Offshore Islands Conservation Programme




ANTIGUA & BARBUDA

Feasibility study for the eradication of black rats *Rattus rattus* from Redonda, with new observations on the island's biodiversity and ecology

By

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Cover illustrations: Red-footed boobies (Adam Long, British Mountaineering Council); Redonda (Jenny Daltry, Fauna & Flora International – Offshore Islands Conservation Programme); Black rat eating prickly pear on Redonda (John Cancalosi, Fauna & Flora International); Turk's cap cactus (Dave Turnbull, British Mountaineering Council).

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The award-winning Offshore Islands Conservation Programme (OICP) was established in 1995 as the Antiguan Racer Conservation Project, and operates under a Memorandum of Understanding between the Government of Antigua and Barbuda, Environmental Awareness Group, Durrell Wildlife Conservation Trust, Fauna & Flora International, Island Resources Foundation and Black Hills State University. This partnership is working towards the Vision of *healthy, functioning coastal ecosystems that are sustainably managed for the conservation of native wildlife and for the benefit of local people*. Our activities include environmental education, endangered species management, invasive species control, habitat restoration, research and monitoring, and strengthening local governance and management capacity.

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EXECUTIVE SUMMARY

Rodents have been successfully eradicated from hundreds of islands ranging in size from 1 to 11,200 hectares throughout the world, including more than 20 islands in the Caribbean. These cases demonstrate how safely and effectively rats can be eliminated, and the remarkable benefits their removal can bring to both wildlife and people. Some of the best examples are in Antigua and Barbuda, where a dozen islands have been cleared of alien invasive black rats *Rattus rattus* since 1995.

In recent years, a number of organisations and individuals, including technical staff of the Environmental Awareness Group and Government of Antigua and Barbuda, have put forward the idea of eradicating rats from Redonda to support the recovery and conservation of the island's biodiversity. At approximately 53 ha, planar area (or circa 80 ha, surface area), Redonda is one of the largest islands in Antigua and Barbuda and has been identified in the national land use plan as a priority site for environmental conservation.

This report **presents the findings of a study to determine the methods and cost of eradicating rats from Redonda**, and examines the possible benefits this could bring to wildlife and people. The study entailed a trip to Redonda from 10-14 April and 18 April 2012, a literature review, and a series of consultations with key government and non-governmental stakeholders on Antigua. While the main focus of our study was on the rats, this report also contains new information on the status and ecology of native wildlife and the feral goats on Redonda, which will also assist with conservation planning.

Redonda has been formally recognised as an Important Bird Area and **supports rare and unique animals and plants of both national and global importance.** At least three endemic lizards still remain: Redonda ground lizards *Ameiva atrata*, Redonda tree lizards *Anolis nubilus* and an unnamed dwarf gecko *Sphaerodactylus* sp.; all of which qualify as globally threatened according to the findings from this survey. Birds include regionally, even globally, significant colonies of brown boobies (774 pairs), masked boobies (164 pairs), red-footed boobies (over 150 pairs) and magnificent frigatebirds (119 pairs), plus smaller numbers of red-billed tropicbirds, brown noddies and bridled terns. However, the seabird colonies appear smaller and less diverse than they ought to be, and there is a dearth of terrestrial birds - only two peregrines and a few zenaida doves were observed in April 2012. Seventy species of plants and a few invertebrates have been recorded, but some species are also feared to be extinct and more extensive surveys are warranted. No amphibians or native mammals have been recorded.

The Eurasian black rats on Redonda are unusually large and their density is exceptionally high. Use of trapping lines indicated that Redonda has at least 70 rats per hectare, or a total population of approximately 5,500 rats. Only black rats are known to be present: brown rats *R. norvegicus* and house mice *Mus musculus* were not detected during this or previous studies and it appears that previous reports of brown rats were in error. The omnivorous **black rats are having a very severe impact on the wild animals and plants of Redonda**. Rats were observed killing seabird chicks larger than themselves, while autopsies of trapped rats found the rats eating a wide range of food items including various plants, seabird eggs and chicks, lizards and goat droppings. Many native birds, reptiles, plants and invertebrates have already disappeared, and many remaining species are now critically scarce. Species not seen for many years include the last Antiguan burrowing owls *Athene cunicularia amaura* and the endemic Redonda skink *Copeoglossum redondae*. Their decline is almost certainly linked to predation by rats.

The island's high density of rats, remote location and very rugged terrain presents a number of challenges. As described in this report, the research team carried out a full site assessment, measured rat density and distribution, identified and evaluated risks, difficulties and mitigation measures, conducted bait trials to test whether the rats would accept rodenticide, identified non-target species, and evaluated different

methods and materials. This assessment **concludes that the eradication of black rats from Redonda is technically feasible**, and this report outlines the set out the operational options and technical requirements for the proposed eradication.

The aim of the proposed operation should be to eradicate all rats from Redonda while minimising any adverse impacts on the environment, non-target species and people. It is recommended that the eradication takes place outside the hurricane season, ideally January to April, in **a combined aerial and ground-based operation using rodenticide containing the anticoagulant brodifacoum**. The proposed eradication techniques have proven to be safe and effective and are supported by similar operations in the Caribbean and around the world. Up to 13 persons will be required to complete this work effectively: five helicopter team members (including pilot and ground crew) and eight ground-based operators. Additional persons will be required to monitor wildlife, logistical support, communications and outreach on Antigua & Barbuda and Montserrat.

This rat eradication operation would involve a number of stages. Necessary tasks include: (i) produce a detailed Operational Plan; (ii) obtain required permits and approvals; (iii) continue stakeholder consultation; (iv) prepare tenders and contracts; (v) establish monitoring and research programmes; (vi) appoint eradication personnel; (vii) purchase all equipment and bait; (viii) implement the rat eradication (i.e. baiting and evaluation); (ix) develop and implement a post-eradication biosecurity strategy to prevent rats and other species from (re)invading Redonda; and (x) design and implement long-term monitoring of flora and fauna species and the ecosystem to measure the effects of the rat eradication. It may also be necessary to (xi) move some of the endemic lizards to a temporary ex-situ facility on Antigua during the eradication operation to remove any risk of direct or secondary poisoning. Monitoring to detect any surviving or invading rats should also be continued, with a final evaluation of the success of the eradication carried out after two years.

Taking into account the relatively large size of Redonda and its remote location, rugged terrain, high transport costs and lack of infrastructure, the rat eradication operation would cost approximately US$250,000. We recommend allocating **up to US$630,000 over four years** to include necessary pre- and post-eradication monitoring, biosecurity, contingency costs and a temporary ex-situ facility for lizards, should this prove necessary. After the eradication, the **long-term maintenance costs will be low** and could realistically be sustained from small grants or nature-based revenue generated by the island. A detailed inventory of equipment and manpower is provided in this report.

There would be **significant benefits to eradicating rats from Redonda,** as detailed in this report. Populations of some of the island's rare and endemic species would increase significantly, including the reptiles, seabirds, certain plants and invertebrates. Furthermore, in the near future, the rat-free Redonda could potentially be recolonised by animals and plants that historically occurred there, such as the iconic burrowing owl. Eradicating rats from Redonda would therefore be a major achievement and a very clear demonstration of Antigua and Barbuda's commitment to the Convention on Biological Diversity.

However, it is conceded that the island's ecological recovery will be limited as long as feral goats remain on the island. This report strongly **recommends the goat herd also be removed** in the interests of animal welfare, to conserve native biodiversity, to reverse the ongoing process of deforestation and desertification, and to strengthen the island's natural resilience to climate change. Fewer than 50 goats inhabit Redonda at the time of writing, the majority of them adult males, and mass die-offs from starvation have been observed during droughts.

In our consultations we found **strong interest among stakeholders**, including technical agencies in the Government of Antigua and Barbuda, the Environmental Awareness Group, in this proposed eradication of rats. It is imperative that all of the **relevant government agencies maintain an integral role in the**

planning, preparation and implementation of this project, working alongside civil society to ensure its success. Redonda is uninhabited and rarely visited, but excites great curiosity and excitement. Ongoing consultation and communication about the proposed eradication to Antiguans, Barbudans and the neighbouring Montserratian communities will also be essential to ensure lasting success.

In summary:

1. Black rats *Rattus rattus* have a very **severe impact on the native biodiversity** of Redonda, and additional species are predicated to disappear if rats remain. The rats were confirmed to feed on a wide variety of items including plants, eggs, chicks, lizards, goat droppings and invertebrates.
2. Using index trapping, the mean rat density on Redonda was estimated to be **at least 70 rats per hectare**, giving a total population of approximately 5,500 rats. This is a very high density.
3. The eradication of black rats from Redonda is **technically feasible, using a combined aerial (helicopter) and ground-based operation**. The entire operation, including post-eradication monitoring and establishment of biosecurity measures, is estimated to cost approximately US$630,000.
4. To achieve success, the rat eradication would require **experienced operators** and the combined support of the Government of Antigua and Barbuda, the Environmental Awareness Group and international partners. All stakeholders consulted in 2012 appeared very interested and supportive of the proposal to eradicate rats from Redonda.
5. The recommended rat poison for the proposed eradication operation should be **brodifacoum, an anticoagulant rodenticide**. Approximately 2 tonnes of bait will be needed.
6. The proposed rat eradication should be undertaken during the dry season, from **January to April**, but preparatory work – including further stakeholder consultations and fundraising – are needed at least one year in advance.
7. As described in this report, the design and implementation of the proposed eradication programme must include measures to **minimise risks to non-target species**, especially the Redondan endemics, and contingency plans to deal with any incidents.
8. Rats, birds, reptiles, invertebrates, vegetation and goats should be **monitored before and after the eradication programme** to assess the project's success and impacts. Data in this report can serve as a baseline for evaluating future changes.
9. Adequate **biosecurity protocols need to be established** and maintained to reduce the risk of rats re-invading Redonda in the future. Surveillance by boat owners and operators will be vital to ensure rodents are not accidentally brought to the island on their boats.
10. Based on field data gathered during this study it is **strongly recommended that the feral goats are also removed** for both conservation and animal welfare reasons. The herd is under extreme stress and their presence is driving deforestation, desertification and the loss of native biodiversity.

Before eradicating rats, we also recommend developing **a site management strategy** to determine whether and how Redonda will be used for biodiversity conservation, cultural heritage preservation, tourism, education, research, and/or other functions in the future. This will clarify the context of the rat eradication and help to ensure that post-eradication biosecurity measures are fully compatible with other management activities.

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1 Introduction

1.1 Preamble

Black rats are one of the most widespread invasive species, occurring on 80% of the world's islands (Atkinson, 1985; Jones *et al.* 2008). Rats have had devastating impacts on islands through predation, competition and habitat modification (Towns *et al.* 2006; Jones *et al.* 2008), but have been successfully removed from islands ranging in size from 1 to 11,200 hectares (Towns & Broome, 2003; Howald *et al.* 2007). The majority of rat eradication operations have taken place in New Zealand, where appropriate poisoning techniques were first developed. Poisoning methods range from ground based distribution (bait station or hand spreading) to aerial broadcasting operations, and in some cases a combination of methods is used. The best method depends on the physical characteristics and ecological characteristics (specifically the risk to non-target species) of the island and the species of rat being targeted.

Black rats have been successfully eradicated from more than 20 islands throughout the Caribbean region (e.g. Day & Daltry, 1996; Daltry, 2000; Varnham & Daltry, 2006; Witmer *et al.* 2007; Varnham, 2010; Bell, 2012). More than a dozen operations have been carried out on islands around Antigua under the auspices of the Antiguan Racer Conservation Project and Offshore Islands Conservation Programme: specifically, Great Bird, Galley Major, Galley Minor, Rabbit, Redhead, Lobster, Little Lobster, Codrington, Maiden (West), Maiden (East), Green and York. The largest of these is Green Island, at 45 hectares. All of these operations involved Antiguan and Barbudan personnel (staff and volunteers from the Forestry Unit and Environmental Awareness Group) working alongside international organisations (specifically, Fauna & Flora International, Durrell Wildlife Conservation Trust and Island Resources Foundation).

The effects of eradicating black rats from smaller islands around Antigua have been remarkable. They are associated with a 10-fold rise in the population of Critically Endangered Antiguan racers *Alsophis antiguae*, a four-fold increase in red-billed tropic birds (*Phaethon aethereus*), a 10-fold increase in brown pelicans *Pelecanus occidentalis* and a 16-fold increase in Near Threatened white-crowned pigeons *Patagioenas leucocephala* (Daltry *et al.* 2010). Native plant biomass on the same islands has also increased by at least 25% within 10 years of removing rats, based on the evidence of fixed-point photographs (J.C. Daltry, unpublished data). A comparative study in 2010 and 2011 found a significantly higher density and diversity of birds on rat-free islands than on neighbouring rat-infested islands, and three times a higher density of lizards (Ross, 2011; Varnham *et al.* 2012). Furthermore the restored islands have become very popular with local users and tourists, generating well over US$5 million per year in boat transport revenue alone (J.C. Daltry, unpublished data).

Because of this very successful track record of eradicating rats from Antiguan islands, members of the Offshore Islands Conservation Programme posed the question of whether rats could be eradicated from Redonda. The objective of restoring Redonda was incorporated into the Offshore Islands Conservation Programme's Memorandum of Understanding, 2010-2015[1]. Over the past few years, staff from the

[1] Objective 11, to develop a restoration project for Redonda, is in the Offshore Islands Conservation Programme Memorandum of Understanding, 2010-2015, signed by the Ministry of Agriculture, Lands, Housing and Environment, Environmental Awareness Group, Durrell Wildlife Conservation Trust, Fauna & Flora International, Island Resources Foundation and Black Hills State University. Baseline surveys of Redonda and a feasibility study for eradicating rats are Activities 11a and 11b in the Memorandum.

Environmental Awareness Group (EAG), Forestry Unit, Department of Environment, Department of Agriculture, Island Resources Foundation, British Mountaineering Council, Environmental Protection in the Insular Caribbean, and Fauna & Flora International (FFI) have conducted a number of short day trips to Redonda to gather baseline information about its wildlife and terrain (e.g. Turnbull, 2011; Ross, 2011; Lowrie *et al.* 2012). No one failed to notice the large rats on Redonda, every on short visits during the middle of the day. In addition, a regional priority-setting workshop held in Antigua in July 2009 ("*Restoring Seabirds and other Native Species in the Caribbean*"), attended by government and NGO representatives from almost every Caribbean state, identified Redonda as the top priority island in the Eastern Caribbean for alien invasive species removal.

Redonda is, however, significantly bigger and technically more challenging than any of the sites previously restored in this country. Recognising that Redonda may demand methods not previously used in Antigua and Barbuda, Wildlife Management International Ltd (WMIL) was contracted to assess the feasibility of eradicating black rats from Redonda and provide detailed advice on how this could be achieved.

This report, prepared by Ms. Elizabeth Bell (WMIL) and Dr. Jenny Daltry (FFI) describes a detailed assessment of the feasibility of eradicating rats from Redonda, including a five-day field survey completed in April 2012. The species of rat was confirmed, rat density, food, breeding status and body condition clarified, an assessment of issues that could affect the success of the project was undertaken, technical requirements, consultation with interested parties and level of support was gathered. This feasibility study also outlines the planning requirements, methods, equipment, transport, personnel, timetable, logistics and estimated costs required for the proposed eradication of black rats from Redonda.

Because successful restoration projects require a good understanding of the biodiversity and ecology of the site, we also conducted research to fill in some important gaps concerning the status, distribution and behaviour of feral goats and native wildlife on Redonda. Even though a number of articles have been written about Redonda during the past 150 years or so, most accounts are anecdotal and none provide a fully rounded picture of Redonda's flora and fauna, or attempt to understand how the island has been impacted by invasive alien species.

This report concludes that although Redonda has some difficult aspects, a total eradication of black rats is entirely possible with the aid of a well-planned, adequately resourced, and well-executed programme that is fully supported by the Government of Antigua and Barbuda and led by experienced operators.

It must be emphasised that the scope of this report is largely confined to the logistics of eradicating rats from Redonda. While this action would have greatly beneficial effects upon the fauna of Redonda, by itself it cannot address all of the island's problems or opportunities. We strongly advise that even before attempting this eradication, a management strategy or plan for Redonda is developed to provide the context for removing rats and enable us to ensure the post-eradication biosecurity methods (Section 8) are appropriate and sustainable. Such a plan need not be lengthy, but should explain the overall national goals for managing Redonda, identify any other management actions that need to be taken, and identify which organisations or agencies will take the lead in implementation.

On this subject, the recent national land use plan (GENIVAR, 2011) proposed Redonda be made an "environmental protection area with public access at designated areas". This would have biodiversity conservation goals as well as support education and limited tourism 'due to the presence of outstanding physical features and unique flora and fauna, which include an extensive variety and quantity of birds'.

1.2 Redonda

Redonda (16°56'N; 62°21'W) is the third largest island in Antigua and Barbuda; lying 56 km southwest of Antigua, 22 km northwest of Montserrat and 32 km southeast of Nevis. Redonda is uninhabited and is 1.6 km long, 0.5 km wide and rises to nearly 400 m (Prosper *et al.* 2008). The island's planar area is approximately 53 hectares, but its actual surface area is estimated to be at least 80 hectares[2] (Figure 1, Morse, 1979). Redonda has a tropical dry climate with low rainfall (<1,000 mm per year). The wet season, which overlaps with the hurricane season, extends from August to November, but Redonda's small size and lack of trees means that few clouds gather here.

A remnant volcanic core, Redonda rises steeply from the sea. There are sheer cliffs around most of the island, with only one access route from the shore. The top of the island slopes eastward, with few flat areas. Large rock scree and boulders cover these sloping areas. There is limited vegetation; generally restricted to a few trees growing on steep cliff faces and a flush of green herbs (mostly non-native *Cleome* spp.) after rain. There is no permanent source of freshwater, although several rainwater seepage points were found during the present survey, including one in Centaur's Cave. There are a number of ruins and archaeological structures on the island, but no accommodation or other facilities. Access is difficult; either from the shore via a steep and dangerously unstable gully or by helicopter to several flat areas on the island.

Redonda is stated-owned (crown land). The island was mined for guano between 1865 and 1914, during which time up to 120 people lived and worked here (Morse, 1979; Prosper *et al.* 2008). A number of buildings and other structures, including a wharf, were constructed during this period. A post office was established and a caretaker lived on the island in 1978 (Morse, 1979), but most structures are in ruins, many of them damaged by hurricanes.

Around 70 species of plants have been recorded on Redonda over the past 70 years, but some of these have disappeared and more than a quarter are not native to the Caribbean, including ornamental plants brought by the miners (see Section 2.6). Historical paintings indicate that Redonda used to be forested and, even photographs from the 1960s and 1970s still show many shrubs and agave blanketing its surface. Today, however, only a handful of woody plants remain today, and much of the island has a barren appearance. Some short-leafed fig trees *Ficus citrifolia* can be found, most of them clinging to the cliffs, and a single Australian casuarina tree stands near the ruins of the mine manager's house between 'the plateau' and Shiel's Summit. There is little or no evidence of tree regeneration (see Section 2.6). With the loss of vegetation has come the loss of topsoil, and much of the island is seriously eroded and unstable. Much of the habitat on Redonda is sparsely vegetated cliffs, talus/scree slopes and jumbled boulders (Devine *et al.* 2010).

Redonda has been designated an Important Bird Area (no. AG001) because it holds regionally significant populations of seabirds, specifically magnificent frigatebird *Fregata magnificens*, masked booby *Sula dactylatra*, red-footed booby *S. sula* and brown booby *S. leucogaster*, as well as smaller numbers of red-billed tropic bird *Phaethon aethereus*, brown noddy *Anous stolidus* and bridled tern *Sterna anaethetus*

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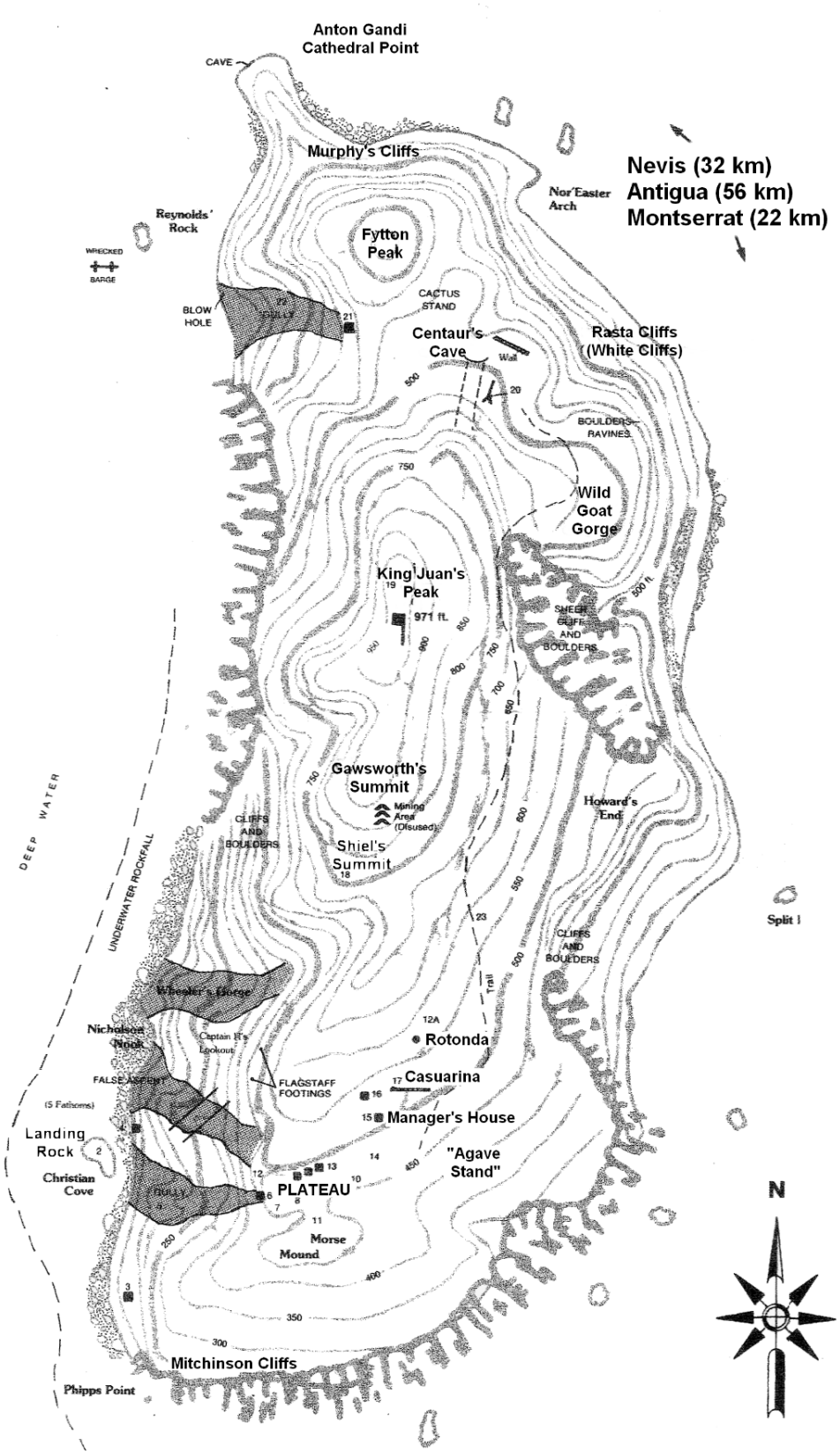
[2] Published areas vary widely, with mistakes often repeated by subsequent authors. For example, Prosper *et al.* (2008) give the area as being up to 260 hectares, while Horwith & Lindsay (1997) contain a table giving the area of Redonda as 500 hectares. However, the island is just 1.6 km long and 0.5 km wide at its widest point, so these higher figures are not credible. The planar area of 53 hectares was measured by Dr. Brian Cooper using GIS from the best available topographic map of the island, but should be verified using a good geo-rectified satellite image when one becomes available. The 'three-dimensional' surface area is probably nearer 80 hectares owing to its steeply pointed shape, and is the estimate used in this report, but again this should be verified with an accurate GIS model.

