eradication operation succeeded in removing rats but did not succeed for mice, then the benefits might not be as great as if both species were successfully removed. Mouse populations would likely increase (Caut et al. 2007), perhaps causing greater agricultural damage and domestic nuisance than they currently do. The increased mouse population might also have an increased effect on the island's ecology (eg Smith et al. 2002). It is possible that, over time, mice would evolve to become significant predators of seabird chicks, as they have done on Gough Island (Wanless et al. 2007). Wanless et al. (2007) speculated that one

of the factors that precipitated the evolution of predatory behaviour in Gough mice was the absence of other mammalian predators and competitors on the island, meaning that the mice could become very numerous and expand their niche. It should however be noted that to date, and as far as is currently known, the Gough Island predatory mouse are unique. It is not clear how likely it is that such behaviour would also evolve on Tristan in the absence of rats. It is clear that the removal of rats alone would have major conservation value for many burrowing seabird species and probably also for the thrush. Furthermore, eradication of rats would be a major facilitating step in the removal of mice. It is suspected that failure to eradicate mice in some combined rat-mouse operations is due to interactions between the species, with rats preventing the mice accessing the bait. Removal of rats is also the primary community-driven goal – the eradication of mice although also desirable is of lesser importance to the islanders.

5. Challenges for a Potential Eradication Operation

5.1. THE SCALE OF TRISTAN IN RELATION TO OTHER ERADICATION OPERATIONS

Table 1. Largest islands from which eradications have been successful for rodent taxa

Species	Island	Area (ha)	Reference
Rattus rattus & Mus musculus	Tristan da Cunha	9,837	
Single species			
Rattus norvegicus	Campbell Island, NZ	11,300	McClelland and Tyree 2002
R rattus	St Paul Is, French subantarctic	800	Micol and Jouventin 2002
R exulans	Little Barrier Island, NZ	3,083	Howald et al. in press
M musculus	Enderby Island, NZ	710	Torr 2002
Multi-species			
R norvegicus & R rattus	Lundy Island, UK	430	Lock 2006
R norvegicus & R exulans	Raoul Island, NZ	2,983	M. Ambrose *pers comm*.
R rattus & *M musculus*	Flat Island, Mauritius*	253	Bell 2002

As can be seen, Tristan is one of the largest islands contemplated for eradication of rodents, and is significantly larger than anything yet successful for either ship rats or for mice, or for both in combination. To some degree this reflects the relative distribution of rodents on New Zealand islands, where *Rattus norvegicus* and *Rattus exulans* predominate and therefore feature more commonly in successful eradications in island eradication databases. There is no difference in the difficulty of eradicating the different *Rattus* species from temperate islands, based on evidence to date.

There is a growing confidence in eradication technology, based on the experience gained from a large number of recent operations and their very high success rate. To illustrate this, an operational plan for the combined eradication of ship rats, mice and rabbits *Oryctolagus cuniculus* from 12,900 ha Macquarie Island (Australian sub-Antarctic territory) has been developed and awaits funding (Tasmania Parks & Wildlife Servce and Tasmania Biodiversity Conservation Branch 2007).

Relatively few eradication operations have occurred against mice, as their

effects on native island wildlife have generally been considered less than those of rats, and consequently their removal has been given lower priority.

An eradication operation targeting both ship rats and mice occurred on Ile Australie (2,100 ha) in the Kerguelen Island group (French subantarctic) in 2004. It currently appears that the operation eradicated rats, but it is known that it failed to eradicate mice (T Micol pers comm.). The St Paul island operation (Table 1) also failed to eradicate mice from the island. In both of these cases, equipment breakdown resulting in incomplete bait coverage were suspected of being the reason for the failure to eradicate mice. However, among other operations, the failure rate for mice has been somewhat higher than for *Rattus* spp.. Clout & Russell (2006) report that during the 1990s, success rates in NZ were 100% for *R exulans* and *R rattus*, 86% for *R norvegicus*, and 68% for *M musculus*. Overall, information and prior experience on eradication of mice is more limited, and reasons for the failures that have occurred are not entirely clear. Some concerns have been raised about whether the bait is palatable to all mice within a population, and the fact that it takes (by body mass) proportionately far more bait to kill a mouse than it does for a rat. Interactions between rats and mice are also a concern where both species are present (see above).

Conversely, several of these failures occurred where mice were an incidental part of operations directed at rats on the same island, and no particular attention was paid to ensuring that mice were also eradicated. In addition, with the exceptions of St Paul and Australie mentioned above, the few aerial baiting operations conducted to date against mice have been successful (n ≥5 operations).

In conclusion, Tristan is significantly larger than any island on which ship rat or mouse eradication has occurred, but lies within the range of successful rat eradications. Given the high success of recent operations, a properly conducted eradication operation on Tristan is believed to have a very high likelihood of success. Eradication of mice also appears possible, but less certain, based on the limited information available.

5.2. TOPOGRAPHY

Tristan is an imposing island, of considerable size and relief. There are vertical or near vertical cliffs of several hundred metres in height around much of the island, separating the settlement and coastal plains from the bulk of the island (the 'Base' plateau) at higher altitudes. Cliff areas will require special treatment regimes to ensure total bait coverage in all areas where rodents may feasibly occur. While the cliffs are large, many islands where rodents have been successfully eradicated have also had major cliff areas. A baiting regime can be designed to cater for such areas.