Figure 1. Topographic map of Redonda (Antigua and Barbuda), prepared by Desmond Nicholson.

Redonda is 1.6 km long and 0.5 km wide (at its widest point). This topographic map contains some errors, but is considered the most accurate available. It gives a planar area of not more than 53 hectares.



(Prosper *et al.* 2008; BirdLife International, 2012; Section 2.2). Audubon's shearwater *Puffinus iherminieri* was previously listed as present on the island (Sylvester *et al.* 2009), but no recent records have been reported excluding a possible call heard in 2009 (Lowrie *et al.* 2009). The island is surprising for its lack of other small nesting seabirds, particularly terns and gulls, which may be attributable to the very high density of large rats. See Section 2.2 for more details.

There are very few records of land birds on the island (see Section 2.2). The burrowing owl *Athene cunicularia* has been recorded on Redonda (Clarke, 1957; Office of the Prime Minister 2001), but there have been no recent sightings. Only a handful of zenaida doves *Zenaida aurita* and peregrines *Falco peregrinus* were observed in 2012 (Section 2.2.4), but it is possible some additional species pass through on migration or periodically come from Montserrat. Kevel Lindsay (*in litt.*) speculates that raptors may visit occasionally to take advantage of Redonda's birds, lizards and rats, which have little vegetation to hide them.

Redonda has six species of lizard, at least four of which are endemic to the island (Malhotra & Thorpe, 1999; Daltry, 2007; Prosper *et al.* 2008; Hedges & Conn, 2012; Section 2.3). The Redonda ground lizard *Ameiva atrata* and Redonda tree lizard *Anolis nubilus* are the most conspicuous. An unnamed dwarf gecko (*Sphaerodactylus* sp.) is currently being identified (Section 2.3). The Redonda skink *Copeoglossum redondae* (previously mis-assigned to the genus *Mabuya*) is another island endemic but has not been seen for decades. An iguana (possibly *Iguana iguana, I. delicatissima* or an endemic species), is also feared extinct. The sixth lizard recorded on Redonda is the common house gecko *Hemidactylus mabouia,* an alien invasive species. No snakes or tortoises have ever been recorded on Redonda. Green turtles *Chelonia mydas* and hawksbill turtles *Eretmochelys imbricata* have commonly been seen in the waters around the island (Prosper *et al.* 2008), but presumably do not nest here because Redonda lacks sandy beaches.

Although domestic sheep *Ovis aries*, dogs *Canis lupus familiaris* and cats *Felis catus* were on Redonda during the mining period (Morse, 1979), currently the only mammals still present on the island are the non-native feral goats *Capra hircus* and black rats *Rattus rattus*. It is possible goats have been on Redonda since the 1600s, left by early explorers (Morse, 1979; Lindsay, 2012), although additional stock may have been introduced over time. There were approximately 65 goats on the island in April 2012, though some of these have since died (Section 2.4). No bats have been recorded on Redonda, although they may have been present historically.

It is likely that black rats were accidentally introduced to Redonda sometime after the 17th century when rats were first recorded in the Caribbean region (Campbell, 1991; Long, 2003); probably when ships were wrecked along the shores. Rats have been implicated as causing major impacts on island biodiversity (Towns *et al.* 2006; Jones *et al.* 2008) and they are known to affect important species on Redonda. Prosper *et al.* (2008) suggested that brown or Norway rats *Rattus norvegicus* may have invaded Redonda, and they were listed as present by Lowrie *et al.* (2012), but we consider this to be a misidentification of the resident black rats, which are brownish and unusually large. *Rattus norvegicus* are present in urban areas on Montserrat, Antigua and other large islands in this region, but none were observed on Redonda during the present survey. No house mice *Mus musculus* have ever been recorded on Redonda.

There have been few studies of the invertebrate fauna of Redonda, but it is clear that their current diversity is abnormally low: Section 2.5 summarises the known taxa. It can be reliably inferred that many native species have been lost due to deforestation and the impacts of alien species.

1.3 Black Rat

Originally from the Indian subcontinent, black rats *Rattus rattus* are now found throughout the world, having been dispersed by humans. They are relatively large, with a slender body, long scaly tail, large ears and dark hairy feet (King, 1990; Novak, 1999). Black rats can grow up to 230 mm in length and weigh up

to 300 g (Cunningham & Moor, 1993). There are three colour phases, termed *rattus* (black back and dark grey belly), *alexandrinus* (brown back and pale grey belly) and *frugivorus* (brown back and white or cream belly). The proportion of colour morphs can vary depending on the location, although *frugivorus* is usually the most common colour phase (Cunningham & Moor, 1993; King, 1990). The *frugivorus* colour morph is the most frequent form on Redonda (Figure 6).

Males are larger than females, and when mature, have a prominent scrotum at the base of the tail (King, 1990; Novak, 1999). Usually only breeding females have visible nipples (King, 1990; Novak, 1999). Black rats have excellent smell, touch, taste and hearing sense (King, 1990). Black rats are omnivorous (but can also be specialist) feeders, taking advantage of any potential food source and will often cache food (King, 1990; Nowak, 1999). When on the ground, black rats usually prefer to eat food under cover; but in the trees rats will feed on any available flat surface (King, 1990).

Black rats are well documented to be major predators of land and seabirds, invertebrates, lizards and native mammals, and are voracious consumers of vegetation, seeds and fruit. They have caused the extinction of a number of plant species, particularly those on isolated offshore islands (Atkinson, 1985; Bell, 1978; Imber, 1985; King, 1990). Although natural food normally forms a high proportion of black rat diet, human products (stores, vegetables and crops) are also targeted (King, 1990).

Black rats are very agile and skilful climbers, and live both in trees and on the ground (King, 1990). They are reluctant to enter water, but have been recorded swimming between islands up to 750 m apart (King, 1990). Black rats do not often burrow, preferring to nest in trees, under thick vegetation or in rock tumbles or crevices (King, 1990; Nowak, 1999). Despite this, tracks and runs are common in areas of black rat activity (King, 1990). Black rats are usually associated with forests or vegetated areas, but can live in a range of habitats from barren ground, coasts, grassland to lush forest as well as human dwellings, buildings and farms (King, 1990; Nowak, 1999).

In natural habitats, black rats do not live in colonies, preferring to disperse throughout the available area (King, 1990). However in urban areas, a small number of adult females and one dominant male will live together in a territory that will be aggressively defended against other rats (King, 1990). Home ranges can vary in size from 0.1 ha to 1 ha in all types of habitats, depending on food availability and habitat quality (Moors, 1985; King, 1990). Males have larger home ranges than females, which prefer to stay close to breeding sites, but this may vary depending on habitat quality, food availability, predation pressure and other factors (King, 1990; Nowak, 1999).

Black rats construct nests out of various items, including newspaper and cardboard, but they are usually made from vegetation (twigs and leaves) and feathers, with new material added regularly (King, 1990; Nowak, 1999). They can breed throughout the year, but this generally depends on food availability and habitat (King, 1990; Nowak, 1999). Gestation is between 20 and 22 days and litter size varies from three to 10 young (usually five-six); the average annual production can be up to 40 young per year (King, 1990; Nowak, 1999). The young are weaned when they are between 21 and 28 days old (about 40 g) and can be sexually mature at three months old (King, 1990; Nowak, 1999). Black rats usually live between 12 and 18 months in the wild, with females generally living longer than males (Daniel, 1972; King, 1990).

Black rats are typically nocturnal and generally shy; however this depends on habitat, predation pressure, hierarchy, disturbance and food availability (King, 1990). They explore all areas and objects within their home range, but can be cautious regarding new or strange objects within this area (King, 1990).

Black rats are commonly infested with fleas and mites as well as being known carriers of several diseases, including leptospirosis and salmonellosis (King, 1990).

2 Site Assessment of Redonda

Redonda was visited by the authors from 10 to 14 April 2012 and again for a day visit on 18 April 2012. Tom Aveling and Ruleo Camacho (EAG volunteers) also assisted with the field work. Transport to Redonda for the camping visit was by helicopter (Caribbean Helicopters) and by boat (Coastguard of Antigua and Barbuda) from Antigua. Accommodation was in tents close to the helicopter landing site on the saddle near the ruins of the mining operation (Figure 1).

The main objective of this visit was to assess the feasibility of eradicating rats from Redonda and investigate the requirements for the rat eradication operation (particularly techniques, difficulties, bait station design, bait type and non-target impacts). A survey of the island was completed in order to determine how island topography, archaeology and vegetation may impact on the proposed eradication. Meetings were held with EAG and various Government of Antigua and Barbuda departments to discuss the proposed eradication, assess the level of support, and obtain historical information and recent developments or plans for Redonda.

2.1 Rat Density, Distribution, Identification and Diet

Index trapping and tracking tunnels were undertaken to assess density and distribution of black rats on Redonda. Traps were set the length of Redonda on the top of the island from 10 to 13 April 2012 (Figure 2). Tracking tunnels were set in two locations close to the camp and old mining operation sites from 12 to 13 April 2012 to determine whether mice were present on Redonda (Figure 2).

All rats caught in the traps were necropsied. A standard dissecting kit, containing scalpels, forceps, pins, scissors and probes, and ruler were used. The following measurements were taken: head-body length (HBL), tail length, nose to ear, right ear and right hind foot (with claw). In addition, age class (adult or juvenile), sex, stomach contents, body condition and breeding status were recorded. No samples were collected. All carcasses were disposed of on the island, where they were rapidly consumed by other rats and crabs.

Complete analysis of measurements was restricted to adult rats to reduce bias from juveniles, although juvenile measurements are listed in Appendix 12.1.

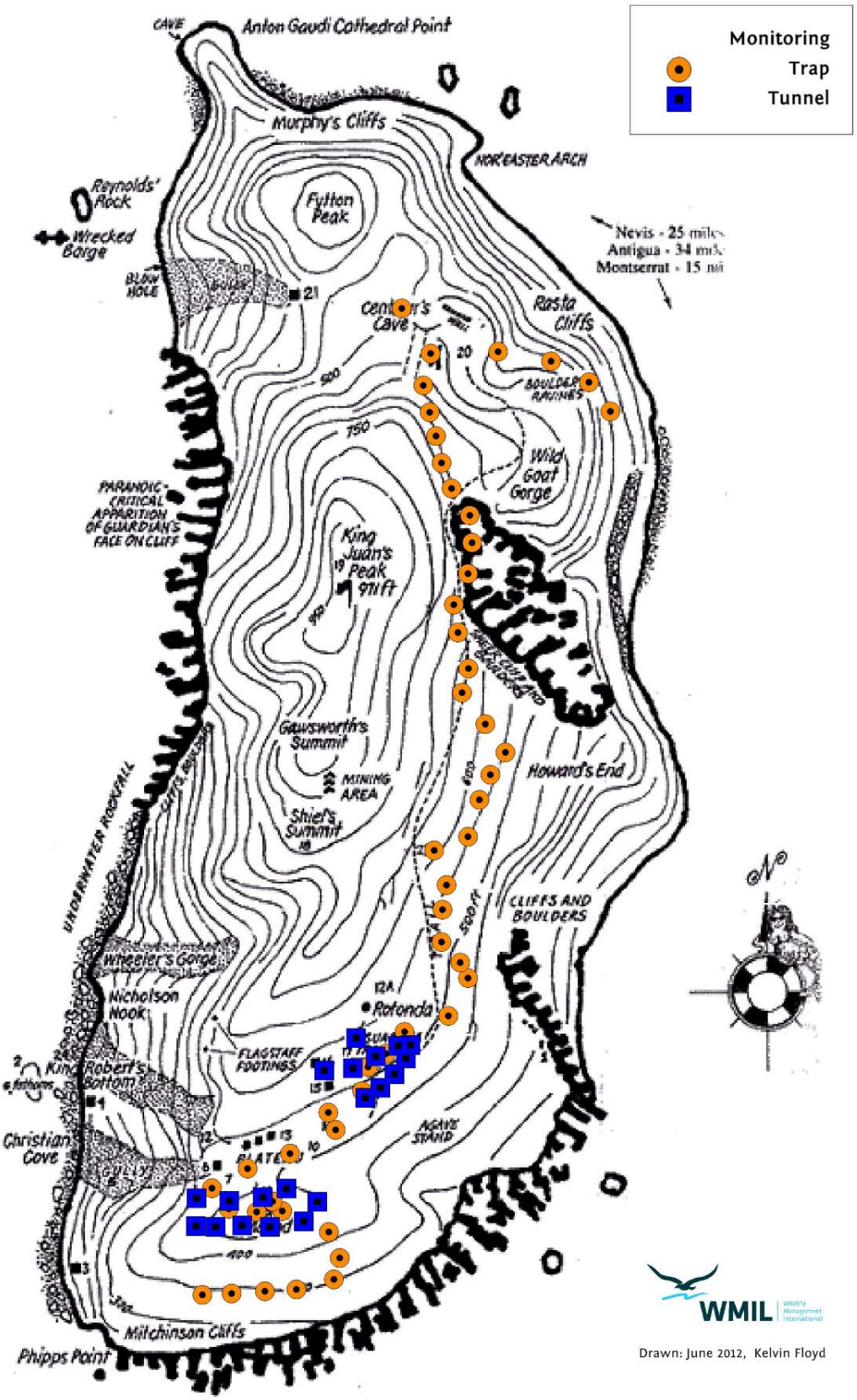
2.1.1 Identification of rat species on Redonda

The results of the trapping showed that only black rats *Rattus rattus* were present on Redonda, and we believe the recent reports of *R. norvegicus* (Prosper *et al.* 2008; Lowrie *et al.* 2012) were in error. A total of 242 rats were caught; 109 males, 127 females and 6 of unknown sex (Table 1, Figure 3). All captured rats were necropsied. Complete capture and necropsy data is given in Appendix 12.1 and a summary is given in Table 1.

Table 1. Summary of black rats *Rattus rattus* caught on Redonda in April 2012.

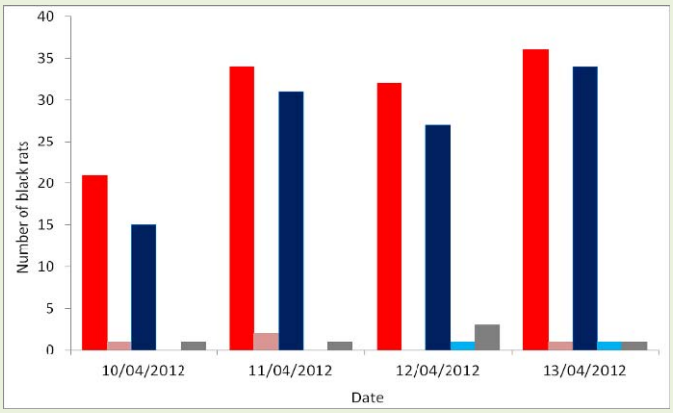
Location	*Total*	*Male*	*Female*	*Unknown*	*Adults*	*Juveniles*
Redonda (Night 1: 10/4/12)	38	15	22	1	37	1
Redonda (Night 2: 11/4/12)	68	31	36	1	66	2
Redonda (Night 3: 12/4/12)	63	28	32	3	62	1
Redonda (Night 4: 13/4/12)	73	35	37	1	71	2
Total	**242**	**109**	**127**	**6**	**236**	**6**

Figure 2. Rat survey locations. Base map reproduced from Morse (1979).



More females were caught on each night (Table 1, Figure 3). Interestingly, the final night of trapping on Redonda had the highest capture rate of the trip (n=73). A number of rats were eaten by other rats overnight leaving only skin or partial carcasses in the traps (n=57). Although juveniles were caught every night, the majority of rats caught were adults (n=236, 97.5%, Table 1).

Figure 3. Number, age and sex of black rats caught on Redonda in April 2012: ■ adult female; ■ juvenile female; ■ adult male; ■ juvenile male; ■ unknown.



There were a total of 236 adult rats (123 females, 107 males and six of unknown sex, Table 1, Figure 3). Using the 230 adults of known gender, the largest (Head-Body Length, HBL) was a male measuring 216 mm. The heaviest were two males both weighing 235 g (Appendix 12.1). This weight is higher than usually reported in black rats (which are typically less than 225 g), but less than the highest recorded weight (300 g) for this species (King, 1990; Cunningham & Moors, 1993).

Table 2. Mean measurements (± SE) from adult black rats (n = 230; 123 female and 107 male) caught on Redonda in April 2012.

	Female	***Male***	***All***
Weight (g)	148.9 ± 2.4	157.9 ± 3.8	153.0 ± 2.2
Head-Body (mm)	178.7 ± 1.0	181.3 ± 1.5	179.9 ± 0.9
Tail (mm)	230.9 ± 1.4	227.6 ± 1.6	229.4 ± 1.1
Nose to Ear (mm)	44.6 ± 0.3	44.3 ± 0.3	44.5 ± 0.2
Ear (mm)	22.8 ± 0.1	22.5 ± 0.2	22.7 ± 0.1
Hind foot (mm)	33.0 ± 0.2	33.3 ± 0.3	33.2 ± 0.2
Hind Foot and Claw (mm)	35.2 ± 0.2	35.8 ± 0.2	35.5 ± 0.1

Generally males were larger than females, but interestingly many females had longer tails and larger ears than males (Table 2, Appendix 12.1). Summary details of measurements are shown in Table 2 and correlation between head-body length and tail length is given in Figure 4.

Ninety-six (78%) adult female rats were either pregnant (n=6; 5%) or lactating (i.e. producing milk to feed young, n=63; 51%) or both pregnant and lactating (i.e. still raising young while preparing to give birth to another litter, n=27; 22%; Appendix 12.1). One juvenile female rat was non-perforated (i.e. had not bred to date), while the other three were preparing to breed (i.e. had swollen ovaries) (Appendix 12.1). Of the adult male rats, most (n=101, 94%) had large bald testes (i.e. sexually mature and dominant; Appendix 12.1).

Only two of the three colour phases (*rattus*, *alexandrinus* or *frugivorus*) of adult black rats were caught on Redonda, with the brown and cream *frugivorus* phase being the most common (Figure 5, Appendix 12.1. Only 11% females and 12% of males caught on Redonda were of the brown/grey *alexandrinus* phase (Figure 6, Appendix 12.1).

Figure 4. Correlation between head-body length and tail length for adult black rats (n = 230; 123 female and 107 male) caught on Redonda in April 2012. ■ female; ● male .

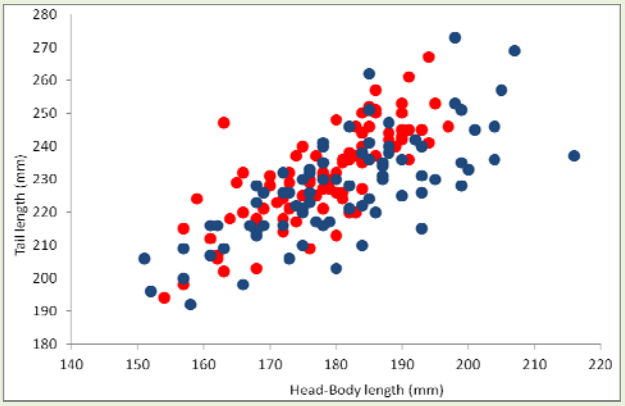
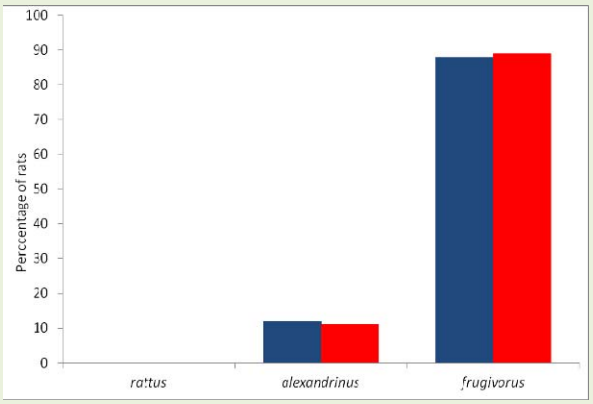


Figure 5. Colour phases of adult black rats (n = 230; 123 female and 107 male) caught on Redonda in April 2012. ■ females; ■ males.



2.1.2 Black rat abundance on Redonda

Monitoring the distribution and density of rats in an area is usually undertaken to determine the effectiveness of control operations or to determine current rodent levels. There are several methods (such as dropping identification, chew sign, night counts and tracking plates), but the most commonly used is index trapping. We used index trapping and tracking tunnels on Redonda.

Rat density is recognised as low (index of less than 10%, or fewer than 10 rats caught per 100 trap nights), moderate (between 11-25%), high (between 26-50%) and very high (over 50%) (King, 1990; Moors, 1985). Islands usually vary between 5-25% (5-25 rats per 100 trap nights), but there have been exceptions such as Campbell Island with 123% (King, 1990) and Mauritius with 102% (E.A. Bell, pers. obs.).

Index trapping was originally developed in New Zealand by the Department of Scientific and Industrial Research as a standardised method for sampling rodents in the same habitat and can obtain information on identification and relative abundance of rodents (Cunningham & Moors, 1993). The index of abundance that can be used to compare rodent populations in different regions, habitats, or seasons.

Figure 6. Examples of the two colour phases of adult black rats caught on Redonda in April 2012. Photo: E.A. Bell (WMIL) Where top rat = brown/grey *alexandrinus* phase and bottom rat = brown/cream *frugivorus* phase. Photo: E.A. Bell (WMIL).

We used back-breaker or kill traps (Big Snap-E®) for index trapping. The same type of trap was used for all index-trap lines. The traps were set as sensitively as possible. Rat traps were tied down so that injured

rats, or other rats eating the carcasses, could not drag them away. Traps were baited with peanut butter, which was replaced as necessary.

Trap sets were spaced 30 metres apart with two traps placed back to back at each set. There were 30 trap sets (60 traps) on the first night (10 April 2012) and 50 trap sets (with 99 traps) on nights two to four (11 to 13 April 2012). Traps were placed in level sites and made to be completely stable. Traps were placed where there was natural cover and where rats were likely to be active (i.e. rat runs, large rocks etc.). All trap sets were covered using vegetation or rocks and set in the evening and set off each morning to prevent non-target captures. Each trap line was mapped using GPS (Garmin e-trex) and plotted on GIS (Figure 2).

Index trapping was carried out from 10 to 13 April 2012. Trap lines were run for four consecutive nights and the traps were checked daily. Records were taken of date, location, trap number, capture, sprung trap (i.e. trap set off, but no capture) and still-set traps. Traps were only set overnight; traps were left in place during the day and reset at dusk.

These records were put into the formula to calculate the Index of Abundance (IoA, rats per 100 trap nights) for that area (Table 3, Cunningham & Moors, 1993). This formula makes allowance for traps that have been set off, but not caught a rat (i.e. corrected trap nights). A corrected trap night is assumed to have been set for half the night and set off for the other half (i.e. subtract half a night).

Table 3. Example of the Index of Abundance calculation (from Cunningham & Moors, 1993).

Factor	***Calculation***
50 traps run	Total trap nights (TTN) = number of traps x number of nights:- TTN = 50 x 3 = 150
3 nights	Lost trap nights (LTN) = ½ (captures + sprung, empty traps):-
7 rats caught	LTN = ½ (7+13) = ½ (20) = 10
13 sprung traps	Corrected trap nights (CTN) = TTN – LTN:- CTN = 150 – 10 = 140
	Index of Abundance (IoA) = $\frac{\text{captures x 100}}{\text{CTN}}$
	IoA = $\frac{7 \times 100}{140} = \frac{700}{140}$ = 5.0 rats per 100 trap nights (5%)

This study produced very high indices ranging from 122% to 139% over the four nights on Redonda (Table 4, Figure 8). The total rat density over Redonda is calculated to be at least 70 rats per ha (Table 4) which is extremely high and unexpected for an island of this size with such a depauperate ecosystem. Rat capture rates unexpectedly increased steadily over the four nights of trapping (Table 4), which differs from usual trapping trends (in which rat captures peak on night two and drop significantly by nights three and four). Complete trapping and indices of abundance information is given in Appendix 13.2. Rat activity was high throughout the site visit to Redonda and rats were commonly seen by all of the survey team members throughout daylight hours.

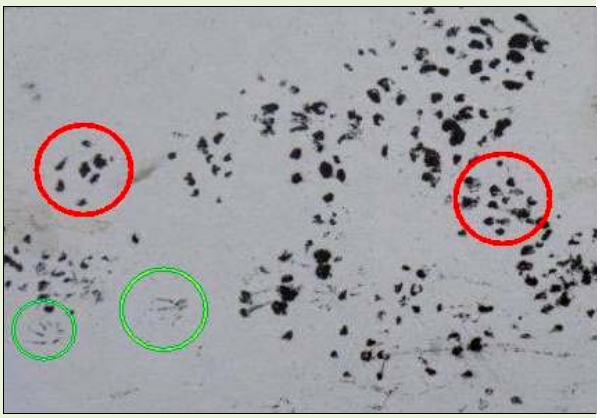
Table 4. Indices of Abundance calculated from index-trapping on Redonda (10-13 April 2012).

	Number of traps	***Rat Captures***	***Index of Abundance***	***Rats per hectare***
Redonda (Night 1: 10/4/12)	60	38	129 rats per 100 trap nights	12
Redonda (Night 2: 11/4/12)	99	68	127 rats per 100 trap nights	19
Redonda (Night 3: 12/4/12)	99	63	122 rats per 100 trap nights	18
Redonda (Night 4: 13/4/12)	99	73	139 rats per 100 trap nights	21
Total or Mean	**357**	**242**	**129 rats per 100 trap nights**	**70**
Mean (± SEM)		**61 (± 8)**	**129 (± 4) rats per 100 trap nights**	**18 (± 2)**

Tracking tunnels, also known as ink plates, were first developed to obtain presence/absence and activity information on rodents in Britain (Quy *et al.* 1993). This method has been adapted and standardised to estimate rodent abundance. Tracking tunnels were used on Redonda (Figures 2 and 7).

Figure 7. Example of a tracking tunnel in place (showing rat prints on card). (E.A. Bell, WMIL)

Figure 8. Rat and lizard tracks on tracking cards set on Redonda in April 2012 (E.A. Bell, WMIL): ■ rat prints; ■ lizard prints.



The tunnels were held in place by metal pegs (or rocks if the ground was too hard) and a card with ink spread in the centre was placed inside the tunnel (Figure 7). Tunnels were baited with peanut butter. Tunnels were spaced 30 metres apart, with 10 sets per line. Two tracking lines were established: one at the camp and the other near mining operation ruins (Figure 2). Tunnels were placed in level sites and made to be completely stable. Tunnels were placed where rats were likely to be active (rat runs, ruins, large rocks etc.). Each line was mapped using GPS and plotted on GIS (Figure 2).

Tracking tunnel index lines were run for two nights at each site and the cards were collected and replaced after each check. Records were taken of date, location, tunnel (and card) number and track (i.e. rat, mouse, or other).

The number of cards that had rat tracks present were used to estimate the tracking index (TI, or abundance, e.g. 4 out of 10 tunnels with rat tracks = 40% abundance). Tracking results were 100% rat density across Redonda for each night on each tracking tunnel set (Table 5). Both lizard and rat tracks were recorded on the cards (Figure 8).

Table 5. Indices of Abundance for black rats calculated from the tracking tunnels on Redonda in April 2012.

AREA	*Lizard*	*Rat*	*Index of Abundance (rats)*
Line 1 (Night 1: 12/4/12)	10	10	100
Line 1 (Night 2: 13/4/12)	10	10	100
Line 2 (Night 1: 12/4/12)	10	10	100
Line 2 (Night 2: 13/4/12)	10	10	100
Redonda (total)	**40**	**40**	**100**

Index trapping and tracking tunnels are an effective way of monitoring changes to rodent densities and activity in specific habitats (Brown *et al.* 1996; Blackwell *et al.* 2002). However, it is important to place

tracking tunnels in similar or the same habitat as the traps (Blackwell *et al.* 2002). It is also important to realise that the tracking tunnels are susceptible to the same individual rat tracking through a number of tunnels and that the spacing therefore needs to take into account the home range of the rat (Blackwell *et al.* 2002).

It is usually best to run multiple types of abundance estimates, which is why both tracking tunnels and index trapping were used on Redonda. The average rat density over Redonda from the tracking tunnels was 100%, which was lower than the density from the trapping index (129%), but this is related to number of tunnels available to rats rather than fewer rats in these sites. Rat tracks were abundant over the tracking cards (Figure 8), and this probably relates to higher densities of rats using the tunnels. Each card also recorded that lizards entered every tunnel as well as rats (Table 5, Figure 8).

It should be stressed that this density estimate is just a snapshot in time. Rat densities will fluctuate throughout the year, as well as over different years. Rats have been recorded at high levels by a number of visitors to Redonda, and it is likely numbers rise after wet periods, when there is an extended growing period resulting in more available food for rats (Morse, 1979).

Rats and rat sign were found all over the island, and our rat captures also showed similar densities along the length of the island. Rat sign was noted on the coast and slopes of Redonda, but appeared to be highest on the top of the island (area marked in green on Figure 35). This distribution pattern is common on most islands, where rats are dependent on foraging for food along the shore and among seabird colonies. This type of distribution generally results in greater impacts on the bird nesting locations.

2.1.3 Surveys to detect house mice **Mus musculus** *on Redonda*

House mice are an alien species in the Caribbean, and have been accidentally introduced to many islands, including Antigua, Barbuda and Montserrat. As the presence of house mice could affect the recovery of the biodiversity of Redonda, and alter the technical requirements of the eradication if targeted, it was important to assess whether mice were present. Mice have never been recorded on Redonda (Morse, 1979); but can be difficult to detect when rats are present, because rats can suppress the mouse population.

The tracking tunnels run during the site visit to Redonda were checked for the presence of mouse tracks. Surveys for mice tracks or feeding sign were also completed during checks of other areas over the island. No sign of mice was detected during this four-day site visit.

2.1.4 Stomach contents of black rats on Redonda

Only 204 adult rats (87%) had complete stomachs when removed from the traps (Appendix 13.3), the rest having been eaten by other rats, crabs and lizards. Analysis of stomach contents showed that the black rats on Redonda were eating a variety of prey and food items including bird eggs and chicks, lizards, vegetation (including prickly pear, *Opuntia* spp.), invertebrates and feral goat droppings (Figure 7, Appendix 13.3).

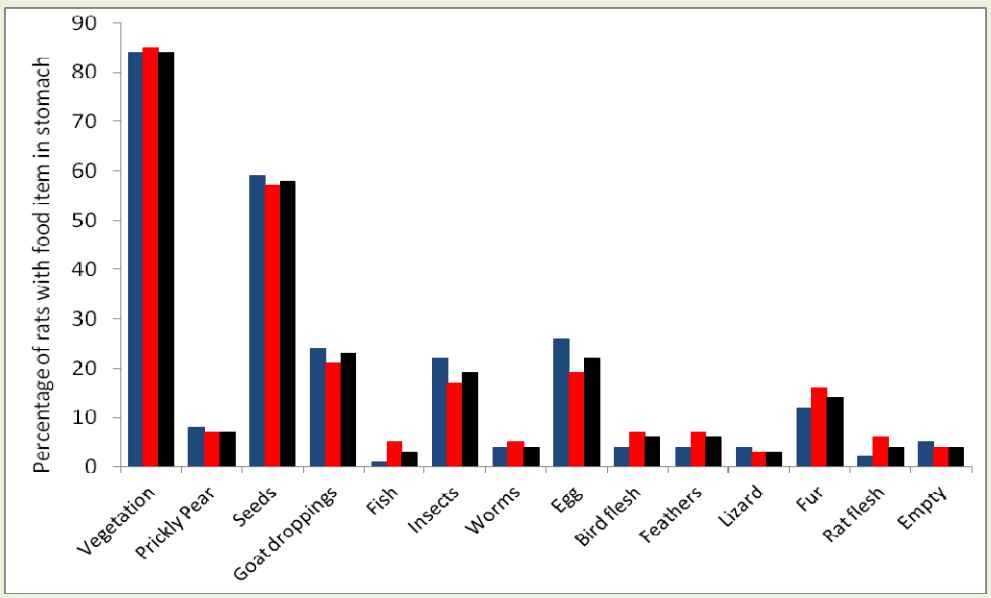
Most rats were eating vegetation (84%) and both males (8%) and females (7%) had prickly pear in their stomachs (Figure 7, Appendix 13.3). Rats also had eaten eggs (22%) and seabird chicks (6% flesh and 6% feathers in the stomachs) (Figure 7, Appendix 13.3). Several had rat fur (14%) or rat flesh (4%) after scavenging dead rats from the traps (Figure 7, Appendix 13.3).

The most surprising finding was that 23% of all rats had eaten goat droppings (Figure 7, Appendix 13.3), as their stomachs were full of fibrous vegetation and faecal material. This may sustain the rat population during lean times on Redonda, and probably makes up a large portion of their regular diet.

There was a clear tendency towards food items that were readily available at the time of this study, including goat droppings, vegetation, seabird chicks and eggs, and insects.

Only 4% of the rats caught on Redonda had empty stomachs (5% males and 4% females, Figure 7, Appendix 13.3). Over 10% of rats also had peanut butter and another 2% had flagging tape in their stomachs (Appendix 13.3).

Figure 9. Percentage of food items recorded in stomach contents of adult black rats caught on Redonda in April 2012: ■ female (n = 112); ■ male (n = 92); ■ all adults (n = 204)



2.1.5 Non-toxic bait trials

To determine whether rats on Redonda would take alternative food (i.e. bait), a grain-based pellet (a non-toxic form of PestOff® produced by Animal Control Products, New Zealand) was trialled. Bait was placed in the open around the campsite on Redonda on 12 April 2012. Rats took the pellets at the campsite immediately (Figure 11).

The non-toxic PestOff bait was also placed in the open in areas that were often used by feral goats ('Wild Goat Gorge' and 'Centaur's Cave') to assess whether feral goats would be at risk from this bait. No bait was taken by feral goats during this short trial, but further assessments on bait type and formulation is recommended.

Redonda ground lizards were not observed eating the non-toxic PestOff bait during these short trials, but the closely related Anguilla Bank ground lizard *Ameiva plei* on Dog Island, Anguilla, has been observed eating PestOff bait on a number of occasions (Bell, 2012). Again, it will be important to assess whether the endemic ground lizards on Redonda will be at risk from this or any alternative bait.

No other bait was trialled in 2012. In 1998, however, rats on Redonda were also offered Klerat® waxy bait and, again, accepted it very readily (Karen Varnham, pers. comm.). Figure 10 shows a black rat on Redonda eating a 20-g block of Klerat. This bait has been used in all previous rat eradication operations on Antigua, Anguilla and Saint Lucia, and has shown high rates of acceptance by black rats in this region without attracting attention from ground lizards or other non-target vertebrates.

Figure 10. (right) Black rat eating Klerat® bait on Redonda in 1998. Photo: J. Cancalosi (FFI).

Figure 11. (below) Black rat eating non-toxic, grain-based pellet (PestOff®) on Redonda in April 2012 Photo: J. Daltry (FFI-OICP).

2.2 Status and Distribution of Birds

2.2.1 Previous surveys

Redonda is rightly famed for its seabird colonies and has been designated an Important Bird Area (No. AG001) (Prosper *et al.* 2008). According to BirdLife International (2012), the breeding colonies of magnificent frigatebirds *Fregata magnificens*, masked boobies *Sula dactylatra*, red-footed boobies *S. sula* and brown boobies *S. leucogaster* are "regionally significant". The same source also states that burrowing owls *Athene cunicularia* are thought to be resident, but admits the quality of data from Redonda is 'poor'.

The most comprehensive study to have been carried out in recent years was Lowrie *et al*. (2012), but their work was restricted to counting the number of nesting pairs of seabirds in March 2009 and June 2010. They did not survey land birds, nor attempt to map the distribution of the seabird colonies.

2.2.2 Survey aims and methods

The main aim of the present survey was to determine which bird species are present on Redonda during the dry season – when an eradication would be carried out –, paying particular attention to those that might be positively or negatively affected by the proposed rat eradication. The second aim was to fill in gaps concerning the status and distribution of birds on Redonda, and clarify the significance of this site to Antigua and Barbuda and to the Caribbean region as a whole. Thirdly, the checklist of species, and the number of breeding pairs provided below, is intended to provide a baseline for monitoring changes in response to eradicating rats or other management actions.

From 10 to 13 April 2012, the second author (J.C. Daltry) systematically mapped the main seabird nesting areas on Redonda by searching across all accessible parts of the island on foot three times (green area on

Figure 35), using binoculars to scan the steeper slopes and cliffs. In addition, the cliffs surrounding the island were also viewed from a boat on 18 April 2012, focusing especially on recesses that were difficult to see while standing on the island. This proved especially useful for mapping the tree-nesting species on the steep Eastern coast. Most of the nests were spotted during the first searches of the island, on 10 and 11 April. All Apparently Occupied Nests (AONs) were plotted on a map of the island, based on the presence of nesting material and at least one of the following: eggs, chicks or an adult bird. Every AON was assumed to equate to one breeding pair, on the understanding that all of the species surveyed breed monogamously.

April coincided with the later part of the nesting season for boobies and frigatebirds, but many brown boobies and masked boobies were observed with eggs, possibly second clutches after losing young to rats or other hazards earlier in the season. This visit was too early in the year to survey any gulls, terns and noddies that might nest on the island.

Survey methods for other (non-seabird) species were opportunistic. The second author and other members of the survey team spent four days walking around the island, usually starting before dawn and continuing until dusk. All other species of birds seen during this time were also identified, counted and their location recorded.

Table 6. Number of breeding pairs of birds on Redonda since late 1990s

- = not discussed by authors.

Source	***Lindsay & Horwith (1997b)***	***Schreiber & Lee (2000)***	***Prosper et al. (2008)*** [c]	***Lowrie et al. (2012)***	***This study - J.C. Daltry***
Survey months	Not stated	Not stated	Not stated	March 2009 June 2010	April 2012
Species					
Red-billed tropic bird	-	100	-	62	30
White-tailed tropic bird	-	5-15	-	0	0
Bridled tern	-	0	-	41	0
Brown noddy[f]	-	?	47 (*140*)	31	0
Audubon's shearwater	?	0	0	? [d]*	0
Brown booby	Present [a]	"unknown"[b]	100 (*300*)	182	774
Masked booby	Present	? [b]	57 (*170*)	37	164
Red-footed booby	Present	1,000?[b]	100 (*300*)	166	c. 150[e]
Magnificent frigatebird	50-100	? [b]	167 (*500*)	108	119
Burrowing owl	-	-	? [g]	-	0
Peregrine	-	-	-	-	1*
Zenaida dove	-	-	-	-	2*

[a] "most common booby occurring in Redonda"; [b] Citing van Halewyn & Norton (1984) (reference not seen); [c] Number of breeding pairs obtained by dividing the *total number of individuals* including chicks (shown in brackets) by three; [d] "distant call thought to be heard"; [e] 98 occupied nests with large chicks plus approximately 50 fully fledged young on the East coast; [f] This is probably the 'egg bird' reported on Redonda by Naish (1873); [g] "thought to be resident" but no new evidence presented; * Present, but not confirmed to be breeding on Redonda.

2.2.3 Seabirds

Five species of seabird were recorded during this survey: brown booby, masked booby, red-footed booby, magnificent frigatebird and red-billed tropic bird. Table 6 summarises the numbers of nesting pairs recorded in April 2012, alongside previous bird survey findings for comparison.

Of particular note is the much higher number of brown boobies (774 pairs) and masked boobies (164 pairs) than in recent surveys. This is unlikely to be due to a genuine increase in their population, but rather the present survey was more thorough and took place when a larger proportion of these populations were still breeding. Even these figures may be too low because many booby chicks had already fledged and left the nest. It is also possible that some nests were missed, hidden among large boulders.

Drawing all their food from the sea, these colonies represent the main suppliers of nutrients to Dog Island, through their faeces, eggs, waste food and carcasses. Seabirds are important, if not essential, to supporting the island's native wildlife, but also help to maintain the large rat population.

Brown booby

This survey raises the confirmed number of nesting pairs on Redonda to 774, to give an estimated total colony size of well over 2,000 individuals (adults and young). The brown boobies nest on the flatter parts of the island up to the highest peaks, with some nests isolated and others in groups, often mixed with masked boobies. See Figure 12 for the distribution of nests. In April 2012, some chicks had already fledged while many other birds were still laying eggs. Although most of the birds laid two eggs, only one chick (at most) was raised to fledging.

Brown boobies nest on the ground. There is very little vegetation on Redonda, and most of the nests were formed from the dead stalks of the alien invasive herbs *Cleome* spp. When approached, nesting brown boobies tended to fly away if they were sitting on eggs or if the chick was a fledgling or well covered in down. The parent birds were generally reluctant to leave newly hatched chicks that were still bald (and thus likely to die if exposed to the full sun) and often struck out towards the legs of people walking by.

Brown boobies are a pantropical species, with the subspecies *S. l. leucogaster* recorded in the Caribbean. Brown boobies can be observed nesting from October/November until May (J. Daltry, pers. obs.), so it is possible that early breeders will have already left the island by April and the count of 774 pairs is therefore an underestimate.

Although Lowrie *et al*. (2012) recorded only 182 breeding pairs of brown boobies, they counted 729 brown boobies roosting "*within a precipitous ghaut*" on Redonda in 2009, which corroborates the observation that Redonda support a relatively large colony. The present, conservative count of 774 pairs is more than 20% of the total breeding pairs of brown boobies in the Lesser Antilles, 9% of the wider Caribbean population, and, remarkably, more than 1% of the known global population (see figures in Lowrie *et al.* 2012).

Masked booby

(Figure 36). This survey raises the confirmed number of nesting pairs on Redonda to 164, to give an estimated total colony size of just under 500 individuals (adults and young). Like the brown boobies, masked boobies nest on the flatter parts of the island up to the highest peaks, with some nests isolated and others in small groups, often mixed with brown boobies. See Figure 13 for the distribution of nests observed.

In April 2012, some chicks had already fledged while many other birds were still laying eggs. Although most of the birds laid two eggs, only one chick (at most) was observed being successfully raised to fledging. The behaviour of nesting birds was very similar to that of the brown boobies.

Figure 12. Distribution of active brown booby nests (April 2012)

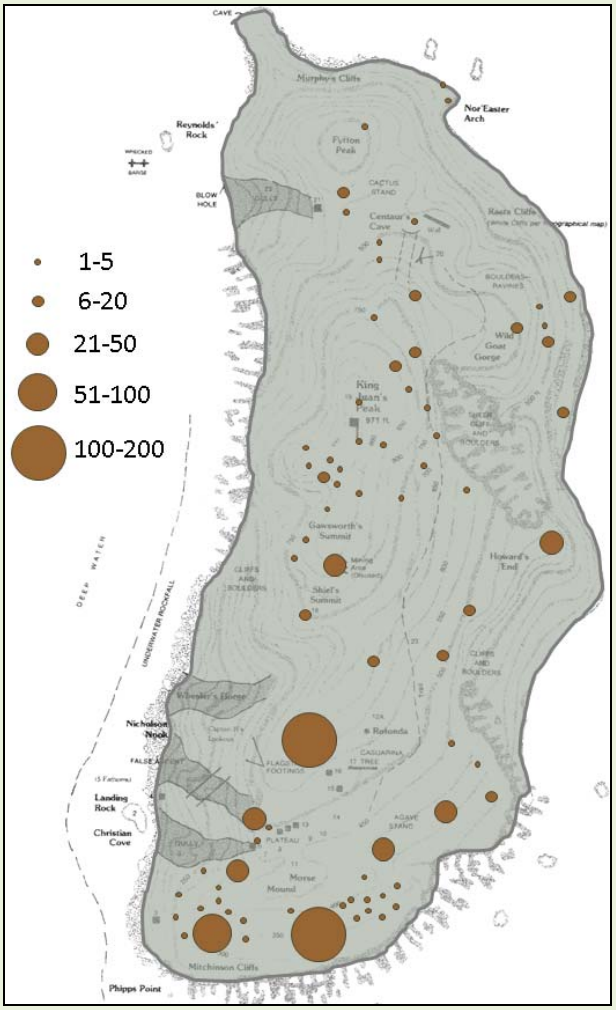
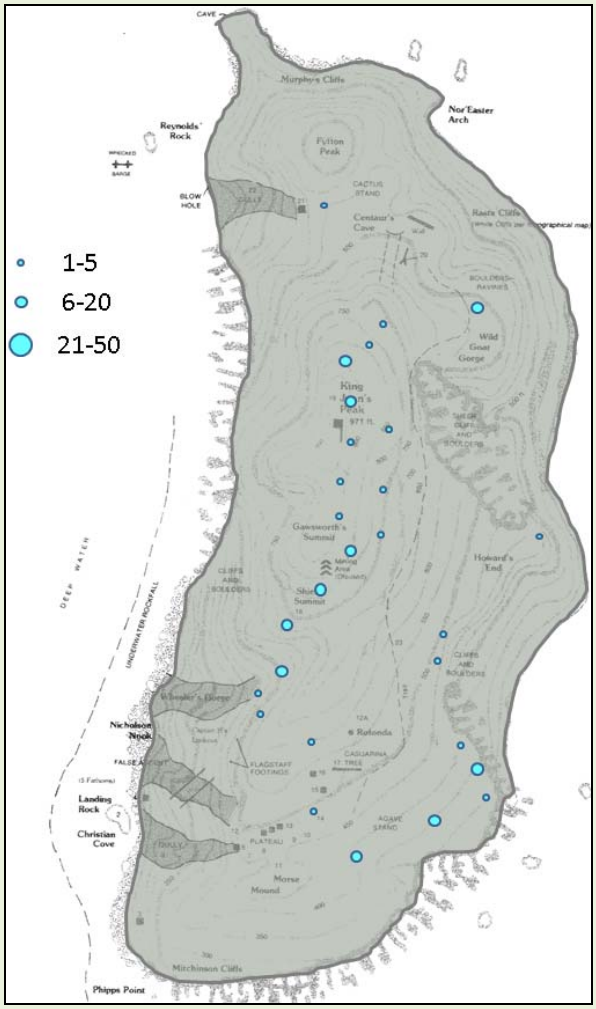


Figure 13. Distribution of active masked booby nests (April 2012)



The present count of 164 pairs represents more than 50% of the total breeding pairs of masked boobies in the Lesser Antilles and 15% of the wider Caribbean population, but only 0.25% of the global population (see figures in Lowrie *et al.* 2012).