The height of much of the island and remoteness from the settlement means that remote bait-loading sites may need to be used, adding to logistical issues. Use of bait-loading sites close to areas being treated allows for reduction in helicopter 'ferrying' time, maximising actual bait broadcasting during the often short windows of suitable weather.

There are numerous steeply incised water courses ('gulches') radiating from the peak. These create significant obstacles to cross-island travel but most do not

normally carry flowing water except after heavy rain events. They do not appear to provide any real obstacle to an aerial baiting operation, though flight altitude may have to alter to compensate for the steep, high sides of the gulches, and/or an extra bait swath specifically applied along the length of the gulch.

Several caves are known on the island, three of which are known to be utilised by broad-billed prions for breeding. Two of these appear to be relatively short, but one is of considerable depth (unknown, but at least several hundred metres). All such caves potentially offer habitat for rodents, and cannot be effectively treated by an aerial bait broadcast. It may be necessary for bait to be hand-placed in caves of more than 20 m depth to ensure any rodents living partially or entirely within them have access to bait.

In conclusion, Tristan's topography is challenging, but manageable.

5.3. CLIMATE

Climate is an important issue for an aerial-based rodent eradication campaign. Strong winds affect helicopter operations and/or accuracy of bait placement, while rain events may damage or wash away distributed bait, making it unavailable to rodents. Periods of heavy rain need to be avoided if at all possible to prevent such scenarios. Cloud cover or fog and mist also prevent helicopter flying, and may cause delays in distribution of bait, which creates added risk to the operation (ideally the entire island should be treated within the shortest possible timeframe).

While there are some extreme weather events, the climate of Tristan is relatively mild in comparison to some islands for which aerial-based rodent eradications have successfully occurred, such as Campbell and Codfish Islands.

Five-day forecasts for Tristan are available from the South African Weather Service. The passage of fronts across Tristan is relatively predictable from the synoptic charts that are available (A. Rothwell pers. comm.). There are significant rain events, of up to 180 mm per day (Hoflich, quoted in Ryan & Glass 2001), but average rainfall is 1676 mm per annum. Mean monthly rainfall is relatively evenly distributed throughout the year, being 121 mm in summer months to 157 mm winter months. Anecdotal information suggests rainfall at higher altitudes may be twice as heavy as at the settlement.

Mist and low cloud frequently occur, and while this would prevent helicopter operations on some days, it appears that clear or partially clear weather occurs frequently enough to give a degree of confidence that helicopter bait broadcast could be undertaken with only a small chance of long delays. Orographic cloud occurs regularly on the Peak, though it appears to be concentrated on the windward side, meaning that at least part of the higher portions of the island often remain cloud-free.

Snow and ice occur intermittently above 600 m altitude. Heavy snow may cause problems for high altitude baiting, because it can cover and damage bait, and can temporarily reduce rodent activity, all of which could mean some individuals do not gain access to the bait. Snow may occur at any time of year, but may reach lower altitudes and last longer on the ground in winter.

Prevailing winds are from the westerly quarter, but tend to veer east prior to the passage of a front. The mean wind speed is 10m s^{-1}, with gales occurring on only 2%

of summer days and 10% of winter days (cf Campbell Island which has gales on >70% of days throughout the year).

In conclusion, weather is a factor, but does not appear to be a major impediment to eradication, and should be predictable to a certain degree. Normal contingencies would apply.

5.4. LOGISTICS

Being widely regarded as the most isolated inhabited island in the world, getting up to 200 tonnes of bait and other equipment, plus helicopters and bait-spreading equipment to Tristan poses a massive logistical challenge.

Bait is likely to be sourced from the factory in New Zealand that has provided the bait for most previous aerial eradication operations. Similarly, bait spreading buckets would need to be obtained from a New Zealand source.

Helicopters would have to be hired from South Africa or another location. A suitable ship would have to be available to carry the personnel, supplies and helicopters to and from the island.

In conclusion, an eradication on_Tristan would be a major logistical exercise, probably greater than any eradication operation yet undertaken. However, with appropriate planning and preparation, it appears feasible, with no insurmountable problems identified.

5.5. HUMAN RESIDENCE

The presence of a relatively large population of humans on an island is an issue not yet faced in an eradication operation where aerial baiting is required. While it appears that virtually all the Tristan islanders support the concept of eradication in principle, there are appreciable risks (or perceived risks) to human health as a consequence of such an operation.

The potential risks to humans who are present during or after an eradication attempt using brodifacoum poisoning are considered to be:

- Primary ingestion of toxin through accidental consumption, skin contact, or presence of bait in drinking water supplies
- Children picking up bait from where it lies on the ground and deliberately tasting and/or swallowing it
- Secondary consumption of toxin through eating mutton, beef, pork or poultry meat from animals that have ingested bait

Material safety data sheets for the poison baits suggest the 'bait presents a very low hazard to operators unless taken orally'.

Brodifacoum is extremely insoluble in water, and the likelihood of it causing any health issues through bait falling into water catchment areas is considered remote. However, during the feasibility study, islanders repeatedly raised it as an issue. New Zealand operations involving the same bait have undertaken considerable testing of water bodies for potential leaching of toxin. One operation using up to 23 kg ha^{-1} of bait (almost certainly more than would be used for most locations on Tristan) collected 204 separate samples from streams within the treatment area, and failed to detect even a trace of the toxin in any sample (C Speedy *pers comm*.).

Possible solutions to concerns about water safety include providing bottled water for the duration of the baiting operation, or providing bulk water from outside

sources, or pre-storing bulk water on the island. Water testing for toxin residues should be part of any Operational Plan for eradication, to assure islanders of the safety of the water, both for themselves and for their pets and livestock.

The toxicity of brodifacoum to humans is relatively low. It is highly unlikely that any individual will have access to toxic levels of bait, as information available for brodifacoum suggests that significant amounts have to be ingested for ill-effects to occur. Nevertheless, the health of the islanders would be paramount, and health screening may be an option, as part of the Operational Plan, for those concerned about possible effects. The greatest risk may be to those personnel loading the helicopter bait-buckets, and these people would be trained and provided with all necessary safety equipment (overalls, gloves, masks/respirators) to minimise possible ingestion, inhalation or skin contact.

To achieve eradication, poison bait must be distributed to all corners of the island, including within the Settlement. Relatively large quantities of bait, whether aerially distributed or in bait stations, present a risk to children, who may pick up and taste them. Some islanders suggested an option for mothers and young children to be temporarily removed from the island (possibly using the ship bringing eradication supplies and helicopters to the island as an accommodation base) as a means of alleviating any potential risk to young children. Another option would be to treat the settlement area using bait stations rather than an aerial operation. This would be a labour-intensive operation, far more costly than an aerial spread, but may allow for more careful placement of bait, reducing but not entirely eliminating the risk to children and to free-roaming dogs or poultry.

Brodifacoum is a chronic poison, taking a number of days to take effect, with symptoms often becoming obvious well before any potentially serious or fatal effect. There is an antidote readily available (Vitamin K) that can be administered by health officials.

Secondary consumption is quite possible, because although the toxin is naturally broken down and excreted from the body, this process is slow, and traces of brodifacoum can remain in body tissue of living animals for considerable lengths of time. It is almost certain there would need to be a ban on all killing and consumption of livestock for several months after an eradication operation using brodifacoum. The ban would perhaps need to be of even longer duration, depending on results of regular sampling; certain organs (liver in particular, but also kidneys, lungs and pancreas) where the toxin tends to concentrate may not be consumable by humans or dogs for a year or more. The use of brodifacoum pellets as used in this operation is now severely restricted on the main (inhabited) islands of New Zealand, as traces of the toxin have been detected in the liver of wild game (pigs, deer) harvested for premier meat markets.

Possible solutions include killing and storing significant quantities of meat (up to a year's supply) in the run-up to a baiting operation, or temporarily relying on imported meats. A veterinarian and/or toxicologist would almost certainly have to be included in the team as part of an eradication Operational Plan. Their role would be to conduct regular sampling of local livestock and/or meat products for an extended period after the baiting operation, to detect any potentially

harmful level of toxin still remaining within body tissue.

The attitude of most islanders talked to was that they would put up with such inconveniences and risks over a short term if it meant the rats would be removed. However, more detailed information needs to be presented to all islanders so that they can make an informed decision on this.

In conclusion, the presence of a permanent and relatively large human population presents a hitherto unique problem. There is virtually no prior experience on which to base any predictions of actual rather than potential effects. All residents of the island must be totally supportive of the operation and its potential consequences before it can proceed. Human concerns and issues need to be clearly identified, and mitigation measures established and agreed upon by all key parties

5.6. NON-TARGET SPECIES – LIVESTOCK

There are approximately 450 cattle, perhaps 2,000 sheep, 78 dogs, 6 donkeys, small numbers of (penned) pigs and hundreds of mixed poultry (ducks, geese and hens). All occur on the Settlement Plain, with the exception of small herds of semi-feral cattle at Stony Beach (*ca* 90), the Caves (*ca* 40) and Sandy Point (*ca* 20), and an unknown number (estimated to be at least several hundred) of feral and semi-feral sheep on the Base.

Potential risk to livestock, and the subsequent risk of human consumption, is one of the most problematic issues facing a potential rodent eradication on Tristan. The risk of secondary consumption of brodifacoum is discussed in the section above. However, risk to the livestock itself is also an issue. Available information suggests that the toxic dose for sheep ranges from 7.5-37.5 kg of bait. It is unlikely but possible that a single sheep could find such a quantity of bait (baiting rates are likely to be 12-25 kg ha^{-1}). As the toxin is only slowly excreted, the risk of consumption of a fatal dose would remain for as long as bait remained accessible to the livestock, estimated to be over a month in normal weather conditions. The average toxic doses (LD50's) to kill cattle or donkeys are unknown.

Dogs are also vulnerable to the toxin, either through direct ingestion of the bait, or through eating dead or dying rodents or other wildlife that have consumed bait, or through being fed meat or offal from livestock that may have consumed quantities of bait. Published LD50's for dogs range quite widely, but the worst case suggested the average dog would need to consume only 250g of bait to obtain a lethal dose. Some individual animals would be more susceptible than this.

Some Islanders believed that their dogs would not eat dead or dying rodents. This view may be supported by the fact there has been no evidence of secondary poisoning of dogs from the current rodent poisoning efforts around the settlement, as well as observations that dogs used for 'ratting' work will kill but not seek to consume the rodents they catch. The attractiveness of the bait itself is untested, and may be more of an issue. Dogs may need to be temporarily removed from the island or kept in confinement while the areas around the settlement are treated, but some bait may persist (uneaten by rodents) for several weeks. The view of some islanders that well-fed dogs would not be interested in the bait may be correct, but may also be a risky approach

to take. Further evaluation of how to minimise risk to dogs would need to be undertaken.