Red-footed booby

This survey recorded at least 150 pairs, slightly fewer than 166 recorded by Lowrie *et al.* (2012) and considerably fewer than the 1,000 estimated by van Halewyn & Norton (1984). Red-footed boobies are a pantropical species that normally nest in trees. All of the nesting pairs observed during this study were in fig trees on very steep slopes or cliffs on the eastern side of the island. See Figure 14 for the distribution of nests observed. Both the brown phase and the white phase were present.

Schreiber & Lee (2000) report that red-footed boobies may nest on the ground where trees are not available, but this was not been observed on Redonda during the present study nor reported in previous surveys here. Red-footed boobies are markedly smaller than brown boobies and masked boobies, and their eggs and young are very vulnerable to rats, especially on the ground.

Figure 14. Distribution of active red-footed booby nests (April 2012)

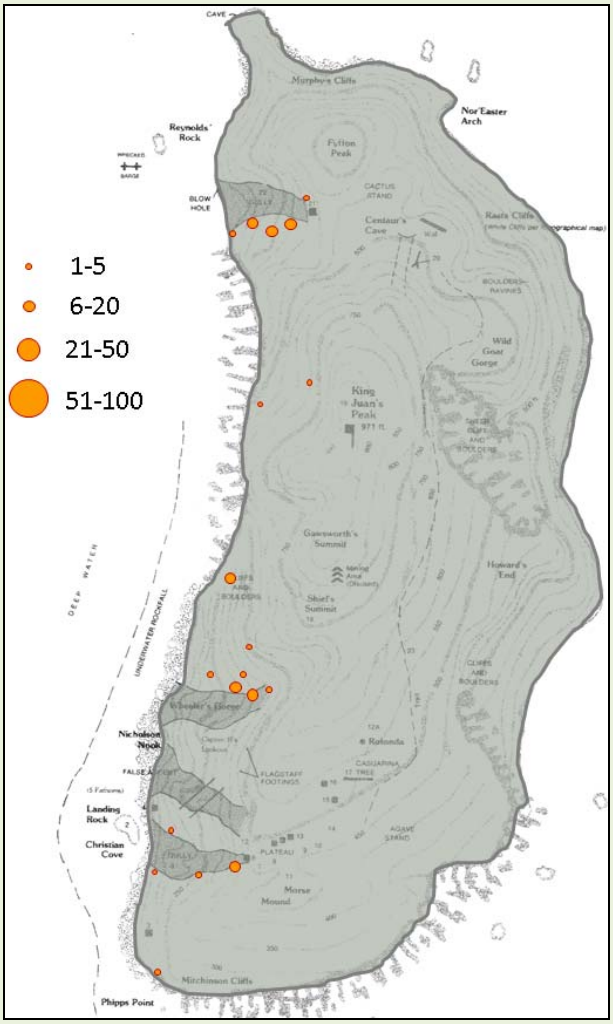
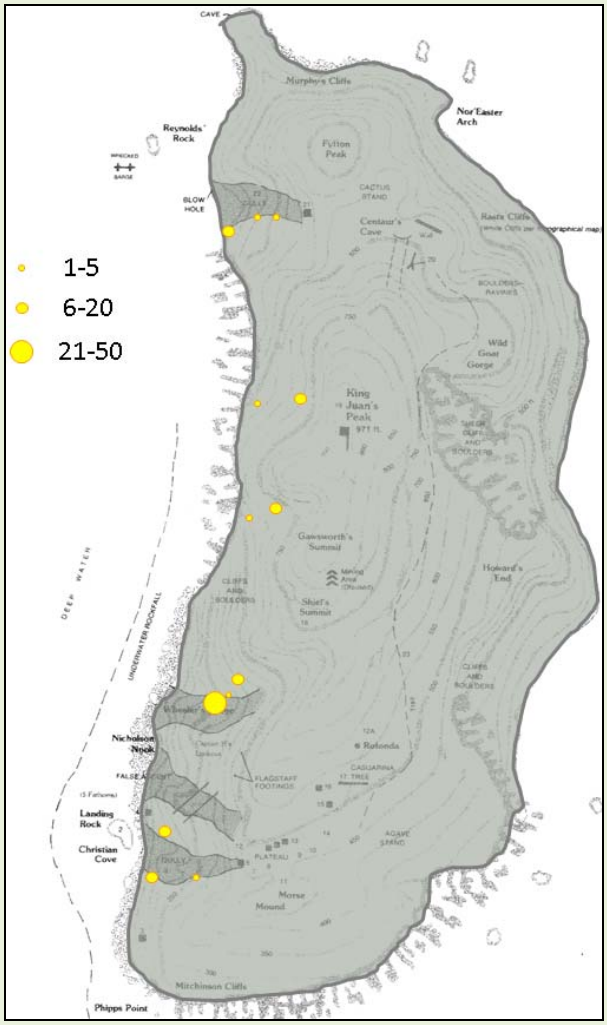


Figure 15. Distribution of active magnificent frigatebird nests (April 2012)



Redonda's red-footed boobies and magnificent frigatebirds appeared to prefer or need the same nesting habitats –sturdy fig trees with a broad crown – and sometimes occupy the same tree. Some aggressive interactions were observed between magnificent frigatebirds and red-footed boobies where their nests were in close proximity. The botanist Howard (1962) observed only a few scattered fig trees and three seedlings on Redonda, which he believed to have been newly introduced by frugivorous birds. However, there is strong evidence that Redonda used to be more densely covered in shrubs and trees (Section 2.6), and these tree-nesting seabirds could have utilised a variety of species in the past.

Although Raffaele *et al*. (1998) state that red-footed boobies nest in April and May, Schreiber & Lee (2000) consider the breeding season in the northern Caribbean to extend from October to May. By April 2012, it was clear that their breeding season on Redonda was nearing the end, and many birds had already fledged. Juvenile red-footed boobies formed loose groups along the cliff edge on the eastern side of the island, but it was impossible to assess how many had already left the island (young birds were observed far out to sea when we travelled to Redonda by boat on 18 April 2012). Future surveys should therefore ideally take place earlier in the year, perhaps January or February.

Based on the present, conservative count of 150 pairs, Redonda supports 8% of the total breeding pairs of red-footed boobies in the Lesser Antilles and 3.5% of the Caribbean population, but only 0.39% of the global population (see figures in Lowrie *et al.* 2012).

Magnificent frigatebird

(Figure 43). This survey recorded 119 breeding pairs - slightly more than other recent surveys - which equates to an estimated 357 individuals. Magnificent frigatebirds are a pantropical species that normally nest in low bushes (Raffaele *et al.* 1998). All of the nesting pairs observed during this study were in fig trees on very steep slopes or cliffs on the eastern side of the island, often in close proximity to red-footed boobies (above). See Figure 15 for the distribution of nests observed in April 2012.

The present survey was carried out quite late in the season, as frigatebirds may begin nesting in September or October (Schreiber & Lee, 2000), so it is possible that some young had already left the nest.

Frigatebirds commonly obtain food by taking it from other seabirds, and the frigatebirds on Redonda were observed harassing all of the other species of seabirds, especially red-billed tropic birds.

Based on the conservative count of 119 pairs, Redonda supports 12% of the total breeding pairs of magnificent frigatebirds in the Lesser Antilles and 2% of the Caribbean population (but only 0.18% of the global population: see figures in Lowrie *et al.* 2012).

Red-billed tropic bird

This survey recorded only 30 pairs in April, fewer than half of the 62 recorded by Lowrie *et al.* (2012) in March and June and considerably fewer than the 100 estimated by Schreiber & Lee (2000). The form on Redonda is the West Indian subspecies, *Phaethon aethereus mesonauta*, which ranges from Puerto Rico to islands off Venezuela and Panama. Nesting areas were detected on steep slopes and cliffs on both the eastern and western sides of Redonda (Figure 16).

It is likely that all of the above counts severely underestimate the number of red-billed tropic birds that use Redonda. Monitoring this species is particularly challenging because the tropic birds usually nest in natural crevices, often favouring those on steep cliffs. It takes time to detect nests by waiting for an adult to enter or leave, and many of the steeper cliffs on Redonda are not fully visible from above. A survey method that can work quite well on smaller islands is to count the number of adult birds in the air between approximately 3pm and 4pm, when they commonly gather together into flocks and fly around the island, calling loudly (J. Daltry, pers. obs.). However, Redonda is so large that it was difficult to determine whether the birds seen flying around different parts of the island belonged to the same or different flocks.

A further challenge is that the breeding season of the red-billed tropic bird is greatly extended (breeding on Antigua has been observed from September until June; J.C. Daltry, pers. obs.), and the birds or nests found at any one time may be only a fraction of those on the island each year. Future surveys should therefore be carried out at several times of year, ideally with multiple researchers stationed on different parts of the island.

Based on the Lowrie *et al.* (2012) count of 62 pairs, Redonda supports 1.9% of the total breeding pairs of red-footed boobies in the Lesser Antilles and 1.3% of the Caribbean population, and only 0.3% of the global population (see figures in Lowrie *et al.* 2012).

No white-tailed tropic birds were recorded during this survey, or by Lowrie *et al*. (2012), and it is questionable whether this species nests on Redonda.

Figure 16. Distribution of active red-billed tropic bird nests (April 2012) – note symbols use a different scale to previous species.

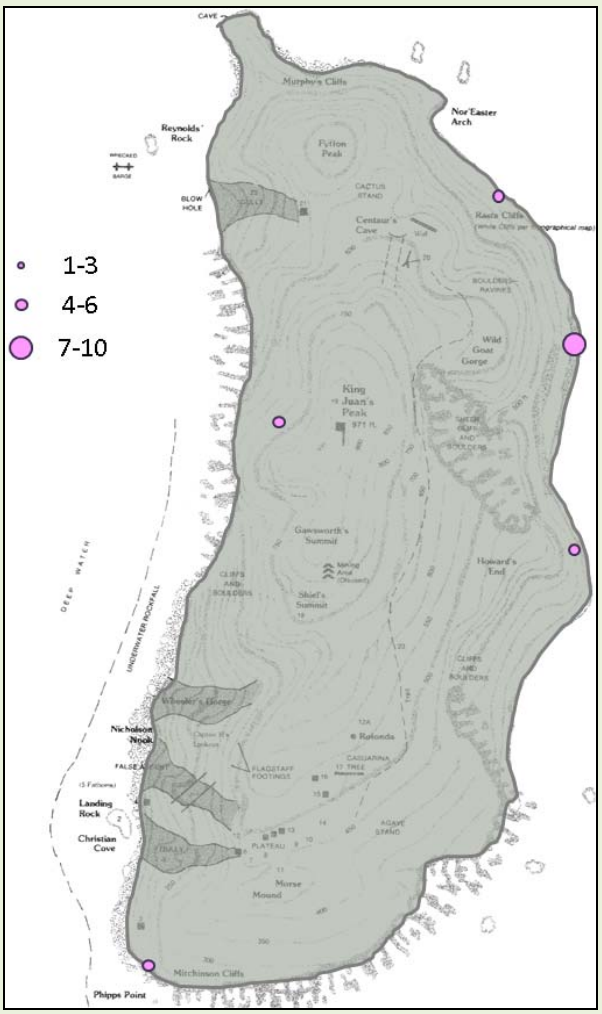
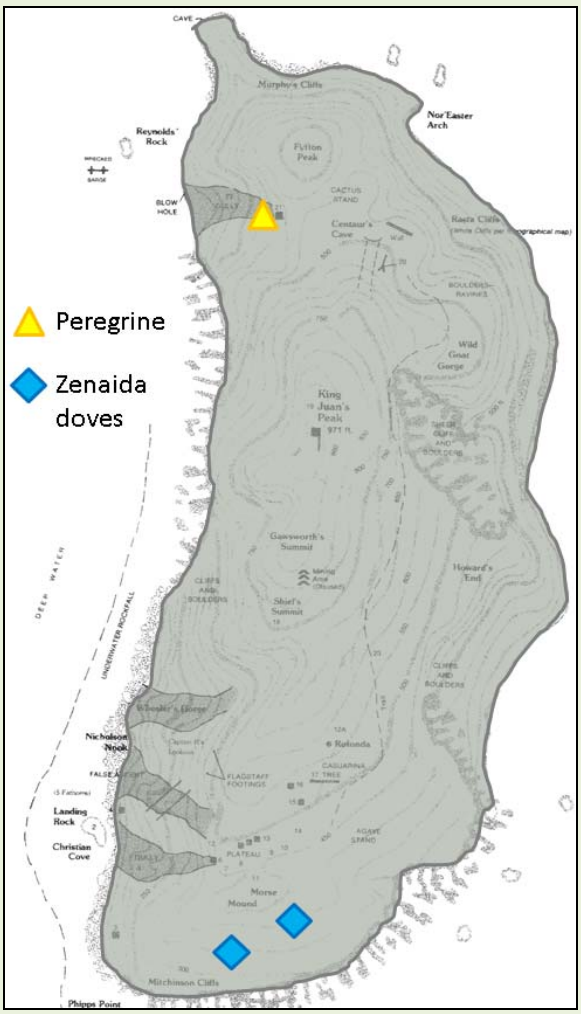


Figure 17. Distribution of other birds (April 2012), showing where the birds were most frequently sighted.



2.2.4 Other birds

In addition to the five species of seabirds, only two species of birds were seen during the April 2012 survey: peregrines and zenaida doves. Neither would prey on rats or carrion, but their eggs and young could be vulnerable to predation by rats.

Peregrine

A male and female *Falco peregrinus*, inferred to a breeding pair, were observed on several occasions in the Northwest of the island, and the female was seen on two separate days perched on a ledge near the top of the gully (as indicated on Figure 17).

Peregrines prey on other birds caught in flight, and it is likely this pair were preying on seabirds. The gully where the falcons were most frequently sighted may be their nesting area and/or they may be attracted by

the concentration of red-footed boobies (the smallest of the booby species) that nest on fig trees along the gully sides.

Zenaida dove

A small flock of four *Zenaida aurita* was observed on three successive days by J. Daltry and R. Camacho in the South of the island (Figure 17), usually close to the tallest stands of prickly pears. It is not known whether this dove breeds on Redonda, as no nests were observed. This species is common in the West Indies, where it typically nests in bushes and trees, and feeds mainly on seeds on the ground (Raffaele *et al.* 1998).

Other species previously reported on Redonda, but not seen during the April 2012 survey, are:

Burrowing owl: Specifically the Antiguan subspecies *Athene cunicularia amaura*, which has disappeared across the rest of its range (Antigua, St Kitts and Nevis). This species was apparently first reported by J.F. Clarke (in Schmitt, 1959): "*most noteworthy among the feathered residents was the burrowing owl,* Speotyto cunicularia amaura*. Identified by Dr. Alexander Wetmore from my description of its appearance and plaintive call, this is a new record for the species*". While no special effort was made to locate burrowing owls, it is could be significant that neither sightings nor signs (pellets, calls) of these owls were found when our four biologists walked all over the island for four days. Burrowing owls are active both night and day, and generally not very difficult to spot when they are present in open habitats. No other recent surveys on Redonda have reported burrowing owls. It is possible, if not very probable, this species has disappeared. Burrowing owls are generalist predators that take rodents as well as lizards and insects, but any eggs and chicks on Redonda would be highly vulnerable to predation by rats.

American kestrel: Kestrels *Falco sparvarius* nested on Redonda in the late 1990s (Kevel Lindsay, *in litt.*, described this as the most common non-seabird), but none were seen during the present survey. These raptors are present on neighbouring islands (Montserrat, St Kitts, Antigua) and can move readily between islands. American kestrels often feed on lizards and insects, and may be capable of taking a rat.

Kevel Lindsay commented (*in litt.* to J Daltry) that "*Overall, a number of birds have been reported for Redonda since the earliest reports, some IDs you can only guess according to the common name used at the time or the description. Birds included hummingbirds (both common spp.), ground doves, the bullfinch, bananaquit and grassquit*". However, no dates or other details of these sightings were given.

What is most striking is how few birds - both in terms of the number of species as well as the number of individuals – were observed on Redonda in 2012. We believe the island is too small and open for our team to have missed the sight or sounds of other bird species on this visit. Besides, most birds - even such common and adaptable species as the bananaquit and Lesser Antillean bullfinch - would struggle to find suitable food or safe nesting sites on Redonda in its present state.

2.2.5 Evidence of impacts on birds from alien mammals

While Redonda undoubtedly deserves its recognition as an Important Bird Area, it currently falls far short of the diversity and abundance of species that it could support if its ecosystem was in good condition.

The island has fewer seabirds than might be expected from size, terrain and absence of humans. As Lowrie *et al.* (2012) states: "*The key target for conservation action should be Redonda. It appears to be below its carrying capacity for breeding seabirds as a result of the large rat population almost certainly taking seabird eggs and chicks and the presence of feral goats*".

Besides finding eggs gnawed by rats, our team witnessed seabird chicks being killed and eaten by rats. Figure 18 shows an example of a brown booby chick that was expertly scalped by a rat. An even larger

chick was observed being dragged away by a rat. The fact that the black rats on Redonda are bold and large (Section 2.1) means they can overpower relatively large animals: the lack of small prey may well be driving a strong selection pressure on the black rats to reach record sizes. It is understandable why these black rats have been mistaken for brown rats *Rattus norvegicus* (e.g. Prosper *et al.* 2008; Lowrie *et al.* 2012).

Figure 18. A brown booby chick, moments after being mauled by a rat (T. Aveling, EAG-OICP)

Figure 19. Black rat eating an older booby chick (J. Daltry, FFI-OICP)

Historically, the density and perhaps diversity of seabirds appears to have been considerably higher. Southee (1859) described a visit to the island in March 1959 where he remarked upon "*the immense quantity of young boobies. They were crowded so thick on the ground, that in some places we could not pass without kicking or treading on them*." Naish (1873) cited a report from visiting naturalists that "*The boobies were so numerous that we knocked them down with sticks*". The fact that the island was used for guano mining for many years is a further indication that is used to support a much greater density of birds than it does today. The miners were reportedly forbidden to harm the birds.

In addition to predation on seabirds, the alien mammals affect seabirds by reducing the quality of nesting habitat. Space for the tree-nesting magnificent frigatebirds and red-footed boobies is now in very short supply, with all of these birds vying for space on a few mature fig trees that cling to the cliff edges on the Eastern coast. The fact that there is no apparent tree regeneration on the island means that nesting habitat is projected to decline as the existing trees die off, likely leading to the decline and demise of the colonies of red-footed boobies and magnificent frigatebirds. Brown noddies also appear to prefer to nest in shrubs and trees and may struggle to maintain a colony on this island. Rats are known to play a key role in suppressing vegetation by feeding on seeds, roots and seedlings, but probably the main culprits here are the feral goats (Section 2.4).

As noted by Lowrie *et al*. (2012), it is remarkable that there are no recent records of sooty terns, a globally widespread (pantropical) and abundant species, nor indeed any other terns apart from a handful of bridled terns (not seen during the present visit). Even laughing gulls are absent. Small, ground nesting seabirds are especially vulnerable to rat predation and trampling by goats. Lowrie *et al*. (2012) pointed out that goats can trigger rock slides while moving around on Redonda's loose slopes, crushing nests below. While we did not see crushed nests during the present survey, it was certainly hazardous to be downslope of the goats, as they frequently cause small rocks to tumble down.

There is strong circumstantial evidence that land birds have been even more severely affected by the alien mammals. Our total head count in April 2012 was only two peregrines and four zenaida doves, and we are confident that no other species or individuals were missed. The apparent absence of many common species may best be explained by a combination of predation of chicks and young by rats, and the lack of trees and shrubs due to previous human activities and overgrazing by feral goats and black rats. While is perfectly possible ospreys and other species pass through on migration, and raptors from neighbouring islands might come to hunt rats or lizards (Kevel Lindsay, pers. comm.), overall there is a remarkable dearth of resident land birds.

2.3 Status and Distribution of Reptiles

2.3.1 Preamble

In terms of global conservation significance, Redonda's most important and irreplaceable residents are its endemics species. At least four of the terrestrial reptiles that have been recorded on Redonda to date are found nowhere else, and all of them are threatened with extinction (see below and Table 7).

Previous work on the reptiles has been limited, however, and little has been published. Toby Ross (2011) conducted a rapid survey of the relative abundance of ground lizards and tree lizards.

2.3.2 Survey aims and methods

The main aim of the present survey was to determine which reptile species are present on Redonda, paying particular attention to those that might be affected by the proposed rat eradication. The second aim was to fill in gaps concerning the status, distribution, ecology and conservation needs of lizards on Redonda. Thirdly, the density counts of two species – the Redonda ground lizard and Redonda tree lizard – will be a useful baseline for monitoring changes in response to eradicating rats or other actions.

The main survey method used was standardized point counts (used to evaluate the density and distribution of ground lizards and tree lizards - see below for details). However, general searches were also conducted for other species, in particular, rocks and other surface objects were turned over to find geckos.

For safety reasons, little work was carried out at night: only brief visual searches by torchlight close to the project campsite on the Plateau (Figure 1, Figure 47). No live traps were used during this short survey, mainly because of the difficulty of protecting captured lizards from overheating and the predatory rats.

Assessments of the lizards' global conservation status followed IUCN (2001).