Pigs are considered to be quite susceptible to the toxin, with deaths of a few wild pigs in monitored populations being recorded in New Zealand as a result of brodifacoum baiting operations. Pigs on Tristan are confined within small sties, so access to bait should be very restricted.

Poultry would be attracted to the bait pellets, which would resemble poultry feed to them, so would need to be securely confined in pens for a period during and after the baiting operation. Any free-ranging poultry would in all likelihood receive appreciable and possibly fatal doses of toxin if they had unrestricted access to bait.

A number of islanders expressed a view that in order to see rats removed from the island, they would be willing to accept some stock losses as a consequence. However, the exact nature of such potential losses is unclear, and warrants further investigation. Some options are available to minimise risk to livestock.

Risks may be reduced by a 'staggered' baiting of the various fenced pastures, with some areas being treated several days before others. This adds a small but manageable risk factor to an eradication operation. By this action, livestock could be excluded from the initially baited areas until much of the bait has been removed by rodents. The sheep and cattle could then be shifted there, to enable their holding paddocks to also be treated. Livestock would therefore encounter far less bait than if it were applied to paddocks while they were present.

There is a far greater risk to livestock that cannot be shifted, ie the cattle in the unfenced areas of Stony Beach, the Caves and Sandy Point, and all the sheep on the Base or outside fenced areas. There is a real risk that some of these animals may find enough bait to receive a fatal dose, and also a risk they would have significant toxin levels that could be passed on to humans through consumption of their meat.

There is also a considerable risk that the free-ranging cattle and sheep may consume so much of the bait (as it is likely to be attractive to them) that insufficient quantities remain to ensure all rodents in the area receive a toxic dose. This would be particularly applicable in the cattle areas, where grasses are grazed so low that bait pellets would be easily found by the cattle. As a consequence, special attention may have to be given to such areas, and they may require higher baiting rates to compensate for this. This may in turn accentuate the risk of fatal poisoning of livestock.

Some possible mitigation actions to reduce potential effects on livestock include:

- Contain all Settlement Plain stock in a fenced pasture at one end of the plain while aerial baiting occurs on unoccupied pasture. Shift stock after 2-3 days (by which time much of the bait will have been consumed by rodents) and then treat the remaining areas
- Reduce sheep numbers on the Base significantly prior to an eradication, *via* major drives and culls
- Reduce cattle numbers at Stony Beach, Sandy Point and the Caves as far as possible prior to the aerial baiting and/or build holding yards at each location

- Augment or replace aerial baiting at Stony Beach, Sandy Point and the Caves with bait stations, to make bait less accessible to cattle. This is not desirable, and would be very labour-intensive, but is an option to overcome potential issues
- Pen all poultry and confine them until virtually all bait on the ground has disappeared
- Keep all pigs penned, and remove any fallen bait from within pigsties.
- Dogs to be tied up or otherwise restrained from roaming for several days or even weeks after a baiting operation. They should not be fed any meat or offal from animals that have had access to bait
- Veterinarian to be present during an eradication operation, with equipment to screen for and treat any poisoned animals

In conclusion, the presence of dogs, pigs and poultry around the Settlement, and large numbers of livestock over most of the island, presents a major obstacle to a rodent eradication. Such a complicated issue has not been faced in previous eradication operations, and there is little prior experience with which to predict the degree of potential effect on the various species of domestic animals. Mitigation of potential effects would be a major part of any Operational Plan for an eradication, and the islanders will need to be fully aware and accepting of the potential impacts before an eradication could occur.

5.7. NON-TARGET SPECIES - WILDLIFE

Three species were identified as being of particular concern with regard to the potential for mortality as a result of consumption of toxic bait, either by eating the bait directly, or through consuming rodents that have eaten the bait (secondary poisoning).

The Gough moorhen is considered to be at significant risk through both primary and secondary means. Rallidae species have been impacted severely in some New Zealand eradication operations, with complete loss of some small populations, and large reductions (though no complete population loss) in larger populations similar to the estimated 3,000 pairs of moorhens on Tristan. There was some discussion about the value of retention of the Gough moorhen on Tristan amongst the islanders (they were introduced to Tristan in 1956 after the presumed extinction of the Tristan moorhen *Gallinula nesiotis* earlier that century). However, it is an IUCN 'Vulnerable' species that effectively fills the niche of the extinct Tristanian endemic species, and as such its retention on Tristan is probably desirable from an ecological viewpoint. To ensure the preservation of the moorhen population, some birds may need to be held in captive facilities during the baiting operation as a safeguard against total loss of the wild population. Alternatively, further birds could be translocated from the Gough population to replace an extirpated Tristan population, or to supplement a much-reduced one. It is likely that successful rat eradication would benefit the moorhen population in the longer term through reduced competition for food resources.

The Tristan thrush or 'starchy' (IUCN 'Near Threatened') will almost certainly benefit significantly from the eradication of rats and mice, both in terms of reduced nest predation and consequent increased breeding productivity, and reduced competition for food resources such as

fruits and invertebrates. However, it is considered probable that some individuals of this generalist feeder will succumb to the toxin through direct consumption of bait or through scavenging dead rodents. Similar passerines (song thrushes *Turdus philomelos*, blackbirds *Turdus merula*) have been affected in New Zealand eradication operations, but not at a population level. In the worst case scenario, it is possible that the entire Tristan population could be lost, and therefore some mitigation measures would have to be undertaken. This would entail either temporary captive holding of a number of birds during an eradication operation, and/or re-stocking of Tristan from the nearby Nightingale or Inaccessible populations. The latter raises the question of the distinctiveness of the various island populations. Each island is currently considered to support a different subspecies. However, transport of birds from the two smaller islands to Tristan (for children's pets) has regularly occurred in the recent past (J Glass *pers comm*.), and some of these birds have escaped from captivity and presumably mixed with the Tristan population. Between-island translocations should not be considered until this question is satisfactorily resolved – if there is little or no genetic variation between the island populations then translocations could be considered as a safety net in the event that the Tristan population is severely affected by the rodent bait. Such inter-island transfers will not be allowed without permit in terms of the new conservation ordinance. If it were desirable to maintain separation between populations, then captive holding of Tristan birds would be the only appropriate mitigation measure. This would almost certainly be a major effort due to the small and scattered population: capture of an sufficient pairs may prove difficult.

The (Tristan) southern skua *Catharacta antarctica hamiltoni* is potentially very vulnerable. Rats appear to feature heavily in the diet of Tristan skua, and secondary poisoning through consumption of poisoned rats would be expected for any skua present on the island at the time of the baiting operation. Skuas have been recorded as significant non-target kill in some previous operations (eg Enderby Island (NZ, Torr 2002) and Île Chateau (Kerguelen Islands, T Micol *pers comm*. to J. Cooper)). However this mortality occurred during summer, when skuas are breeding, and therefore land-based. Skuas have not been significantly affected during winter eradication operations such as Campbell Island, because the operation occurred at a time when most skuas had departed the island (it seems most island populations of southern skua spend non-breeding periods mainly at sea). Seasonal timing may therefore have a major influence on whether Tristan skuas are affected. In the worst case scenario - the complete loss of the relatively small population on Tristan (estimated at 50 pairs, Angel & Cooper 2006) – the population would be replaced by natural immigration from the much larger populations which exist on Nightingale and Inaccessible. Long-term, the successful eradication of rodents from Tristan would probably benefit skua populations by facilitating the return of populations of smaller seabirds, their natural prey.

Other seabirds such as albatrosses, penguins and burrow-nesting procellariiform species are very unlikely to be significantly affected in any negative way, based on wide previous experience.

In conclusion, Gough moorhen and Tristan thrush are vulnerable non-target species, potentially at a population level. Protection of a portion of the populations and/or restocking from other islands will be necessary mitigation measures. Further genetic work on moorhens and thrushes to determine their phylogenetic distinctness (if any) is desirable. Skuas are unlikely to be present on the island during the probable timing of a rodent eradication, but would be vulnerable if present. Natural recovery and/or re-establishment would be expected.

5.8. ALTERNATIVE FOOD SOURCES / COMMENSAL RODENTS

Successful rodent eradication critically relies on the attractiveness of the toxic bait to the whole rodent population. Ideally, eradication operations should occur at a time of year when natural food resources are low, increasing the palatability of the bait even further. If there are plentiful alternative food sources that a few rodents are keyed in on, there is a risk that these individuals would not take the toxic bait. On Tristan, the major points of concern in this regard are the alternative food resources available to the commensal populations of rodents (ie those rats and mice living within the settlement). There are a number of issues, many of which appear to present enough of a risk that they should be addressed as a matter of priority before any eradication attempt is considered.

- Residential waste is often stored in open-top bins or unprotected plastic rubbish bags. Rodents (along with dogs) have almost unrestricted access to these. Rubbish is collected on a weekly basis, so easily accessible food waste is almost always present within the settlement.
- Rubbish is dumped within a poorly defined area north of the 1962 volcano. It is occasionally set afire, but the incineration is partial, and ineffective at destroying food value of organic matter within it
- The large numbers of poultry in and around the settlement, along with a smaller number of pigs, are often messily fed, with food often being scattered on the ground rather than placed in troughs or hoppers. This causes appreciable wastage of food, which creates a food resource for rodents
- The fish factory produces significant crayfish processing waste. This is ground down through a crusher, and pushed with water to an outlet in the intertidal zone near the wharf. Rats make obvious use of the crayfish waste both at the crusher end and at the outlet. The fishing season usually commences in August, and ends when quota is reached anytime from October to December. Therefore, fishery waste would only be an issue during the fishing season
- Recreational (subsistence) fishing waste and bait material for the commercial crayfish operation is inadequately disposed of at the wharf. Filleted fish carcasses and other waste are frequently left on and around the wharf, offering a substantial food resource for rodents

All of the above issues contribute to the current rodent problem around the settlement. Wild rodent populations on cool temperate islands appear to undergo massive population declines in periods of low food availability (usually the late

autumn-winter period). However, the reliable availability of alternative (anthropogenic) food resources in and around the settlement almost certainly means that the commensal rodent population is held at artificially high levels, accelerating population increases during the breeding season and exacerbating the year-round problem.

Disposal of offal from livestock killed in pasture areas or in remote areas (the Base or isolated cattle areas) would need to be addressed in order to limit alternative food resources immediately prior to, during and after a baiting operation. Natural mortality of livestock would also need to be monitored, with carcasses disposed off if at all practical.

In conclusion, the alternative food resources available to rodents within the settlement and its associated rubbish and sewage disposal areas are one of the greatest threats to a successful rodent eradication. Action must be taken to minimise these resources as far as practically possible, a significant period prior to any eradication attempt taking place. An eradication should not occur (due to the higher risk of failure) until it has been clearly demonstrated that these issues have been addressed.