2.3.3 Terrestrial reptiles

Of the six species of terrestrial reptiles (all lizards) recorded on Redonda, only three species were confirmed to be present during the 2012 survey (Table 7).

Redonda ground lizard

The Redonda ground lizard *Ameiva atrata* is a highly active, diurnal lizard that is almost entirely black above and blueish grey below (Figure 20). This species is relatively large, with some males exceeding 15 cm from snout to vent. Its closest relative is the Montserrat ground lizard, *A. pluvionotata*. The males and females are almost identical in appearance, but adult males tend to be larger and have a more robust head. Like other ground lizards, each adult occupies a distinct home range that overlaps with those of other males and females, and the animals spend most of the day walking all over their ranges in search of food.

Figure 20. Redonda ground lizard *Ameiva atrata* – an island endemic (J. Daltry, FFI)

Figure 21. Redonda ground lizard being eaten by a rat (T. Aveling, EAG-OICP)

Ninety-six point counts were carried out to provide baseline information on the density and distribution of ground lizards by J. Daltry (26), R. Camacho (36), T. Aveling (19) and E. Bell (16) across the 'safe' zone of the island (shown in green on Figure 35) during dry weather between 09:00 and 17:00 hours. Every point count was an imaginary circle of 10 metres radius. To conduct a point count, a single observer stands or sits at a randomly selected observation point and counts every lizard that comes within 10 metres' radius. The point counts began not less than five minutes after arriving at a site to allow the lizards to adjust to the presence of the observer, and every survey lasted exactly 10 minutes. The time of day and weather was recorded, because these can affect lizard activity.

Both ground lizard and tree lizards (see below) were surveyed simultaneously from the same observation points, recording only those individuals within the designated distance for their species (10 metres and 2 metres respectively). The lizards typically resumed normal basking, displaying, and foraging activities shortly after the arrival of the observer, and occasionally used the observer as a perch. It is not difficult to avoid double-counting the same individuals.

During the 96 point counts, a total of 443 ground lizards were recorded, of which 111 (25%) were tentatively classed as juveniles (the animals were not captured for closer examination). Given the area of each point count circle is 314.46 m^2 (for a radius of 10 metres), this survey gives a mean density of 146.89 individuals per hectare for the area sampled. This in turn indicates a population of between 4,400 and 7,800 on Redonda (Table 7). The lower figure may be more realistic because the lizards appear to be much scarcer on the cliffs and scree slopes than within the flatter, more food-rich areas that were sampled. Indeed the highest point count figures were recorded within the main booby nesting areas, where there is a more reliable supply of fish, carrion and invertebrates.

While 147 individuals per hectare might sound high, this is below the densities of closely related species in healthier, more vegetated island habitats. For example, 483 *Ameiva griswoldi* per hectare on Redhead Island, Antigua (Smith *et al.* 2002); 460 adult *Ameiva ameiva* per hectare on Grenada (Simmons *et al.* 2005); 375 *A. erythrocephala* per hectare on Sint Eustatius (Kerr *et al.* 2005) and even 229 *A. plei* per hectare on the rat- and goat-damaged Dog Island, Anguilla (Daltry, 2010). It can be safely concluded the number of ground lizards on Redonda is significantly below the natural, pre-1700s carrying capacity of the island. This population continues to be constrained by the low density of invertebrate prey and by predation by, and competition with, black rats.

Like rats, Redonda ground lizards are highly omnivorous. In April 2012, lizards were observed feeding on carrion, including dead seabird chicks (Figure 39), dead rats and dead fish (dropped by seabirds), beetles and moths. They probably also take *Opuntia* fruits and figs, when available.

The lizards were generally observed to be in good condition, but many had damaged tails that could be indicative of heavy predation pressure and/or intraspecific fighting. On 11 April 2012, all members of the survey expedition observed a large adult male ground lizard chasing, catching and killing a smaller ground lizard (gender unknown), before pulling it into a crevice. This attack appeared predatory, but may have been triggered by a conflict over food or other resources. Tom Aveling reported a plausible sighting of a ground lizard killing a tree lizard. It is very likely the larger ground lizards prey on other, smaller lizard species on Redonda.

In the past, the main natural predators of the ground lizards on Redonda would have included kestrels or broad-winged hawks and burrowing owls, but none of these raptors were found in 2012. Black rats feed on lizard eggs and were observed attacking even large adults (Figure 21). Lizard remains were found in the guts of approximately 3% of the black rats autopsied (Section 2.1.4). This species would therefore be expected to benefit greatly from the eradication of rats.

Based on the fact that these lizards are confined to a single, small location, the threat from rats and the ongoing decline in the quality of habitat (see Section 2.6), the Redonda ground lizard firmly meets the IUCN Red List category of **Endangered**, specifically EN B1ab(i,ii,iii,v),B2ab(i,ii,iii,v),C2a(ii), if not Critically Endangered. This species has not previously been assessed.

Redonda tree lizard

The Redonda tree lizard or anole *Anolis nubilus* (also commonly spelled *nubilis*) is an active, diurnal lizard that is predominately greenish-grey in colour (Figure 22). This species is generally smaller than the ground lizard, rarely exceeding 8 cm from snout to vent. This species has been kept in captivity, where it fed on arthropods (Flaschendrager & Wijffels, 1996; 2009; cited by Henderson & Powell, 2009).

Point counts were carried out to provide baseline information on the density and distribution, using the same 96 observation points used for the ground lizards (above), all spread across the 'safe' zone of the island (shown in green on Figure 35). For the Redonda tree lizards, however, every point count was an imaginary circle of 2 metres radius (*cf.* 10 metres for the ground lizard). A smaller radius was selected for the tree lizards because they are generally much smaller, less mobile, often well camouflaged and thus may be concealed from sight over a larger distance. As for the ground lizard point counts, which were carried out simultaneously, the observer stood or sat almost motionless at the centre of the circle (the observation point) and counts every lizard observed within the specified distance. Point counts began not less than five minutes after arriving at a site to allow the lizards to adjust to the presence of the observer, and each survey lasted 10 minutes.

Anole densities can be estimated by knowing the area of the circle (12.57m^2 for 2 metres radius). This survey produce a mean of 770.91 individuals per hectare within the 'safe' access zone (Figure 35), with some individuals found up to the highest peak. However, the distribution of tree lizards was very uneven, with the highest concentrations around the few trees on the island. They appear scarce on non-vegetated areas and very rare/ absent on scree slopes. This suggests the total population, including juveniles, lies somewhere between 15,000 and 30,000, and probably nearer the lower end of this scale.

While these densities might sound impressive, many related species reach much higher densities in healthier, more vegetated island habitats. For example, *Anolis stratulus* numbers 23,600/ha in parts of Puerto Rico (Reagan, 1992), *A. cristatellus* is recorded at 1,000-1,100/ha on Guana Island, British Virgin Islands (Rodda *et al.* 2001), *A. wattsi* attains 4,780-9,950/ha on Saint Eustatius (Henderson & Powell, 1999), and *A. luciae* numbers 2,700/ha on the rat-free Maria Major island, Saint Lucia (Daltry, 2009).

Figure 22. Adult male Redonda tree lizard *Anolis nubilus* – an island endemic (J. Daltry, FFI)

Figure 23. The dwarf gecko *Sphaerodactylus* sp. – this one was later released (J. Daltry, FFI)

Historically, Redonda tree lizards are inferred to have been more abundant and highly arboreal, much like their closest relatives, the Montserrat tree lizards *Anolis lividus*, which descend to the ground to forage, but otherwise spend most of the time perched on shrubs and trees. At night, Montserrat anoles typically sleep on leaves at the end of fine branches, remaining out of the reach of most predators (J. Daltry, pers. obs.). On Redonda's solitary casuarina tree, the Redonda tree lizards were similarly observed perched several metres above the ground, and this tree appears to be a prized location for the most dominant adults in the vicinity. The ongoing deforestation of Redonda has forced most of this lizard population to live among boulders and, while they have adapted surprisingly well to this, they are undoubtedly exposed to much greater risk of predation by rats, raptors, and probably ground lizards (see above).

Based on the fact that these lizards are confined to a single, small location, the threat from rats and the ongoing decline in the quality of habitat (see Section 2.6), the lizards qualify at the very least for the IUCN Red List category of **Vulnerable**, specifically VU B1ab(i,ii,iii,v),B2ab(i,ii,iii,v),C2a(ii),D2, and could even be placed in a higher category. (This species is currently listed by IUCN as Least Concern, but this was entirely based on old and poorly substantiated information, and failed to take into account the ongoing deterioration in habitat quality).

Dwarf gecko

Redonda is known to contain a species of dwarf gecko, *Sphaerodactylus* sp. (Daltry, 2007), first reported by Kevel Lindsay during the 1990s, but not identified (H. Kaiser, *in litt.*). Several individuals have been seen and photographed by J. Daltry in recent, brief visits to the island, all beneath rocks under the casuarina tree near the mine manager's house (Figure 41).

On the present survey, a more concerted effort was made to find the geckos and obtain specimens to support the identification and, if necessary, the first formal description of this species. Between 10 and 12 April 2012, J. Daltry found five individuals under rocks. One under a root ball – the remains of a long-dead *Agave karatto*; one beneath a paving slab by the mine manager's house; one under a stone at the base of the casuarina tree beside the manager's house; and the final two were under rocks by the tall stands of prickly pears (*Opuntia*) on the southern end of the island (Figure 45). The final two were collected as voucher specimens by J. Daltry and a description of the species is under preparation.

Not fewer than 400 rocks and other surface objects were turned over by J. Daltry to reveal these five dwarf geckos, and R. Camacho and T. Aveling also turned over dozens of rocks without seeing any. Based on the experience of surveying dwarf geckos of the genus *Sphaerodactylus* on many islands across the West Indies, this is a very poor detection rate. Dwarf geckos normally and naturally occur at very high

densities. For example, *S. parvus* reaches 52,000 per hectare on Anguilla (Nava *et al.* 2001), and *S. macrolepis* numbers up to 67,000/ha on Guana Island, British Virgin Islands (Rodda *et al*. 2001). On Grand Terre, *S. fantasticus* has been recorded at densities of 10,000 per hectare (Breuil, 2002, cited by Henderson & Powell, 2009). On many islands in this region, one can expect to find a dwarf gecko after turning only a few suitable rocks or other surface objects.

The sample size of five individuals is rather too low to provide reliable density estimates. However, if every overturned object represents on average, an area of 30 cm x 30 cm, and suitable objects cover 70% of the island surface that was surveyed, this gives a crude estimated density of *Sphaerodactylus* on Redonda of between 700 and 800 individuals per hectare. However, the fact that all five specimens were found in association with trees (which are scarce), agaves (all now dead on Redonda) or tall *Opuntia* (also very scarce) suggests that the distribution of this species is very patchy. If these geckos are indeed closely tied to the distribution of large plants, their effective distribution range is only a few hectares, and declining.

Why is this dwarf gecko scarce? The low diversity and abundance of very small invertebrates could be a key factor because members of the genus *Sphaerodactylus* prey mainly on small ants and termites, which also appear to be scarce and patchy because of the overall deforestation and desertification of Redonda by humans, goats and rats. Dwarf geckos also tend to prefer areas with higher humidity, especially microhabitats with a dense canopy cover and deep leaf litter, which are very scarce on Redonda.

Based on the fact that these lizards are confined to a single, small location, the threat from rats and the ongoing decline in the quality of habitat (see Section 2.6), the Redonda dwarf gecko population belongs in the IUCN Red List category of **Critically Endangered**, specifically CR B1ab(i,ii,iii,v), B2ab(i,ii,iii,v).

Before these geckos can be formally placed on the IUCN Red List, however, it is first necessary to determine their taxonomy. Preliminary morphological examinations by J. Daltry confirm that they are not the Antigua and Barbuda dwarf gecko *S. elegantulus*, but appear more closely affiliated to *S. fantasticus*, a highly variable species in the Windward Islands that has been divided into a number of distinct island subspecies. Further study is required to determine whether the Redonda dwarf geckos are a new subspecies of *S. fantasticus* or constitute a different species entirely.

Other species previously reported on Redonda, but not seen during the April 2012 survey, are:

Redonda skink. The endemic lizard *Copeoglossum redondae* was very recently described by Hedges & Conn (2012), based on a single museum specimen that was collected sometime between 1863 and 1873 and deposited at the Academy of Natural Sciences of Philadelphia. This new species was previously misidentified as *Mabuya mabouya, M. sloani* or *M. bistriata*. Many species of skinks have declined or become extinct in the Lesser Antilles, putatively due to alien invasive mammals (e.g. Daltry, 2009; Hedges & Conn, 2012). If any skinks remain on Redonda, they qualify as Critically Endangered (Hedges & Conn, 2012) and merit urgent attention.

Iguana. An unidentified species of iguana (*Iguana* sp.) has been recorded on Redonda (Naish, 1873; Underwood, 1962), but no sightings have been reported in over 70 years. Their colour was described as 'dirty brown' (Naish, 1873), but this is not a very useful guide to identity. In view of Redonda's proximity to Antigua and Montserrat, the species might have been the regionally endemic and globally Endangered Lesser Antillean iguana *Iguana delicatissima* (which historically occurred on Antigua), or a native or introduced form of green iguana *I. iguana* (which still occurs on Montserrat). Interestingly, genetic studies have indicated that the 'common green iguanas' of the Windward Islands might belong to new, undescribed species (C. Malone, *in litt.*; Daltry, 2009). Iguanas can be difficult to detect, especially when their densities are low, but seems very unlikely any iguanas could remain on Redonda due to the lack of vegetation on the island.

House gecko. The alien invasive lizard *Hemidactylus mabouia* was reported on Redonda by Censky & Kaiser (1999). This species is highly commensal and usually associated with buildings. Little effort was made to search for this species at night, except within the immediate vicinity of the project camp, and it may still be present on the island.

2.3.4 Marine reptiles

Naish (1873) reported that pigs kept on Redonda were fed on turtle meat. Two marine turtles have been frequently sighted close to Redonda – the green turtle *Chelonia mydas* and hawksbill turtle *Eretmochelys imbricata*. During the present survey, more than dozen turtles were seen in the sea within 100 metres of Redonda, mostly off the Southeast coast, but were not identified to species. A number of photographs of the turtles were taken by R. Camacho.

While it is likely the waters around Redonda provide feeding habitat for turtles, it seems very improbable that any of them nest here because of the shortage of sandy nesting beaches. Predation of turtle eggs by rats is therefore not considered to be an issue, and these species are unlikely to be affected positively or negatively by the proposed rat eradication.

Table 7. Reptiles of Redonda

Species	*Distribution*	*IUCN Red List Status*	*Estimated population size*	*Notes*
Redonda ground lizard *Ameiva atrata*[a]	Redonda endemic species	Not listed. Meets criteria for Endangered	4,400-7,800	Active and relatively abundant. Easily monitored.
Redonda tree lizard *Anolis nubilus*	Redonda endemic species	Least Concern, but meets criteria for Vulnerable.	15,000-30,000	Active and relatively abundant. Easily monitored.
Dwarf gecko *Sphaerodactylus* sp.	Redonda endemic species or sub-species?	Not listed. Meets criteria for Critically Endangered	<5,000	Not easy to find or monitor. Two specimens collected to identify/ describe species.
Redonda skink *Copeoglossum redondae*	Redonda endemic species	Not listed. Extinct?	0?	Species described by Hedges & Conn (2012). Not seen since late 18th century
Iguana (*Iguana* sp.)	Unknown, presumed native	Extinct?	0?	Not seen for more than 70 years.
House gecko *Hemidactylus mabouia*	Widespread, alien invasive	Not listed. Meets criteria for Least Concern	?	Recorded by Censky & Lindsay (1999). May still be present.
Green turtles *Chelonia mydas*	Pan-tropical, native	Endangered.	N/a	Both turtles present in near-shore waters, but probably unable to nest on Redonda.
Hawksbill turtle *Eretmochelys imbricata*	Pan-tropical, native	Critically Endangered	N/a	

[a] *Ameiva atrata* is most closely affiliated to Montserrat's *A. pluvionotata*, and used to be classified as its subspecies, *A. p. atrata.* Censky & Kaiser (1999) listed both *A. atrata* and *A. pluvionotata* on Redonda, but this was presumably in error.

2.4 Status and Distribution of Feral Goats

2.4.1 Preamble

Goats are not native to the Caribbean, but may have been deposited on Redonda as food supply for early explorers in the 16th and 17th centuries. During Redonda's mining period, it is possible the animals were harvested to feed the miners, and additional stock may have been imported. Sheep and, according to Naish (1873), pigs and rabbits were also brought to the island during this period, but no longer exist here. The goat population is now totally wild and it appears that nobody claims ownership, but individuals are occasionally caught for meat or removed alive by persons from Montserrat (M. Morton, pers. comm.).

Redonda's goats have not apparently been the subject of a study before, and very little information is available. During a seabird survey, Lowrie *et al.* (2012) estimated there were between 50 and 100 goats on the island, and saw one group numbering 32 individuals. On previous visits by the second author during periods of drought, a dozen goat carcasses were found scattered around the Plateau (and they may well have been others elsewhere on the island), apparently having died from starvation. The goats are generally larger and have more impressive horns than the domestic goats on Antigua, but look superficially similar to many other 'Spanish type' feral populations on islands worldwide, such as the Catalina islands (California) and Galapagos. The goats have not been ascribed to any particular breed, to the best of our knowledge.

2.4.2 Survey aims and methods

The main aim of the present, rapid survey was to fill in knowledge gaps concerning the status, distribution and ecology of goats on Redonda. Insofar as the rat eradication is concerned, the goats are regarded as non-target animals: to avoid them taking poison intended for rats, it is important to learn more about their habits before proceeding with a rat eradication operation. On the other hand, goats are an alien invasive species that have long been known to have significant, serious impacts on island habitats and wildlife (e.g. Coblentz, 1978). Given that the rat eradication is being proposed in the context of supporting the recovery and conservation of native biodiversity on Redonda, further data on the goats could help determine whether they too require active management.

The feral goats were counted first by identifying the various groups and then counting their individual members (from a suitable vantage point and with the aid of binoculars). The goats on Redonda are highly variable in colour (possibly an indicator of mixed ancestry) and in the shape and size of their horns, which made it quite easy to learn to recognise individuals and avoid double-counting. Every individual was classed as an adult male, adult female or juvenile.

This census method was carried out by J. Daltry alone to reduce the risk of double-counting the same individuals, but other members of the team assisted by pointing out where they saw goats during their work around the island. The goat survey was carried out from dawn until dusk from 10 to 13 April, although for much of this time J. Daltry was also collecting trapped rats and recording birds, lizards and other wildlife (previous sections). The goat survey was therefore quite limited in scope and it is possible some individuals were missed.

As an experiment, while conducting point counts for ground lizards (Section 2.3), our team also recorded any goats that came within 10 metres of where we were seated, to determine whether this method could provide a meaningful estimate of the density of goats on Redonda.

Figure 24. Feral goats on Redonda in April 2012. This small family unit was all-white, but colours, markings and horn shape vary widely across this population (J. Daltry, FFI)

Figure 25. Three of the many carcasses found on the plateau in May 2008, apparently starved (J. Daltry, FFI)

2.4.3 Findings

Goats were fairly active throughout the day, and usually rested by trees or among the remaining tall stands of prickly pear cacti at night. During the hottest parts of the day, the goats were frequently seen descending into the ghauts or shaded cliff faces. The large bachelor herd was regularly (three days in a row) observed descending down the cliffs to the immediate west of Shiel's Summit. Besides avoiding the full sun, it is possible the goats retreated to the cliffs to avoid our research team. The goats ran away when approached, but were rather inquisitive and could often be spotted peering at us from a safe distance. While J. Daltry was standing still conducting point counts, one male approached within three metres.

Several distinct groups were identified, some of them periodically split into smaller sub-groups:

- The Harem: 3 adult males (1 dominant, two younger), 10 adult females, 3 kids. First encountered in the Northwest of the island.
- The Prickly Pear Group: 8 adult males, 3 adult females, 2 kids. Usually in the southern part of the island (resting among the prickly pear stands at night), between the Mitchenson Cliffs and Gawsworth's Summit.
- The Bachelor Herd: 23 adult and sub-adult males, 2 kids (weaned). Ranged widely across the central part of the island.
- The Brown Family: 1 adult male, 2 adult females, 2 kids (all brown). Usually seen in central parts of the island.
- The White Family: 1 adult male, 1 adult female, 1 kid (all white - Figure 24). Seen in central parts of the island.

- The Old Male: 1 elderly male with extremely long horns. Usually in the northern part of the island, including the gully below the cableway head.

  Total: 37 adult males, 16 adult females, 9 kids = 62

Most of the above groups were seen on multiple occasions, allowing their numbers to be verified. In addition, one pale grey adult female and two kids was spotted near Shiel's Summit that may or may not have been members of the Prickly Pear Group. If not, they raise the total known population to 65.

Remarkably, analysis of the 96 point counts gave an average density of 0.79 goats per hectare, or a total population estimate of 63 goats for the whole island. This suggests that point counts could be used for monitoring goats, but this method would probably be more accurate if the number of points was increased and the survey radius enlarged to 30 metres or more.

It is surprising that adult males outnumber adult females by 2:1. It is possible that some nannies were overlooked during this survey, but it is unlikely that a large group could have been hidden from view for so long.

A possible explanation for the skewed sex ratio is that hunters have selectively taken females (Brian Cooper *in litt.* to J. Daltry). There are ongoing reports of people taking goats from Redonda to Montserrat, where allegedly a number of them still live (e.g. Matthew Morton, Durrell Wildlife Conservation Trust, pers. comm.). Interestingly, there is an understanding among Montserratians that "*the transfer of the island to Antigua was accompanied by a legal permission for fishermen and hunters from Montserrat to go there from Montserrat without clearing on Antigua*" (Michael Ivie, *in litt*. to J. Daltry), but we do not know whether this arrangement was indeed formally agreed by Antigua and Barbuda. Unlike other Caribbean islands where feral goats are commonly hunted, we found no ropes, snares or other evidence of hunters, which suggests that hunting is not very frequent.

It was also noteworthy that most of the females had only one kid, and many of them had no kids at all. This is a strong indicator of the harsh conditions on Redonda: healthy, well fed nannies can often raise two or even three kids.

The goats were observed feeding on coarse grasses and prickly pear *Opuntia*. The foliage on fig trees appeared cropped to the level a goat could reach. There was no sign of goat damage on the *Aloe vera* stand. On previous visits when *Cleome* spp. was growing, they were also cropped by goats – these herbs could be important for sustaining the herd for parts of the year, although during prolonged dry seasons a large number of goats die off from thirst or starvation (Figure 25). The relatively small size of the population on Redonda is therefore probably determined by food availability, which is declining (Section 2.6).