5.9. PEST QUARANTINE

A fundamental but often overlooked component of pest eradication from islands is the need to ensure that once the island is free of the pest species, policies and procedures are put in place to reduce as far as practical the chances of it ever being accidentally re-introduced to the island.

This pest quarantine is critical for long-term protection of the gains made by the eradication of the pest species, rodents in this case. Current practices with regard to shipping and supplying the island need to be examined, and specific measures adopted to minimise the prospect of rodents arriving on the island in stores or aboard shipping.

As part of this study, a brief inspection was made of existing quarantine procedures. While the consultant was in Cape Town, visits were made to the:

- Department of Environment and Tourism (DEAT) store
- National Department of Public Works (NDPW) store
- Table Bay Marine Ltd store

Although all three agencies place stores on the SA Agulhas, the annual servicing ship for Tristan, only the Table Bay Marine store has direct application to Tristan. The Table Bay Marine store is the principal provisioning agent for Tristan, and packs somewhere around 350 m^3 of stores for Tristan on the SA Agulhas, and smaller amounts on other ships/other times of year. It also supplies other South Atlantic Islands (St Helena, Falklands, Ascension). Virtually all stores are packed into purpose built wooden crates, which are lined by black polythene sheeting.

Commendable aspects of the Table Bay Marine operation with respect to pest quarantine include:

- A system of permanent and regularly maintained rodent bait stations within the store
- Use of methyl bromide treated timber for construction of crates
- Genuine efforts to package most foodstuffs in sealed wooden crates
- Very positive attitude of manager toward quarantine issues

However, some issues were of concern:

- The store does not have any rodent-proof areas – rodents have ready access
- Wooden crates are sometimes constructed tightly enough to restrict rats gaining access to internal parts of the crates, but generally not for mice
- Crates may be stored for some time prior to loading on the ship, giving opportunities for pest species to gain access to crates

It must be acknowledged that cost was the major factor in determining the use of wooden crates. They are cheap to construct and may either be re-used for return from Tristan (a few) or more generally broken down and disposed of after the single one-way journey. The crates are also a suitable size and weight for off-loading into the service barge and boats at the Tristan end. However, if a successful eradication occurred on Tristan, improvements in the packing of supplies would be desirable. This would involve either the purchase of re-usable rodent proof containers, or improvements in the construction of the wooden crates, to eliminate any gaps through which rodents could gain access, and/or placement of rodent bait in each crate just before it is sealed.

The SA Agulhas calls twice to Tristan on its annual Gough servicing trip, once ex-Cape town to offload stores and passengers, and once ex-Gough to pick up return passengers and freight. The latter is not currently an issue for rodent quarantine but could be in future if a rodent eradication occurs on Tristan prior to one occurring on Gough.

The SA Agulhas was inspected with regard to rodent quarantine just prior to sailing and inspection of holds was also conducted while at sea. Rat guards on mooring lines were present but placed so as to be ineffective. Rodent bait stations and flying insect traps were located in working and food service areas, but not in the cargo holds. The ship was particularly tidy and clean, but it was noted that any rodent that accessed the ship from the wharf or during loading had free access between many of the various holds. Open crates of foods (e.g. potatoes) and non rodent-proof wooden crates destined for Tristan meant that there was an abundant potential food resource for any rodents, without any likely encounter with bait stations which were inexplicably absent from the holds. However, according to the Second Mate, the ship's holds are treated just prior to loading and sailing by a pest contractor (unclear what pesticide is used, but presumably methyl bromide).

As the South African supply ship also responsible for servicing the South African stations in the Antarctic and on Marion Island, the issues relating to quarantine on Tristan are not a novel issue for the officers and crew. Maintaining satisfactory standards with regard to pest quarantine on the ship should be a normal day to day part of the routine.

Two South African crayfish ships, the 'Kelso' and 'Edinburgh' between them make approximately nine visits to the island per year. Both these ships are part of the crayfish company which works the crayfish processing factory on Tristan. Therefore the company has a vested interest in maintaining a potential rodent-free status on the island, and can also be influenced by the Tristan government to conform on this issue, as part of negotiating continued contracts. These ships also carry a limited amount of freight to Tristan. This study did not have

the opportunity to investigate quarantine procedures on these vessels, but anecdotal information suggests they are not up to the same standard as the SA Agulhas.

Relatively few other ships arrive at Tristan. A very limited number of other fishing vessels may call irregularly. A small but potentially increasing number of cruise ships call, and unload passengers for day trips when the weather is suitable. Perhaps half a dozen yachts call in each year, generally after sailing from South America or South Africa (C Glass *pers comm*.). In all instances the time required to travel to Tristan from the port of embarkation means that any rodent presence on board a vessel is likely to be detected before arrival. It also means Tristan officials are usually aware well in advance of vessels arriving at the island, so advance preparation for quarantine/border control procedures can occur.

There is a small but appreciable further risk from shipwrecks occurring on the island. There have been several shipwrecked yachts on Tristan in recent decades. All rodent free islands face the largely unavoidable prospect of shipwrecks. A strong, pre-planned 'contingency response' to any shipwreck and possible rodent incursion needs to be an integral part of any pest quarantine operation on rodent free islands.