The impact of goats is very conspicuous and alarming. Very few species of plants remain on Redonda. Almost anything edible is swiftly found and eaten by the wide-ranging goats, and they are able to access most of the island's surface – even some of the steepest cliffs and gullies. The poor vegetation cover, compounded by the trampling by goats, leads to soil erosion, which makes it even more difficult for new plants to become established. Soil erosion is evident all over the island and could be harmful to the surrounding reefs. Lowrie *et al.* (2012) also suspected the goats of directly or indirectly damaging seabird nests. We saw no evidence of any new young trees becoming established (Section 2.6). Not only is this a tragedy for the plants, but a number of the animals – including the red-footed boobies and magnificent frigatebirds – may no longer be able to inhabit Redonda when the last trees disappear.

The goats have a complex ecological relationship with the rats, but on balance they probably do not benefit from the rodents. Both mammals are very strong competitors for food plants, with rats notably feeding on seeds and young shoots before goats are able to eat them: the goat population may therefore be expected to grow if rats were removed from this environment. Elizabeth Bell discovered that the rats eat

goat droppings (Section 2.1.4), which may be an important reserve food during times of hardship. Rats also feed avidly on the carcasses of goats (J. Daltry, pers. obs.). It is not known whether the rats carry any diseases or parasites that may be shared with the goats or other wildlife.

Given the severe and far-reaching impacts that goats have on the native species, habitats and ecological functions of Redonda, it is difficult to justify the eradication of rats without using the same arguments for removing the goats. Indeed, during our consultations to discuss the rat eradication, a number of technical staff (both governmental and non-governmental) strongly recommended that goats should also be removed to help conserve Redonda's wildlife and for other reasons.

It must also be noted that the goats are suffering extreme hardship on the island, especially during droughts. Indeed, around a dozen goat carcasses were found on the Plateau in September 2012, having apparently starved to death (J. Prosper, pers. comm.). This suggests the entire herd has now fallen to around 50 or even fewer. As the vegetation on Redonda continues to deteriorate, how much longer can goats survive on the island? Removing the goats should be considered as not only a vital conservation action, but also a humane act to prevent these state-owned livestock from starving to death.

2.5 Status and Distribution of Invertebrates

Hardly any information has been published on the invertebrates of Antigua and Barbuda, including Redonda. John F.G. Clarke surveyed Redonda in 1956 and 1958, and collected a beetle (subsequently described by Campbell, 1977, as the regionally endemic *Hymenorus antillensis*) as well as "about 20 species" of microlepidopteran moths (in Schmitt, 1957). According to a letter published in Morse (1979), Clarke unfortunately dropped and lost almost all of the specimens from his second trip when part of the access gully gave way. Based on his observations, however, he regarded the insect fauna as 'depauperate'.

Table 8 summarises beetle species, most of which were collected more recently, but not previously published, with tentative identifications kindly provided by Michael Ivie (Montana State University). Based on his wide experience of the West Indies, Prof. Ivie considers that there ought to be hundreds of species of beetles on Redonda and the fact that so few taxa have been found in recent decades shows that this ecosystem is badly degraded (*in litt.* to J. Daltry). It remains to be seen how many native beetles and other species could return if the native vegetation is more actively conserved and restored.

Other invertebrates found on Redonda, including Hymenoptera (exotic leafcutter bee and ants), Hemiptera (several species), Diptera (a couple of species), Embioptera, Orthoptera (cricket), an isopod, plus a single spider (the widespread *Metepeira compsa*) collected on the beach by Clarke in 1958 (M. Ivie, *in litt.* to J. Daltry, 15 October 2012). Redonda is certainly species-poor in comparison with other small West Indian islands of similar size. The decline in the diversity and abundance of vegetation is almost certainly a major factor behind the low diversity of insects, but it is also possible that some plant species have disappeared due to the lack of insect pollinators. It should also be noted that rats can have a major impact on island invertebrate populations. Dr. Nik Cole (Durrell Wildlife Conservation Trust) documented an 80% decline in invertebrate abundance after rats invaded an island in Mauritius (*in litt.* to J. Daltry, 3 September 2012).

Almost as alarming as the dearth of native species is the presence of harmful alien invasive invertebrates. The prickly pear moth *Cactoblastus cactorum* (Howard & Touw, 1982[3]; M. Ivie *in litt.* to J. Daltry) could

[3] This paper reports: "*furthermore, on several islands the opuntia population has been greatly reduced or exterminated by the larvae of the cactoblastid moth. The senior author first visited the island of Redonda in 1961, collected specimens and took many photographs of individual plants and landscapes. On a second visit in 1979 the opuntia population was greatly reduced and large numbers of very sick plants had soft black pads crawling with larvae. Several once massive stands were near extinction. Since the island is uninhabited, the introduction of the moth must have been fortuitous*."

feasibly destroy many of the remaining *Opuntia* prickly pears, especially when exacerbated with heavy pressure from rats and goats (Figure 44, Figure 45).

Table 8. Beetles (Coleoptera) of Redonda

Preliminary identifications and comments provided by M. Ivie.

Family	*Genus and species (if known)*	*Comments*
Carabidae	*Selenophorus discopunctatus*	
Laemophloeidae	*Nasubius* sp.	
Tenebrionidae	*Diastolinus* sp.1	Very common. This genus is probably distasteful to lizards and rats.
	Diastolinus sp.2	Not common, in old booby nests
	Hymenorus antillensis Campbell	66 specimens collected by Clarke (1957), but the species has not been found here since.
Coccinellidae	*Diomus* sp.	
	Scymnus floralis (Fabricius)	Very common in invasive plants
Anthribidae	*Ormiscus* sp.	
Curculionidae	Entiminae (genus and species not identified)	Very common
	Hypothenemus squamosus	(Scolytinae)
	Hypothenemus ?seriatus	(Scolytinae)
Erotylidae	*Loberus* sp.	(Languriinae). Very common
Corylophidae	*Serioderma* sp.	Common
Elateridae	*Conoderus* sp.	
Anthicidae	undet. sp.	
Scydmaenidae	undet. sp.	
Staphylindiae	*Nacaeus* sp.	

No invertebrate specimens were collected during the present visit and because neither of the authors are entomologists, we can add little to the information obtained by Clarke and Ivie. Some general observations are that no scorpions were found while turning over rocks in search of geckos, and surprisingly few insects, spiders or other invertebrates were encountered. Our camp site (Figure 47) attracted a number of unusually slow-flying bluebottle flies. Hermit crabs *Coenobita clypeatus* were very conspicuous, especially after rain. Large red land crabs (*Gecarcinus ?ruricola*) were attracted to dead rats.

Crabs, ants and cockroaches are prone to take rat bait. Though considered impervious to the brodifacoum rodenticide recommended in Section 4, these invertebrates could have an impact on the rat eradication programme if they remove a significant amount of the bait intended for the rats. This is, however, a problem that can be easily addressed by increasing the quantity of bait and, more importantly, adjusting the manner in which it is deployed.

2.6 Status and Distribution of Vegetation

At the time of writing, a fuller report on the vegetation of Redonda is under preparation, led by Kevel Lindsay. This section is therefore merely intended to provide some background information on the flora to help understand how it has been shaped by alien mammals. It should be noted that we are not botanists and are not qualified to verify whether species recorded by other authors were identified correctly.

Historical paintings of the island indicate that this island was forested when the phosphate mine was established (see Morse, 1979), but very few trees and shrubs remain today. Much of the island looks barren, especially during the dry season, and the variety of plant species is low for a West Indian island of this size. The phosphate mining community was undoubtedly to blame for much of the deforestation. Miners used explosives to extract guano and presumably collected wood for fuel and construction while living on the island. However, it is evident from reports and photographs that the natural diversity and abundance of vegetation has continued to deteriorate severely, even since the 1960s and 1970s, decades after the mining community left. Figures below show some of the changes that have taken place around the Plateau in the southern half of the island (Figure 1).

Table 9 summarises approximately 70 plant species that have been recorded on Redonda over the past 100 years, compiled from Howard (1962) and Pratt & Thomas (2011), plus one additional species, *Aloe vera*, confirmed during this survey (Figure 46). An unidentified orchid has also been spotted by Kevel Lindsay from our photographs taken in April 2012, and there is some uncertainty as to the identity of the prickly pear cacti, genus *Opuntia*, on Redonda (*in litt.* to J. Daltry). Of the plants shown on the table below, about 20 species are not considered native to the Eastern Caribbean. Some of these plants are thought to have been deliberately brought to the island and cultivated as ornamental plants or for food or other purposes around the mining settlement (Howard, 1962). The *Aloe vera* was probably introduced for bush medicine (K. Lindsay, *in litt*. to J. Daltry).

Only 27 species were recorded on Redonda by Pratt & Thomas (2011), considerably fewer than Howard (1962). While this may be partly explained by differences in how much of the island they sampled and the time of year, some of the species recorded by Howard were large, perennial species that would be difficult to miss if present. The latter include some of the more showy 'cultivated' plants, such as the bougainvillea *Bougainvillea spectabilis*, as well as some very distinctive native species such as the shrubby lantanas (including *Lantana camara*, described by Howard, 1962, as 'abundant') and agave (*Agave cf. karatto*).

Deforestation, overgrazing by goats, coupled with rats consuming seeds, fruits and shoots, means that only a few hardy xeric plant species have been able to survive until now. Even prickly pears *Opuntia* spp. were observed being heavily attacked by goats and rats, especially the tall species tentatively identified as *O. elatior* or *O. dillenii*, and could soon disappear. Kevel Lindsay (*in litt.* to J. Daltry) suggests that when they were more common, cacti could have served an important role in protecting more edible plant species from the goats. For some plant species, the conspicuous shortage of pollinators (insects, birds, bats) and seed dispersers on the island could also be a terminal problem.

One of the most successful species on the island today is the alien invasive herb *Cleome viscosa*. Figure 30 and Figure 31 illustrate how *Cleome* spp. transform the island for a few months of the year. Pratt & Thomas (2012) commented that more than 95% of the herbaceous biomass on Redonda is made up of this Old World invader. Although known to be eaten by rats and goats, at least to a small degree, this species is thriving. Chris Pratt (*in litt.*), however, predicts this herb would likely become outcompeted by native plants if goats were removed.

Table 9. Plant species recorded on Redonda

Taxa	*Native to E. Caribbean*[4]	*Howard (1962)*	*Pratt & Thomas (2011)*	*Comments*
Agave cf. karatto syn montserratensis	Yes	Present (not uncommon)	Not seen (only 2 dead specimens)	No live specimens - only root balls of a few long-dead individuals in the southern third of the island.
Agave sisalana	No	Present, as ornamental	Not recorded	None seen.
Ageratum conyzoides	Yes	Present (as A. *houstonianum*)	Present ("Rare")	
Aloe vera	No	Not recorded	Not recorded	One large patch in the South East (Figure 46).
Amaranthus dubius	Yes	Present ("weed")	Not recorded	
Annona squamosa	No	Present ("small shrub" planted near manager's house)	Not recorded	
Argemone mexicana	Yes	Not recorded	Present ("Rare")	Very common near Centaur's Cave (flowering in April).
Astraea lobata	Yes	Present ("common") as *Croton lobatus*	Not recorded	
cf. Boerhavia coccinea	No	Present	Present (1 specimen)	
Bougainvillea spectabilis	No	Present (planted near manager's house)	Not recorded	None seen.
Capraria biflora	Yes	Present ("weed")	Not recorded	
Casuarina equisetifolia	No	Present (1 specimen)	Present (1 specimen)	Only one tree, by manager's house. No sign of seedlings or saplings.
Catharanthus roseus	No	Present ("occasional")	Not recorded	None seen.
Centrosema virginianum	Yes	Present	Not recorded	
Centrostachya indica (=Achyranthes aspera?)	No	Present ("weed")	Not recorded	
Chloris barbata	Yes	Present (as *C. inflata*)	Not recorded	
Citrus aurantiifolia	No	Present (shrub near manager's house)	Not recorded	None seen.
Cleome gynandra[5]	No	Not recorded	Present ("Dominant")	
Cleome viscosa[6]	No[7]	Present ("common weed")	Present ("Frequent")	
Croton flavens	Yes	Present ("common")	Not recorded	None seen.
Cynanchum parviflorum	Yes	Present ("common")	Not recorded	
Cyperus ligularis	Yes	Present ("favourite nesting places of boobies")	Present? (Occasional *Cyperus* sp. "needs identification"	Did not notice any seabirds nesting on *Cyperus*.

[4] Following Broome *et al*. (2007) unless otherwise stated.
[5] Some authorities place this in the genus *Gynandropsis*.
[6] Some authorities place this in the genus *Arivela.*
[7] Considered alien invasive by Pratt & Thomas (2011), but native according to Broome *et al.* (2007). Origin uncertain, but many authors point to this being an Old World species.

Taxa	*Native to E. Caribbean*[4]	*Howard (1962)*	*Pratt & Thomas (2011)*	*Comments*
Cyperus sphacelatus	Yes	Present	Not recorded	
Digitaria sanguinalis	No	Present	Not recorded	
Digitaria insularis	Yes	Present (as *Trichachne insularis*)	Not recorded	
Emilia coccinea	No	Present	Not recorded	
Eragrostis ciliaris	No	Present	Not recorded	
Euphorbia heterophylla	No	Present	Not recorded	
Euphorbia hirta	Yes	Present	Not recorded	
Ficus citrifolia	Yes	Present ("Only 3 specimens")	Present ("Frequent")	Mainly on or near cliffs. A few old specimens on flatter areas, but no signs of seedlings or saplings. Rats observed eating figs in the tree.
Galactia sp.	Yes?[8]	Present	Not recorded	
Hyptis pectinata	Yes	Present ("frequent"… "usually browsed by goats")	Not recorded	
Iresine angustifolia	Yes	Present	Not recorded	
Jatropha gossypiifolia	Yes	Present ("weed")	Not recorded	
Justicia sphaerosperma	Yes	Present (as *J. periplocifolia*)	Not recorded	
Lantana camara	Yes	Present ("abundant")	Not recorded	None seen.
Lantana involucrata	Yes	Present	Not recorded	None seen.
Leonotis nepetifolia	No	Present	Not recorded	
Melocactus intortus	Yes	Present	Present ("Occasional")	Mainly near cliffs and near manager's house
Nicotiana tabacum	No	Present (ex-cultivation)	Not recorded	None seen.
Opuntia antillana	Yes?[9]	Present	Not recorded	
Opuntia cf. triacantha	Yes	Present	Present ("Occasional")	Short 'jumping cacti' resembling *O. tricantha.* Common, especially northern end of island.
Opuntia ? dillenii	No?[10]	Not recorded	Present ("Frequent")	A few tall (>2 metres) but badly damaged patches south of Morse Mound, and near Centaur's Cave. Eaten by rats and goats. This may be *O. elatior*, according to Kevel Lindsay (in litt. to J. Daltry)
Opuntia repens	Yes[11]	Present	Not recorded	
Panicum maximum	No[12]	Present	Not recorded	
Pappophorum pappiferum	Yes	Present	Not recorded	

[8] Broome *et al.* (2007) records seven species of *Galactia*, all native to the Eastern Caribbean.
[9] Not listed by Broome *et al.* (2007) – unclear whether the *Opuntia* on this table include synonyms or hybrids.
[10] Introduced from Tropical America according to Broome *et al.* (2007).
[11] Not listed by Broome *et al.* (2007) – unclear whether the *Opuntia* on this table include synonyms or hybrids.
[12] Native according to Broome *et al.* (2007), but introduced according to Pratt & Thomas (2011) and other authors.

Taxa	*Native to E. Caribbean*[4]	*Howard (1962)*	*Pratt & Thomas (2011)*	*Comments*
Paspalum laxum	Yes	Present; Commonest grass	Not recorded	Native
Peperomia simplex	Yes?[13]	Present ("abundant")	Not recorded	
cf. Phlebodium aureum	Yes?[13]	Not seen	Present (1 specimen)	1 specimen at entrance of Centaur's Cave (photographed).
Phyllanthus amarus	Yes	Present ("weed")	Not recorded	
Pilea microphylla	Yes	Present	Not recorded	
Pilosocereus royenii	Yes	Present (as *Cephalocereus royenii*)	Not recorded	Photographed low on cliffs east of Shiel's Summit.
Pityrogramma chrysophylla	Yes[13]	Present	Present	Common
Plumbago scandens	Yes	Present ("abundant")	Not recorded	
Portulaca halimoides	Yes	Present	Not recorded	
Portulaca oleraea	Yes	Present	Not recorded	
Psilotum nudum	Yes? [13]	1 clump	Not seen	
Pterocaulon virgatum	Yes? [13]	Present ("few individuals")	Not recorded	
Ricinus communis	Yes	Present ("common", was cultivated)	Not recorded	
Setaria setosa	Yes	Present	Not recorded	
Sida cordifolia	Yes	Present	Not recorded.	
Stachytarpheta jamaicensis	Yes	Present ("infrequent")	Not recorded	
Talinum paniculatum[14]	Yes	Not recorded	Not recorded	
Talinum fruticosum	Yes	Present (as *T. triangulare*)	Not recorded	No *Talinum* seen.
Tephrosia cinerea	Yes	Present ("abundant")	Not recorded	
Tillandsia recurvata	Yes	Present.	Present ("Rare")	
Tournefortia cf. volubilis	Yes	Not recorded	Present (1 Specimen)	
Trianthema portulacastrum	Yes	Present	Not recorded	None seen.
Trichachne sp.	?	Present	Not recorded	
Tricholaena repens	No?[15]	Present; locally abundant	Not recorded	
Wedelia cf. calycina	Yes	Present ("common")	Present ("Occasional")	

[13] Species not listed by Broome *et al.* (2007).
[14] Recorded by Box (1939) near boat landing area, but not found by subsequent authors.
[15] Species not listed by Broome *et al.* (2007)

Figure 26. 1961: Shrubs still very abundant, e.g. by the old bread ovens (Howard, 1962)

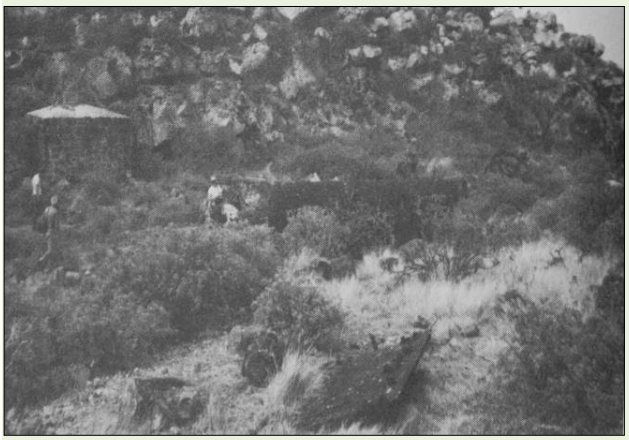


Figure 27. 2012: No shrubs remain around the bread ovens (J. Daltry, FFI-OICP)

Figure 28. 1979: Perennial shrubs still covered most of the island in April (Morse, 1979)

Figure 29. 2012: The same area of the island in April. No perennial shrubs (E.A. Bell, WMIL)

Figure 30. Facing North from the plateau to Shiel's Summit. The slope looks bare apart from a non-native casuarina tree. April 2012 (J. Daltry, FFI)

Figure 31. A green flush of alien invasive herbs (*Cleome* spp.) covers the same slope after rain in 2011 (Ashton Williams, EAG)

3 Aims and Justification of Proposed Rat Eradication

The proposed operation aims to eradicate all black rats from Redonda while minimising any adverse impacts on the environment, non-target species, archaeology and humans for the conservation and restoration of the island's nationally and globally important biodiversity.

Redonda hold an important lizard community, including at least three endemic and globally threatened species (Section 2.3). Redonda is also internationally recognised for seabirds, particularly its magnificent frigatebirds, masked boobies, red-footed boobies and brown boobies (BirdLife, 2011; Section 2.2).

Black rats are strongly implicated in the decline of seabird and lizard populations on Redonda, and exterminating them will make resident seabird and lizard populations more secure. Eradicating the predatory rats could also create opportunities for additional land bird and seabird species to re-colonise Redonda.

More broadly, the reasons to remove black rats from Redonda are:

- To conserve and enhance the regionally and internationally important breeding seabird populations present on the island, facilitate re-colonization by other native seabird and land species in the future, and provide a secure staging post for migrants.
- To conserve and enable the recovery of endemic and globally threatened reptile species on the island, and potentially create opportunities for some species (e.g. iguanas) to be reintroduced.
- To facilitate the recovery and regeneration of rare native plants and invertebrate species.
- To act on the strategic goals of the draft National Environmental Management Strategy.
- To deliver on national commitments to the Convention on Biological Diversity (e.g. Article 8(h) requires the control or eradication on alien species that threaten ecosystems, habitats or species).
- To deliver on national commitments to the St George's Declaration of Principles for Environmental Sustainability in the Organisation of Eastern Caribbean States (e.g. adoption of measures to eradicate invasive alien organisms).
- To deliver on national commitments to the Convention on Desertification (e.g. Article 5(c) requires parties to address the underlying causes of desertification).
- To create new opportunities for environmental education, research and tourism on Redonda.
- To clearly demonstrate Antigua and Barbuda's active invest in Redonda to "ensure that it and the surrounding marine resources continue to be recognised as part of the nation" (GENIVAR, 2011).

4 Practicality of Alternative Control or Eradication Options

Redonda has a very large population of alien invasive rats. A variety of eradication and control techniques were evaluated (Table 10 and Table 11), and we conclude that manual rat control techniques, such as shooting and trapping, would not be suitable for Redonda due to the high cost and difficulties of access. We therefore considered a range of toxins (Table 12), and identified brodifacoum as the preferred choice due to its proven track record in other eradication operations in this region, toxicity to black rats, low solubility in water, range of formulations and availability. Although anticoagulant rodenticides are inhumane to rats (Pesticide Safety Directorate, 1997), the lack of alternatives and the ultimate outcome of preserving and restoring the wildlife populations on Redonda have to be weighed against their use. Anticoagulant rodenticides are currently the most widely recognised effective tool for eradicating rodents from islands.

No eradication operation should be undertaken lightly, and any assessment should ensure: (i) that the seriousness of the problem has been established; (ii) that non-lethal measures have been assessed and found to be impracticable; (iii) that killing is an effective way of addressing the problem; and (iv) that killing will not have an adverse impact on the conservation status of other non-target species. These criteria have been applied to the proposed eradication on Redonda, and we conclude that a complete, island-wide eradication is the only practical option to reduce rodent impacts on seabirds, endemic reptiles, plants and the island ecosystem as whole.

In addition to this assessment, we have assessed the proposed eradication on Redonda using the ethical principles of Humane Vertebrate Pest Control developed by RSPCA Australia's Humane Vertebrate Pest Control Working Group in 2004. The proposed eradication operation on Redonda satisfies all the criteria of the Humane Vertebrate Pest Control principles:

- The aims, benefits and harms of the eradication operation have all been clearly established, and efforts are ongoing to maximise the benefits and minimise the harms, thereby strengthening the ethical justification (Principle 1);
- The eradication operation is technically feasible and likely to succeed (Principle 2);
- The proposed rodenticide to be used, brodifacoum, is the most humane method that will achieve the aims of the eradication operation with a high likelihood of success, having already been used in many successful island operations (Principle 3);
- Methods which are proven to be effective on similar islands will be used (Principle 4);
- Established best-practice removal techniques will be followed wherever practical, and the project will be externally reviewed by the world-leading experts, such as Island Eradication Advisory Group (IEAG, a New Zealand Department of Conservation body) (Principle 5);
- Monitoring will take place two years after the operation in order to assess whether the precise aim has been achieved (Principle 6);
- A wide-range of biosecurity measures will be established to ensure that Redonda remains rodent-free after the operation and that no further control therefore needs to be undertaken (Principle 7);
- On the balance of factors, the method chosen is the only one which is likely to succeed on this island (Principle 8).

A range of eradication techniques was assessed (see tables below), including ground-based methods (using bait stations or broadcast by hand), aerial baiting or a combination of techniques.

A wholly ground-based operation using bait stations across the entire island is not possible because much of the cliff areas and coastal slopes of Redonda are too unstable and steep for people to access, even with ropes (Turnbull, 2011). It would, however, be possible to use bait stations on the top section of Redonda where the terrain is less steep and accessible by foot. A hand-broadcast operation across the entire island is also not possible because it would not be able to spread bait over the cliffs by hand to ensure it reached the entire height of the cliffs because part of the island is inaccessible (Turnbull, 2011). An aerial operation by helicopter is feasible, but would have to be backed up by a ground-based operation to target ruins, caves and crevices. As there are at least three globally threatened endemic species of reptiles on Redonda, it is important to ensure that the risk to these species is minimised. The use of bait stations on the top section of Redonda would reduce the risk to reptiles in this area, while the rest of the island can be targeted by helicopter.

We therefore recommend a combination operation to eradicate black rats from Redonda:

1) A ground-based, bait-station operation using brodifacoum (a second-generation anticoagulant rodenticide) in a cereal-based wax block formulation (e.g. 20-g blocks of Klerat) on the top of the island (all areas accessible to humans on foot), and

2) An aerial application of brodifacoum in a smaller pellet form (e.g. smaller pieces of Klerat or PestOff) over the steep cliffs and inaccessible slopes.

This should take place in the dry season (January to April), when natural foods for the rats are in short supply and when there is little or no risk of the operation being interrupted by tropical storms or hurricanes.

The proposed eradication technique is considered safe and effective, based on previous operations in the Caribbean and around the world. A combination operation will ensure bait is available to every rat on the island, even on steep slopes, while minimising the risk to reptiles and other non-target species. The ground-based component would also enable accurate monitoring of bait take and success of the eradication.

Minimising the risk to non-target species, especially the endemic animals, should of course be a high priority. Using waxy bait in bait stations over the top of the island will ensure that the main populations of reptiles should be at little or no risk of direct poisoning. Bait presented in a wax block formulation has been proven to be unattractive to reptiles in Antigua and elsewhere in the Caribbean (Day & Daltry, 1996; Daltry, 2000; Varnham, 2003; Varnham & Daltry, 2006; Varnham, 2010; Bell, 2012). As an additional precaution, however, it would be prudent to verify that the Redondan lizards have no interest in the proposed bait and to take a number of individuals into captivity while the rat eradication operation is underway (see below).

Table 10. Options for reducing the impacts of black rats *Rattus rattus* on Redonda.

OPTION	*OUTCOME*	
Do nothing	The natural ecosystem of Redonda will continue to deteriorate, especially the survival of breeding seabirds, reptiles and plants on the island. This would contravene both national and international obligations.	UNACCEPTABLE
Undertake long-term rodent control	This would aid the persistence of seabirds and reptiles on Redonda by controlling the rat population through lethal or non-lethal means. However, targeted rat control measures would have to take place throughout the year in perpetuity. The costs of ongoing control would be considerable: • An ongoing welfare cost whose cumulative effect could be greater than a one-off eradication operation. • An ongoing financial cost. The implementation of a regular rat control programme would require personnel and equipment to be present on the island repeatedly. • An ecological and environmental cost, with the risk of resistance and persistence of toxin being greatly increased.	IMPRACTICAL
Relocate the entire rodent population	The safety of breeding seabirds and reptiles, and the island's ecosystem would be assured while trying to ensure the highest standards of welfare for rats on Redonda. For this option to succeed, every last rat would have to be captured and relocated - if any rats remain, they would quickly increase in population and render any biodiversity gains only temporary. It is too challenging (and too time-consuming and expensive) for personnel to catch the entire rat population from Redonda. In addition, it would be difficult to find an appropriate island or obtain permission to relocate the rats that would satisfy community, conservation, disease and welfare concerns.	IMPRACTICAL
Eradicate the entire rodent population	The lethal eradication of all rats on Redonda using anticoagulant rodenticides. Although the one-off welfare cost of this option is high, it offers a sustainable and financially cost-effective solution with possibly fewer welfare costs to rats and non-target species over the long-term than ongoing control. Alternative eradication methods were considered (Table 11). Trapping, gassing, glue boards, repellents, prevention and alternative toxin options are not recommended due to their labour requirements, welfare issues, access, number required and/or impacts on non-target species. The only suitable option to eradicate rats from Redonda is a combination of ground-based operation (i.e. apply anticoagulant rodenticide bait in bait stations) and eradicating the entire rat population in situ. This option is considered technically feasible, and islands larger than Redonda have been successfully cleared of invasive rats using this method (e.g. Bell *et al.* 2000, 2011; Bell, 2004; Howald *et al.* 2007).	PRACTICAL (RECOMMENDED)

Table 11. Details and practicality of options for eradicating black rats *Rattus rattus* from Redonda.

OPTION	***PROS***	***CONS***	***OUTCOME***
Prevention (i.e. rat-proofing)	Non-lethal Environmentally clean Proofing areas prevents damage and effects of rats Useful for buildings and small areas only	Does not deal with rats already present (which can still cause damage or have impacts) Rat-proof fencing is expensive Non-lethal : can shift problem to another location Usually combined with other methods Best suited for small areas Little benefit alone	IMPRACTICAL
Rodent dogs (to detect rats)	Targeted control Environmentally clean Useful for detecting surviving rats	Labour intensive Expensive Lack of trained dogs in Caribbean Terrain in some areas difficult for dogs Rats have to be humanely killed Untested for island-wide eradication projects Ethical concerns Risk of harm or stress to non-target wildlife	IMPRACTICAL
Repellents	Sound or chemical options Non-lethal Targeted control No welfare impacts	Little to no success (Mason & Littin, 2003) Rats habituate to repellent Non-lethal Can move problem to another area Little to no use on an island-wide situation	IMPRACTICAL
Aluminium phosphide fumigation	Targeted control (burrows only) Lethal method	Needs knowledge of habitat and location of burrows Risks to general public Risks to other non-target species Professional use only Ethical concerns Untested for island-wide eradication projects	IMPRACTICAL
“Rodenator” explosive	Targeted control (used to destroy burrows)	Needs knowledge of habitat and location of burrows Risks to general public Risks to other non-target species Professional use only Outdoor use only Ethical concerns	IMPRACTICAL (ILLEGAL)

OPTION	*PROS*	*CONS*	*OUTCOME*
Immuno-contraception	Possible long-term solution Humane Environmentally clean	At research stage only Concerns regarding loss of control Risks to non-target species Irreversible Public concern	IMPRACTICAL (EXPERIMENTAL ONLY)
Biological control (e.g. with disease or predator)	Long-term solution	Involves releasing another potentially harmful species Risks to non-target species Ethical concerns	IMPRACTICAL
Kill traps (i.e. snap, spring or break-back traps)	Lethal (rapid death) Targeted control Environmentally clean Can be used by general public Range of traps commercially available	Labour-intensive Expensive Welfare issues and ethical concerns Need to be checked at least twice daily Only legal traps can be used Experienced trappers required for large-scale operations Requires good accessibility Risk to non-target species (particularly lizards) Untested for island-wide eradication projects	IMPRACTICAL
Live trapping	Humane Environmentally clean Non-target species can be released unharmed Targeted control Range of traps commercially available Can be used by the general public Rats can be released to an alternative location	Labour-intensive Expensive Need experienced trappers for large-scale operations Requires good accessibility Welfare issues and ethical concerns Need to be checked twice daily Risks to non-target species Trapped animals likely to suffer from overheating Only legal traps can be used Rats have to be humanely killed Untested for island-wide eradication projects Release of rats may have impacts at release site or welfare issues for animals	IMPRACTICAL

OPTION	*PROS*	*CONS*	*OUTCOME*
Gas traps	Targeted control Lethal (rapid death) Non-toxic Humane	Labour-intensive Professional use only Safety issues for the public Expensive Welfare issues and ethical concerns Only legal traps can be used Risks to non-target species Untested for island-wide eradication projects No detailed clinical data on efficacy, humaneness, welfare or other effects	IMPRACTICAL
Electrocution traps	Targeted control Lethal (rapid death) Non-toxic Humane (if used correctly)	Needs sufficient power source Labour-intensive and expensive Welfare issues and ethical concerns Only legal traps can be used Risks to non-target species Untested for island-wide eradication projects No detailed clinical data on efficacy, humaneness, welfare or other effects	IMPRACTICAL
Glue boards	Targeted control Environmentally clean Non-toxic	Labour-intensive Welfare issues and ethical concerns Need to be checked twice daily (if set permanently) Animals must be killed humanely Trapped animals likely to suffer from overheating Risks to non-target species, especially lizards Untested for island-wide eradication projects May be removed from international markets shortly as perceived to be inhumane	IMPRACTICAL
Rubber-ring strangulation traps	Targeted control Non-toxic Humane (New Zealand Ethics Standards) Environmentally clean	Labour-intensive Expensive Welfare issues and ethical concerns Need to be checked twice daily Only legal traps can be used Experienced trappers required Risks to non-target species Untested for island-wide removal projects	IMPRACTICAL

OPTION	*PROS*	*CONS*	*OUTCOME*
Alphachloralose	Humane	Use of toxin Non-target impacts Ethical concerns Untested for island-wide eradication projects	IMPRACTICAL
Cellulose pellets	Humane Unlikely to cause secondary poisoning Non- toxic	Untested for island-wide eradication projects Ethical concerns Non-target impacts No detailed clinical data on efficacy, humaneness, welfare or other effects	IMPRACTICAL
Anticoagulant rodenticides	Efficient Large areas covered quickly Most widely used approach to control rats Most cost-effective method of controlling substantial infestations Tested and successful method for one-off island-wide eradication projects Range of application methods Can be used in bait stations to reduce risk to non-target species Antidote available Range of rodenticides available (e.g. first generation or second generation) Range of formulation available (e.g. grain, wax block, pellets etc.) Legally available for use by the public and professionals	Use of toxin Persistence in environment (depending on toxin chosen) Risks to non-target vertebrate species Ethical concerns Resistance issues with prolonged use Legal requirements for certain rodenticide use Requires coverage of whole area Requires use of adequate baits and bait stations Disposal requirements Possible human health and safety concerns	PRACTICAL & RECOMMENDED (TESTED AND EFFECTIVE)

Table 12. Assessment of available anticoagulant rodenticides for eradicating black rats *Rattus rattus* from Redonda.

TOXIN	*PROS*	*CONS*	*OUTCOME*
FIRST-GENERATION			
Warfarin	Low potency Delayed onset of symptoms (i.e. prevents neophobia and bait shyness) Less persistent than second generation anticoagulants Reduced risk of non-target poisoning Reduced secondary poisoning risk Very low risk to raptors Cheaper than second generation anticoagulants Antidote available Insoluble in water	Low potency Multiple feed Large quantity required Repeated applications required Longer access to bait required More labour intensive (as baiting phases of operations must be longer) Non-target species (such as crabs and reptiles) have more time to access bait (i.e. competition with rats) Weather can affect bait because out for longer periods Low persistence (metabolised quickly) Resistance issues	NOT RECOMMENDED (SIGNIFICANTLY INCREASES CHANCE OF FAILURE)
Pindone	Low potency Delayed onset of symptoms Less persistent than second generation anticoagulants Reduced secondary poisoning risk Reduced risk of non-target poisoning Cheaper than second generation anticoagulants Antidote available Low solubility in water Binds strongly to soil and breaks down slowly	Low potency Multiple feed Large quantity required Repeated applications required Longer access to bait required More labour intensive (as baiting phases of operations must be longer) Non-target species have more time to access bait (i.e. competition with rats) Weather can affect bait because out for longer periods Moderate risk to birds Low persistence (metabolised quickly) Untested for island-wide rat eradications	NOT RECOMMENDED (SIGNIFICANTLY INCREASES CHANCE OF FAILURE)

TOXIN	*PROS*	*CONS*	*OUTCOME*
Diphacinone	Low potency Delayed onset of symptoms Less persistent than second generation anticoagulants Reduced secondary poisoning risk Reduced risk of non-target poisoning Low toxicity to raptors (and mice) Used successfully on island eradications in UK Cheaper than second generation anticoagulants Antidote available	Low potency Multiple feed Large quantity required Repeated applications required Longer access to bait required Less persistent (metabolised quickly) Non-target species have longer to access bait (i.e. competition with rats) Less persistent (metabolised quickly)	NOT RECOMMENDED (SIGNIFICANTLY INCREASES CHANCE OF FAILURE)
Coumatetralyl	Low potency (higher than warfarin and pindone) Delayed onset of symptoms Less persistent than second generation anticoagulants Reduced secondary poisoning risk Reduced risk of non-target poisoning Cheaper than second generation anticoagulants Antidote available Binds to soil and breaks down slowly	Low potency Multiple feed Repeated applications required Longer access to bait required Less persistent (metabolised quickly) Non-target species have longer to access bait (i.e. competition with rats) Few successful island-wide eradications	NOT RECOMMENDED (SIGNIFICANTLY INCREASES CHANCE OF FAILURE)
<u>SECOND-GENERATION</u>			
Brodifacoum	Very potent Single feed Delayed onset of symptoms (i.e. prevents neophobia and bait shyness) Very effective on rodents Insoluble in water and binds to soil (slowly degraded) Successfully used in island eradications worldwide Proven track record in Caribbean, including 13 islands cleared of rats in Antigua, 3 Saint Lucia, 3 Anguilla. Efficacy and non-target data widely available Range of bait formulations available Registered for aerial applications Antidote available (long-term treatment required)	Persistence issues (> 9 months) High secondary poisoning risks Non-target impacts recorded (outside of Caribbean) Expensive	RECOMMENDED

TOXIN	*PROS*	*CONS*	*OUTCOME*
Bromadiolone	Moderately potent Single feed Delayed onset of symptoms Effective on rats (*Rattus norvegicus* in particular) Antidote available Not readily soluble in water Binds strongly to soil and breaks down slowly	Less widely used in eradications (although previously successfully used in UK rat eradications) Persistence issues (> 9 months in some species) High secondary poisoning risks Slightly less potent than brodifacoum and flocoumafen Some resistance issues suspected Limited data on non-target impacts	NO ADVANTAGES OVER BRODIFACOUM
Difencaoum	Moderately potent Single feed Delayed onset of symptoms Effective on rats Antidote available (but long-term treatment required) Insoluble in water Binds strongly to soil and breaks down slowly	Less widely used in eradications (although previously successfully used in UK rat eradications) Persistence issues (> 9 months in some species) High secondary poisoning risks Limited data on non-target impacts Slightly less potent than other second-generation toxins	NO ADVANTAGES OVER BRODIFACOUM
Flocoumafen	Very potent Single feed Delayed onset of symptoms Effective on rodents Good availability Antidote available (but long-term treatment required) Not readily soluble in water Binds strongly to soil and breaks down slowly	Not widely used in eradications Persistence issues (> 9 months in some species, and can be longer than brodifacoum) High secondary poisoning risks Limited data on non-target impacts Expensive	NO ADVANTAGES OVER BRODIFACOUM

5 Proposed Rat Eradication Operation on Redonda

Due to the difficult terrain and accessibility of Redonda, the proposed eradication of black rats should be completed using a combination operation: i.e. an aerial application of rodenticide bait on the steeper slopes and cliffs, and ground-based application of rodenticide bait using bait stations on the top of the island, which humans can access safely.

This will reduce the overall risk to non-target species and enable accurate monitoring of non-target interference, rat bait take and success of the eradication. All aspects of the proposed programme including delivery, bait type, staff, equipment, timetable, risks, and estimated costs are outlined below.

To ensure the proposed eradication is successful, the following aspects need to be covered:

- Support and assistance from relevant Government of Antigua and Barbuda departments, including permission to operate on Redonda and facilitating imports of bait and other essential materials;
- Cooperation from the authorities in Montserrat and stakeholders who visit Redonda for fishing, recreation and other purposes;
- Good managerial and logistical support, and belief in the programme's merit and success;
- Careful and thorough planning, and sufficient funding for all stages of the programme;
- The use of experienced eradication operators who can expertly cope with any unexpected problems or challenges; and
- Motivated and experienced office and field personnel with a strong commitment to the project.

5.1 Pre-Eradication Planning Requirements

The proposed eradication operation on Redonda is technically challenging due to its isolated location and rugged terrain. It is crucial that the Government of Antigua and Barbuda and the Environmental Awareness Group, together with all relevant stakeholder groups, are in complete agreement of the proposed eradication. Their united support, input, cooperation and participation will determine the success of the programme, from this feasibility assessment to implementation and post-eradication monitoring and management. We recommend that all stakeholder groups should have the opportunity to comment on the planning and requirements of the proposed eradication to ensure that any concerns or rumours are properly addressed.

A number of pre-operational aspects need to be completed prior to the proposed eradication phase including the following (not necessarily in chronological order):

- Prepare a detailed Operational Plan for the eradication;
- Secure all of the necessary funding for the eradication;
- Obtain required permits and approvals, including permission to distribute bait by helicopter;
- Prepare contracts/ agreements to govern all aspects of the eradication project;
- Contract an experienced eradication operator to lead the eradication;
- Contract an experienced helicopter operator for the aerial bait distribution;
- Select and train all staff and volunteers involved in the eradication;

- Establish temporary captive facilities for several hundred endemic Redondan lizards (if deemed to be at risk from the rodenticide: see Section 7.15.2);
- Prepare health and safety documents, and ensure all personnel are fully briefed;
- Clarify waste management and disposal procedures for activities on Redonda;
- Purchase bait and co-ordinate delivery to the site;
- Purchase bait dispersal bucket for helicopter;
- Construct bait stations and deliver them to Redonda;
- Establish base camp on Redonda;
- Establish the bait station grid on Redonda;
- Ensure all baseline monitoring programmes (birds, reptiles, invertebrates, goats and plant populations and archaeology) are conducted at least once before the eradication begins;
- Develop and implement a detailed Biosecurity Plan;

The Biosecurity Plan should be prepared and in place and tested before the proposed eradication programme begins. It is important that the eradication team lead by example in regard to biosecurity, including transportation of gear and food in rodent-proof containers and checks of equipment and food that are to be transported to Redonda to ensure no rodents or other animals or plant seeds are inadvertently introduced to the island.

The proposed eradication programme ought to be carefully planned, implemented and adequately funded. This will be a multi-year operation (covering pre- and post-eradication programme monitoring as well as the eradication operation), with long lead-in time to ensure all aspects are ready for successful implementation.

5.2 Approvals and Training for the Proposed Eradication

A number of regulatory requirements may need to be fulfilled for the proposed eradication programme on Redonda, including:

- Approval to undertake many of the research and monitoring components of the plan;
- Review of the Feasibility Study and subsequent Operational Plan by the Island Eradication Advisory Group or other relevant agencies to ensure the proposed techniques comply with international best operating practises for island eradications;
- Approval from the Civil Aviation Authority to attach bait distribution buckets to helicopters and/or fly such equipment in Antigua and Barbuda airspace;
- Training of project personnel in safe operation around helicopters, rodent management and safe bait use and handling.

5.3 Timetable

Generally the best time to target a pest population is when individuals are under stress. For rats in temperate countries, this is normally in late autumn or winter when the population has peaked and is coming under stress as the natural food supply dwindles. As a result of such stress, rats are more likely to accept a new food source, which makes baiting more effective. On arid tropical islands like Redonda, the dry season is considered the most stressful period for rats. Therefore we recommend the proposed

eradication on Redonda is conducted between January and April (Table 13 and Table 14), taking care to complete the operation before the hurricane season.

A number of issues and aspects of the programme will need to be organised prior to the eradication including the production of a detailed Operational Plan. A relatively long lead-in time will be required for preparation of the project. During this phase, it is important that all stakeholders are fully involved in decisions about the operation and are aware of all aspects of the programme. There should also be regular reporting to stakeholders (status reports) during the operation, and a full technical report should be produced at the completion of the eradication.

The recommended timetable and other aspects of the proposed eradication programme (monitoring, selection of staff, construction of bait stations, delivery of equipment and bait, bait station grid establishment, helicopter selection, advocacy, etc.) are outlined in Table 13. A detailed timetable of the eradication phase is shown in Table 14. It is important to note that these timetables are subject to change due to project requirements, weather, transport delays, staff issues and other technical difficulties. Additional time should be factored into the operation in case any issues or delays arise, including delays on securing sufficient funding to complete the eradication.

Construction of the bait stations can be completed well before they will be required on Redonda. It is possible that they can be constructed by volunteers or conservation groups as part of their involvement with the project. The bait station grid should also be established, numbered and mapped at the beginning of the proposed eradication, before any aerial baiting occurs.

Intensive monitoring for surviving rats should begin four weeks after baiting begins and continue through the operation, followed by regular, less intensive monitoring for the next two years (by staff from the EAG, Government of Antigua and Barbuda staff, or other participating organisations). The removal of bait stations and other equipment would also require time at the end of the programme, although certain areas may be cleared earlier in the project.

A Communications or Media Plan should be prepared prior to the proposed eradication. This should contain contact details for all personnel (operational and management) and relevant technical information regarding the Redonda operation. This operation is likely to attract regional as well as national interest.

Table 13. Proposed timetable for the eradication of black rats from Redonda.

Where: → = ongoing phase of operation. Note: This timetable is subject to change due to project requirements, travel arrangements, staff, technical developments, weather and transport. Year 1 could be 2013.

	Year 1				Year 2				Year 3				Year 4				Year 5			
Apply for and obtain funding	■	■	■	■	■	■	■	■												
Wider stakeholder consultations (use findings from this feasibility report)	■	■	■	■																
Operational Plan (peer-reviewed)				■	■															
Communications and media plan						■														
Biosecurity plan						■														
Wildlife monitoring (lizards, birds, plants, etc)				■	■			■	■			■	■			■	■			
Contract eradication specialist				■	■	■	■	■	■	■										
Contract helicopter operator						■	■	■	■											
Advertise and select eradication personnel							■	■												
Train eradication personnel								■												
Obtain approvals, consents and permits						■														
Construct and test ex-situ lizard facility						■	■	■												
Implement and maintain biosecurity								■	■	■	■	■	■	■	■	■	■	■	■	→
Order bait						■														
Obtain all required equipment						■	■	■												
Construct bait stations								■												
Establish base camp on Redonda								■												
All equipment and bait delivered to Redonda								■												
Some lizards held in ex-situ facility									■	■										
Eradication (see Table 14)									■											
Operational debrief										■										
Technical report on eradication										■	■									
Long-term monitoring										■	■	■	■	■	■	■	■			
Two-year check for presence of rats																	■			
Formal declaration of rat-free status																		■		
Publication of results in scientific journals																		■		
Monitoring recovery of ecosystem										■	■	■	■	■	■	■	■	■	■	→

Table 14. Detailed timetable for the proposed eradication of black rats from Redonda.