The recognised safe anchorage for larger shipping at Tristan is well offshore, beyond the probable swimming range of rats or mice. Access to the Tristan harbour is currently limited to vessels of less than 2 m draught. Although this is problematic for supplying the island, it is a significant advantage for rodent quarantine. Only small boats such as the island's own service fleet and ships' RIB's or other small motorboats can access the wharf, restricting the potential for any rodents present on the ships to get ashore.

Some evidence of potential pest species invasions on Tristan was recorded. A live lizard was recently discovered by an islander unpacking a transport case sent from South Africa (C Glass *pers comm*.). Various adventive species have been recorded arriving on the island, examples being Australian red-backed spiders (arrived by 1968), a moss species (1966) and ants in 1963 (Wace & Holdgate 1976). This suggests firstly that invasion by pest species is an issue, and secondly that improving quarantine specifically for rodents would be of wider environmental benefit as well.

There is one recorded instance of a live rat being detected aboard a longboat sailing from Tristan to Nightingale Island. It was sought out and killed before the boat got close to its destination.

Several currently activities relating to pest quarantine are highly undesirable. One clear instance of this is the importation of hay from South Africa. Large bales of hay provide an obvious vector for the transportation of rodents, which are known to frequent hay storage areas and to nest within the bales. Hay will also provide a vector for a wide range of other potentially damaging organisms, such as pest plants, invertebrates, fungi and bacteria. Better management of pastures and stock numbers on the island would negate the need for importation of stock feed. At the very least, processed feed eg pelleted stock nuts, should be used in place of raw foodstuffs like hay.

A significant advantage for pest quarantine on the island is that the Tristan government has considerable influence upon the parties involved in supply and

shipping to the island. It has the ability to specify pest quarantine measures expected of the various agents as conditions whilst negotiating service contracts. With only one provisioning agent and one ship used for annual servicing, it should be possible to maintain a high standard of quarantine. The Tristan Government also appoints an official Environmental Inspector, whose role is to ensure that quarantine measures are followed for the annual servicing of Gough Island, but this brief could logically and easily be extended to Tristan itself. Pre-departure inspections of all sailings could be undertaken by a Tristan Government representative such as a Cape Town-based honorary Conservation Officer. This should also apply to the Table Bay Marine stores and offices.

In conclusion, Tristan has many potential advantages over most inhabited islands in the world with respect to establishment and maintenance of effective pest quarantine. While there are constant quarantine issues and risks for any island, it appears that if an effective pest quarantine process is established and maintained on Tristan, the risk of successful rodent re-introduction is small enough that it should not be considered an impediment to an eradication attempt proceeding. However, the islanders and their government should demonstrate their willingness and capability to develop and maintain an effective quarantine/border control system prior to eradication occurring. This would include addressing high-risk activities such as the import of hay, as well as improving security of current operations.

5.10. HOW DOES ERADICATION PRIORITY RELATE TO GOUGH AND TO OTHER OVERSEAS TERRITORIES?

It was not within the scope of this study, but a pertinent question to ask is how the eradication of rodents from Tristan ranks in terms of priority with other potential invasive pest eradications or conservation projects in general on other UK Overseas Territories. This is because it is probable that the funding for such projects would be sought from the same source (UK government agencies).

The potential cost needs to weighed carefully against relative expectation of success, and the potential benefits.

5.11. SUMMARY OF MAIN CHALLENGES

In terms of the feasibility of a rodent eradication, Tristan presents a range of challenges that would mean it is one of the most problematic islands yet considered for such an operation. The presence of a sizeable human population, presence of large numbers of livestock and several distinctive species of wildlife add significant and unprecedented complications. Nevertheless, while the difficulties are appreciable, a pragmatic approach would suggest they can all be practically addressed if there is sufficient desire to see an eradication take place.

6. An Estimation of Costs

6.1. A 'DO-NOTHING' APPROACH

Obviously a 'do-nothing' approach would have no additional financial cost to the island with respect to rodent control. However, it may have long-term implications for costs of health care, and for the cost of construction of new buildings or maintenance of old ones with respect to 'rodent-proofing'. There will also be lost opportunity for economic gains, through eco-tourism opportunities and/or reduction of agricultural imports.

6.2. IMPROVED CONTROL MEASURES

Improved rodent control around the settlement may require a small additional investment in terms of both labour and equipment, but most significant gains could be made at little extra cost simply through adopting a more strategic approach. Any changes to the current regime to achieve a far higher level of control are estimated to amount to only a few hundred pounds per annum. There would be a need for a one-off period of expert advice and training, estimated to cost several thousand pounds.

Initiating effective rodent control around areas of high conservation value would be more problematic. Costs would be appreciable, as most such areas are likely to be isolated from the Settlement, meaning additional labour costs because of the need to hike and/or camp. To achieve a reduced level of predation in areas such as burrowing seabird colonies, control efforts must be sustained over the several months of the breeding season. Actual costs would vary considerably according to location and size of the treatment area, the duration of control measures and the degree of rodent control necessary to achieve the desired reduction in predation. Such factors have not been determined as yet, but it is likely that to achieve any meaningful level of rodent control and ecological response, even in relatively small areas, it would require an annual input of several thousand pounds. If larger areas were targeted, the cost could easily escalate to tens of thousands of pounds.

6.3. ERADICATION

For eradication, costs have ranged significantly in operations undertaken to date. Recent relevant operations in New Zealand have included Kapiti Island, a 1,970 ha island completed at a cost of NZ$254 ha^{-1} (*ca* £100 ha^{-1}), including appreciable non-target species mitigation (captive holding, etc). Mayor Island, (1,277 ha) was a far more straightforward operation, completed at only NZ$114 ha^{-1} (ca £45 ha^{-1}), one of the lowest costs per area for any operation thus far. These islands are situated close to major centres of human habitation, and costs significantly increase in relation to the degree of isolation of the island. Of closer relevance to Tristan is the relatively isolated New Zealand subantarctic island of Campbell Island (11,300 ha) for which the operational cost of an eradication was NZ$180 ha^{-1} (approximately £75 ha^{-1}, but this did not include salary costs of permanent conservation staff associated with the project). Using the same cost per unit area, an eradication operation on Tristan would cost in the order of

£740,000. However, many additional costs are likely to be associated with an operation on Tristan, including appreciably greater transport distances and costs, human and livestock health monitoring and mitigation

This is a very approximate estimation of costs. No attempt has been made to obtain quotes and it is not intended to provide anything more than a ballpark figure on which to base preliminary considerations of feasibility. A more detailed calculation of costs is provided in the accompanying Operational Plan for the eradication of rodents from Tristan da Cunha.

Table 2. First pass estimates of costs for a rodent eradication on Tristan da Cunha

Item	Quantity	Estimated Cost
Bait purchase, NZ transport & storage	At least 150 tonnes	£250,000+
Bait transport, NZ-Cape Town	*Ca* 20 shipping containers	£80,000
Storage, stevedoring, Customs costs etc, Cape Town		£30,000+
Ship charter	At least 40 days	£500,000+
Helicopter hire, pilot & ground crew costs	At least 40 days	£500,000
Salaries, Project Manager & 2IC, plus IT technician, local staff	2 x full year 6-10 x 40-50 days	£150,000
Human health monitoring, human health mitigation (water filtering, etc)		£50,000
Veterinary Support		£40,000
Possible treatment costs, holding facilities &/or compensation for livestock		£20,000
Captive holding facilities for thrush & moorhen, including construction, trials, capture, holding & staff costs		£40,000
Technical and safety equipment, including satellite phones, computers, VHF radios, protective clothing		£10,000
Fauna pre- & post-operation monitoring, & possible translocations.		£30,000
Improvements in quarantine facilities on Tristan		£30,000
Contingencies	10%	£175,000
TOTAL		£2,000,000

7. Recommended Interim Course of Action

Before an eradication operation or planning for such can occur, a number of issues can be addressed that will be of benefit to the island in general and to the potential for success of an eradication operation.

7.1. QUARANTINE

- Prohibit the import of raw products such as hay due to the risk of it acting as a vector for invasive pest species
- Maintain and strengthen the implementation (and policing) of rodent control requirements for all suppliers and shippers to the island to a single high standard that is regularly monitored
- Encourage greater attention bio-security attention to materials that come ashore on Tristan

7.2. WASTE MANAGEMENT

- Develop a better rubbish disposal system, including sealed (lidded with catches) rubbish bins for all residences and work places in the Settlement
- Place greater emphasis on sorting and appropriate disposal of food wastes, and/or proper incineration at the rubbish dump, to limit food resources for rodents
- Develop a change in attitude to disposal of fish waste and other rubbish around the wharf, and rubbish in general around the Settlement
- Encourage 'tidier' feeding of poultry and pigs
- Repair or upgrade the dysfunctional sewage treatment system

7.3. RODENT CONTROL IN AND AROUND THE SETTLEMENT

- Place emphasis on a strategic Settlement-wide rodent control programme rather than piecemeal, reactive control measures
- Avoid all use of rodenticides containing brodifacoum in order to prevent resistance evolving in the rat population
- Establish a grid system of permanent poison bait stations and trap boxes throughout the Settlement (timber from wooden packing crates could be recycled to make boxes), ie widen current control measures to include the entire settlement

7.4. INTERIM PROTECTION AROUND KNOWN PETREL COLONIES

- Deploy poison bait and/or traps in the three known prion caves before and during egg-laying, incubation and chick-rearing (probably August - December)
- Deploy a similar baiting and/or trapping programme around any concentrated burrowing seabird colonies that are discovered within relatively easy access of the Settlement for the same period (laying, incubation and chick-rearing) as appropriate for the species

7.5. ADDITIONAL STEPS TOWARDS ERADICATION PLANNING

- Develop a comprehensive risk assessment document for human health and livestock issues, so that the islanders are fully aware of the potential implications of an eradication
- Seek feedback on this, to ensure that Tristan people are still fully supportive of the eradication option
- Undertake further research on rodent distribution and ecology (currently underway)
- Look at options for control of free-ranging livestock to limit their effect on a potential baiting operation, eg reduction in numbers and distribution, construction of fenced paddocks or holding yards

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www.rspb.org.uk

The Tristan Agriculture and Natural Resources Department is responsible for biodiversity conservation on Tristan da Cunha. It works in partnership with organisations from around the world, specifically in the UK and South Africa, to reduce the rate of biodiversity loss on the Tristan Island group.

The Percy Fitzpatrick Institute of African Ornithology is part of the Department of Zoology at the University of Cape Town. Its mission is to promote and undertake scientific studies involving birds that contribute to the conservation of biological diversity and the sustained use of biological resources.

www.fitzpatrick.uct.ac.za

The Avian Demography Unit is a research unit in the Department of Statistical Sciences at the University of Cape Town. It contributes to the understanding of bird populations, especially population dynamics, and thus provides input to their conservation.

www.aviandemography.org.za

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