Where: ? = aerial baiting by helicopter if required and →= ongoing phase of operation. Note: This timetable is subject to change due to project requirements, travel arrangements, staff, technical developments, weather and transport

	December				January				February				March				April			
Final round of stakeholder briefings, pre-eradication				■																
Check equipment and bait				■																
Obtain any last minute equipment					■															
Helicopter operational briefings					■															
International volunteers arrive					■															
Operational briefing with all personnel					■															
Construct bait stations and monitoring equipment					■	■														
Establish base camp on Redonda						■														
Deliver all equipment and bait to Redonda						■														
Establish bait station grid							■													
Bait (ground-based)								■	■	■	■	■	■	■	■	■				
Bait (aerial)								■		■		■		?		?				
Intensive monitoring											■	■	■	■	■	■	■	■		
Establish permanent bait and monitoring stations															■	■	■	■		
Train staff in long-term monitoring requirements																	■			
Long-term monitoring (ongoing)																			■	→
Remove bait stations																	■			
Dismantle camp and leave Redonda																		■		
Operational debrief																			■	
International volunteers leave Antigua																			■	
Final stakeholder briefing, post-eradication																			■	

5.4 Poison Application Method

It is recommended that the rat eradication on Redonda uses a combined aerial (using helicopters) and ground-based (using bait stations) operation.

The operation will require the use of helicopter and spreader bucket to apply bait to inaccessible areas and coastal slopes. The helicopter operator should have a proven history and experience in the aerial application of rodenticide baits. The helicopters should be fitted with differential GPS to ensure accurate bait coverage of the island. The spreader bucket should be tested and certified to ensure the correct swathe width and bait sowing rates for the eradication. Standard codes of practice for aerial application of bait are available from the New Zealand Department of Conservation, Animal Control Products (2006) and other agencies. A helicopter operator with aerial eradication experience should assist with the preparation of the detailed Operational Plan cover all technical and operational requirements for the aerial aspect of the proposed eradication.

The ground-based operation on the lesser slopes on the top of Redonda will use bait stations. The use of bait stations will reduce the impact on, and unnecessary mortality of, non-target species, reduce the amount of bait in the environment, will ensure that all bait is accounted for and bait take (and consumption) by rats can be recorded. Every bait station will have an individual number, plotted using GPS and all data entered into a GIS-linked database. Bait take and consumption will be recorded in notebooks in the field and transferred onto a computer back at the base.

It is important to note that although the use of bait stations reduces the risk to non-target species, some incidental loss to non-target species may be inevitable, especially in the sections of the island where bait is distributed by helicopters. However, this should be balanced against the long-term benefits to native species and ecosystem recovery.

5.5 Bait Station Design

Bait stations must allow ready access for rats to the bait, but must also prevent entry by key non-target species, such as goats and land birds, if present. Such goat-resistant bait stations (Figure 11) will be made from 1.5 litre clear water bottles (c. 250 mm long, 100 mm diameter), with wire “legs”, rocks or branches to peg them to the ground to prevent movement by animals and/or wind.

If necessary, additional wires can be pushed through both entrances to limit the size of the entrance and further secure the station. Bait is held in the centre of the station by a wire that passes through the station and is twisted over each end (Figure 32). The stations may be placed off the ground in some locations to prevent hermit crabs and other invertebrates from accessing the tubes.

This goat-resistant bottle bait station design was pioneered in Antigua (Varnham &

Figure 32. Example of goat-resistant bottle bait station for the ground-based phase of the black rat eradication (J. Daltry, FFI). Wire holds bait in place. Note entrance slightly raised off the ground to deter insects and crabs.

Figure 33. Example of a wooden "rodent motel" recommended for biosecurity on Redonda.

Daltry, 2006) and has proved effective in a number of eradication programmes in the Caribbean region (e.g. Bell, 2012). Similar tube stations have been used around the world (Varnham, 2003; Bell, 2004; Witmer *et al.* 2007; Bell *et al.* 2011).

In addition to bottle bait stations, permanent lockable plastic bait stations and/or "rodent motels" will be required in various locations around the island (such as high risk areas, seabird colonies and ruins) as part of the long-term biosecurity and quarantine plan (Figure 33, Section 8).

The wooden rodent motel can be used as a monitoring station (as shown) or as a trap or bait station. Bait or a trap is placed in the centre of the box. Bait can be secured into the station by large nails or wires.

5.6 Grid Density and Establishment Phase

Key to the success of ground-based phase of the eradication is the spacing of the bait station grid and availability of bait to the target species. On Redonda, it is recommended that the bait stations be established on a 30 x 30 m grid. Although other black rat eradication projects have used grid sizes up to 50 m (Thomas & Taylor, 2002; Bell, 2002; Towns & Broome, 2003; Witmer *et al.* 2007; Howald *et al.* 2007), a smaller grid ensures that rats are targeted more often inside their home range and the eradication can progress more effectively. It is important that bait stations are placed on offshore stacks which have vegetation or are connected to Redonda, cliffs and caves.

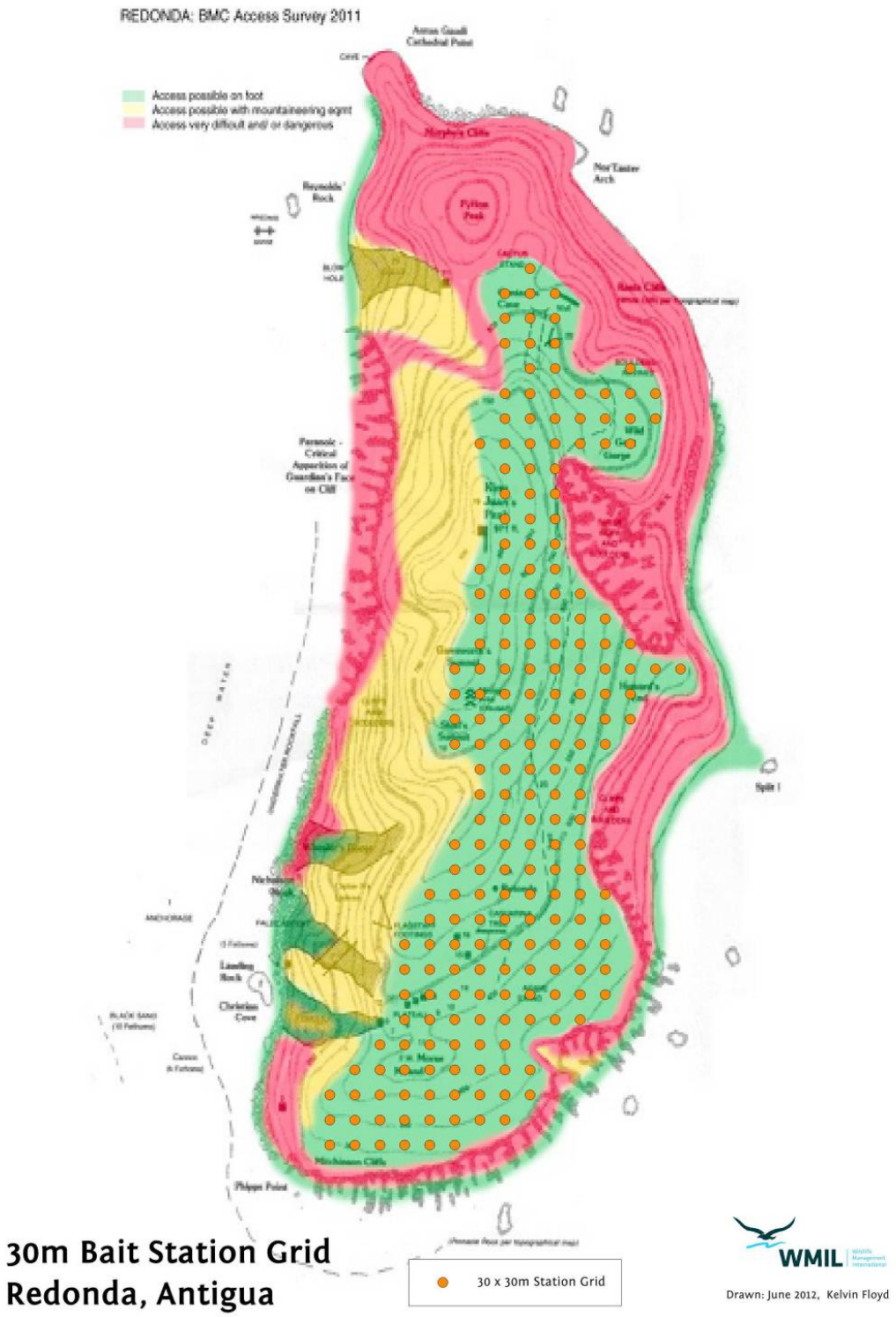
The top of Redonda will have a line of bait stations around the edge and parallel lines of bait stations across the surface. These grid lines will have to be laid out across the rock jumbles and scree slopes. Every bait station will be placed every 30 m along these grid lines. Additional stations will be placed along stone walls, ruined buildings and inside caves and sink holes. In all areas, flagging tape or marking poles (bamboo canes) will assist with locating bait stations. Each station will be individually numbered, have its position recorded using GPS and added into a GIS-linked database. Maps will be produced of the bait station grid for all phases of the operation. Any gaps in the grid can be detected and corrected prior to the poisoning phase. A diagram of the proposed bait station layout for Redonda is shown in Figure 34.

With the size of the top portion of Redonda and the recommended bait station grid, approximately 250 bait stations will be required. As the 'bottle' bait stations are recommended, a public call for empty 1.5 litre water bottles should be issued before the proposed poisoning phase of the eradication (i.e. between October and December of the year before the operation). The stations should be constructed by the eradication team and transported to Redonda in January, prior to the establishment of the bait station grid. It will be important to have a number of spare bait stations and a contingency supply of bait on hand to fill any gaps and cover any damage or losses due to feral goats or weather.

Once all the bait stations are in position on Redonda, they should be left for a week or more (without poison in them) so the rats become accustomed to them and accept them as part of the terrain. The establishment of the bait station grid will take one week using a team of at least six people.

Figure 34. Map of the proposed bait station grid for the ground-based phase of the eradication of black rats from Redonda.

Note: this bait station grid is an example only (n = 220 stations) and bait stations are placed at 30 m apart. Alterations, including additional bait stations, may be required during the operation due to vegetation, archaeological features, seabird colonies, caves, etc. Map reproduced from Turnbull (2011).



5.7 Poison Type

The poison used during the proposed eradication on Redonda should be brodifacoum, a second-generation anticoagulant rodenticide (see Table 12). Brodifacoum has been used successfully in over 70% of eradications completed worldwide and on most of the eradications within the Caribbean region (Howald *et al.* 2007; Varnham, 2010).

Brodifacoum is a second-generation anticoagulant poison that acts by reducing the vertebrate animal's ability to coagulate blood (i.e. inhibits the synthesis of Vitamin K and as a result rats die of internal haemorrhaging, Eason & Wickstrom, 2001). This toxin was developed after rats developed resistance to first-generation poisons such as warfarin (Bull, 1976; Eason & Wickstrom, 2001). Death usually occurs between three and ten days after consumption of a lethal dose (LD_{50}). For a 250 g rat, the LD_{50} for brodifacoum is less than 5 g of bait which can be obtained in a single feed. As a result bait shyness is avoided. The antidote for brodifacoum is Vitamin K_1, which is available as injections or tablets from any veterinary clinic or hospital.

Other second generation poisons (e.g. bromadiolone and difenacoum) and first generation poisons (e.g. diphacinone) have been used successfully in eradications around the world (Bell *et al.* 2000, 2008, 2011; Bell, 2004; Howald *et al.* 2007; Witmer *et al.* 2007). However, as these poisons require rats to eat larger amounts of bait (c. 18 g for difenacoum or c. 12 g for bromadiolone) or require multiple feeds regularly over several days to obtain a lethal dose (3 mg/kg over 5 days for diphacinone), they are less suitable for tropical situations when rats need to be targeted quickly and other natural food options are still available (see Table 12).

Brodifacoum is highly toxic and a risk to humans and non-target species. The medium lethal dose or LD_{50} (i.e. 50% of test subjects die from this level of poison ingestion) for several species is given in Table 15. This toxin is cumulative and can persist in the liver and other internal organs for several months (Table 15). Detailed information on factors such as persistence, toxicity and risk for brodifacoum is listed in Table 15. A Safety Data Sheet for brodifacoum is given in Appendix 12.2. Non-target risk information and mitigation measures are covered in Section 7.15.

Table 15. Technical information and LD50 details for brodifacoum (from Eason & Wickstrom, 2001)

Species	***LD50***	***Factor***	***Brodifacoum***
Rats	0.27 mg/kg	Formula	$C_{31}H_{23}BrO3$
Mice	0.4 mg/kg	Concentration(s)	0.002% (2 ppm) or 0.005% (5 ppm)
Dogs	0.25-3.5 mg/kg	Trade Names	Klerat®, PestOff®, Talon®, Finale®
Cats	0.25-25 mg/kg	Onset of symptoms	Usually within one week
Rabbits	0.2 mg/kg	Organ toxicity	Effects blood mainly (haemorrhaging), but also liver, heart, muscle, kidney
Pigs	0.1 mg/kg	Persistence	170-256 days (liver) [up to 9 months in stock]
Sheep/Goats	5-25 mg/kg	Breakdown in soil	Strongly binds to soil, slowly degraded
Geese	0.75 mg/kg	Breakdown in water	Extremely insoluble
Gulls	0.75-5 mg/kg	Breakdown in vegetation	No data available
Ducks	4.6 mg/kg	Secondary poisoning risk	MODERATE to HIGH (persistence increases risk to secondary poisoning)
Passerines	3-6 mg/kg	Antidote	Vitamin K_1
		Other information	Cumulative Very slowly excreted Limited data on reptiles and amphibians

Based its success in other eradication operations in the tropics and around the world, we recommend that wax-based Klerat® (20 g) blocks and wax-based pellets (10 mm diameter, brand and manufacturer to be determined) are used throughout the eradication. Klerat has been widely used in the Caribbean and should be used as the bait for the ground-based baiting phase and also as a monitoring tool (i.e. to detect rat teethmarks) towards the end of the operation. PestOff pellets have been widely used in aerial eradication operations around the world, but are attractive to some lizards. To minimise risks to the endemic lizards on Redonda, a pellet with a higher wax content should be used for the aerial baiting phase here. The smaller (5-g) blocks of Klerat may be suitable for this purpose, and have been used in rat eradication projects elsewhere (Meier, 2003).

For the aerial application of bait, the sowing rate would be 8 kg/ha for the first bait drop and 4 kg/ha for each following drop. The aerial applications would be one week apart. There should be a minimum of three drops, but a contingency of two further drops should be budgeted in case rats persist on the cliffs and slopes. These sowing rates will require 1.5 tonnes of pellet bait over the aerial poisoning phase (for c. 60 ha of cliff and slope areas). For the ground-based application, the bait will be distributed at a nominal dose rate of 0.5 kg of bait per hectare per bait round (3 blocks per bait station, 110 kg over the top portion of the island per bait round, a total sowing rate of 5 kg/ha). It is expected that bait will be replaced every day in the bait stations (for up to 21 days or until bait take has ceased) to ensure the eradication of all rats. At this rate, 0.5 tonnes of bait will be required to cover the area of the island using bait stations over the programme.

A total of two tonnes of bait (0.5 tonnes of Klerat in 20 g waxy blocks and 1.5 tonnes of Klerat or a similar bait in smaller pieces or pellet form) will be required for the eradication programme. An additional 0.25 tonnes of Klerat 20 g waxy blocks will be required for the long-term monitoring and biosecurity phase of the eradication project (and this will need to be replenished in future years).

5.8 Poisoning Phase of Proposed Eradication

The first aerial drop should occur in February. Subsequent aerial drops of bait should occur every seven days. This will allow the rats to eat and succumb to the bait before further bait is sown. Accurate maps of bait sowing patterns and coverage should be produced as the helicopter is progressing to ensure any gaps can be detected and covered. On the accessible areas of the coastal slopes monitoring of sowing rate, pellet distribution, rat take, etc. should be established and checked daily.

Bait stations should be checked every day, replacing bait as rats consume it. Partially eaten bait should be replaced with a new block. Old or partially eaten bait should be disposed of at a registered landfill as recommended by the safety data sheets (Appendix 12.2). Checking bait stations enables constant monitoring of bait take and the resulting die-off of rats. The success of the eradication and any problems, which need to be overcome during the programme, require the detail of daily recording.

It is also important that the programme provides radios for each person or ensures that all team members have cell phones (Redonda receives patchy coverage from service providers in Antigua and Montserrat). Communication between groups in different areas of the island and with the helicopter operators is vital for safety and enables one team to assist another if they have finished the work in their assigned area early.

Bait take and consumption will be accurately recorded into notebooks in the field for immediate inputting into a GIS-linked database back at base for ongoing analysis. Refinements to the poisoning programme can be made from this real time data. Hot spots of high bait uptake (due to rats or crabs) can be identified quickly and targeted throughout the programme.

The poisoning should begin in February and continue through to mid-March, overlapping with the intensive monitoring phase of the programme. Any surviving rats or problem areas should be obvious by

the end of February and could be treated with an alternative poison or techniques. Baiting can continue further into March if delays to the programme occur or unforeseen circumstances arise.

5.9 Intensive Monitoring Phase

Two to three weeks after first deploying bait, it is likely that all the rats on the island will have died. During the following three weeks an intensive monitoring programme should be established to detect any rats which may have escaped poisoning. A grid of rat-attractive food items (chocolate wax, soap, and candles etc.) as well as tracking tunnels (i.e. inked cards inside tunnels to detect rat footprints) or chew cards should be pegged out as monitoring tools.

All intensive monitoring points would be recorded on GPS, entered into the GIS-linked database and mapped to ensure coverage of the island.

Rats present in low numbers towards the end of an eradication operation (or during a new invasion) can be difficult to detect and fussy about food types. In a number of recent eradications, chocolate-scented wax has proved effective in detecting the last surviving rat. These non-toxic blocks are easy to interpret (identify marks to correct species) and has excellent longevity in a range of climates (E.A. Bell, pers. obs.).

The coverage of the monitoring grid extends beyond that of the bait stations; one monitoring point at the station and one in-between two stations. Each monitoring site is checked regularly daily to detect rat sign (usually teeth marks or foot prints). If any rat sign is detected, an intensive targeting programme (e.g. alternative bait, reduced spacing in the bait station grid, trapping etc.) is started until rat sign in the area ceases.

It is expected that the monitoring phase of the programme would begin from mid-February. The bait station grid can be removed once the intensive monitoring phase has been completed and rat sign is absent.

If rats are detected at the end of the programme, a second baiting and continued monitoring operation would have to be completed to finish the eradication.

5.10 Two-Year Monitoring Phase

It is standard practice to monitor the island for any surviving (or reinvading) rats for two years after the eradication phase before declaring the island rat-free. This is based on the average life expectancy of a wild adult black rat (c. 18 months).

The two-year monitoring programme should ideally occur at least every four to eight weeks throughout the year to confirm the success of the eradication project (i.e. to detect any surviving (or possible invasion) of rats). Permanent bait and monitoring stations should be placed around the island within known seabird areas, optimum rat habitat and in high risk areas to aid in detecting any surviving rats or intercepting invading rats. This monitoring can be undertaken by EAG, Government of Antigua and Barbuda or other relevant agencies staff or volunteers, with appropriate training.

All long-term monitoring points should be recorded on GPS, entered into the GIS-linked database and mapped to ensure coverage of the islands. Any sign or indication of rodents should be photographed and if possible collected or sampled for identification from experts.

This long-term monitoring for the presence of rodents after an eradication operation is usually done as part of the biosecurity programme. It is important to monitor using a range of detection devices, such as wax (chocolate and plain), chew cards, traps, rodent motels, trail cameras and indicator dogs, and have a

regular search effort. Low numbers of rats may take longer to detect than realised. It may also be possible to use the recovery of vulnerable species or establishment of prospecting species (such as shearwaters) to indicate that rats have been successfully eradicated.

The Biosecurity Plan must be effective and fully implemented. It is important to be able to distinguish between the failure of the eradication and a biosecurity failure should rodents be detected during the long-term monitoring. It would be useful to collect DNA samples of black and/or brown rats from Redonda, Antigua, Nevis, St Kitts and Montserrat (Section 6.1).

Once the first two-year monitoring phase has been completed and no rats have been detected, one further intensive island-wide survey should be completed. This involves putting a range of monitoring devices over the island (as in Section 5.9) and checking daily for a month. This final 'two-year check' is completed by the experienced eradication specialist and personnel. Once this check is completed and no rats have been detected after two years, the island can be officially declared rat-free.

5.11 Long-Term Monitoring

Even after the two-year monitoring phase has been completed and the island declared rat-free, basic monitoring should continue in perpetuity as part of the biosecurity programme to combat reinvasions by rats and other rodents (see Section 8). If rats are detected, swift action should be taken to remove (poison) them before they have an opportunity to repopulate the island.

The long term monitoring programme can employ the same permanent bait stations, rat motels and other detection devices established for the two-year monitoring phase (see above). While these devices should ideally be checked, and any bait replenished, at least every four-to-eight weeks, the cost and difficulty of accessing Redonda may make frequent visits impractical. The methods and frequency of monitoring will therefore need to be discussed as part of the development of the Biosecurity Plan, taking into account the probability and pathways of reinvasion, and the human and other resources available (Section 8).

5.12 Personnel

For the eradication programme on Redonda to be successful, it must involve experienced operators: a helicopter team and an island-based team.

There should be two Project Supervisors who will have overall responsibility for the planning and execution of each of the applications methods in the eradication programme. These Project Supervisors require in-depth knowledge and experience in rat eradications and be able to plan, coordinate, direct staff and volunteers and maintain effective communication with the government and NGO agencies, interested parties and stakeholders. These people will need to be involved in all stages of the preparation and implementation of the eradication programme, including attending project planning meetings, maintaining communication between the relevant agencies and project team, obtaining equipment and food and selecting and training personnel and volunteers (i.e. involved for several months throughout the lead-in time as well as the eradication operation).

While a number of Antiguans have acquired relevant skills and experience in eradicating rats from islands around Antigua, Redonda presents a number of new challenges, and this labour-intensive operation will require a number of specialist techniques that have not been used in this country before. It is therefore expected that the Project Supervisors will be contracted or sub-contracted international staff who have experience of similar operations elsewhere. Employing well-respected team leaders with a proven track record in this field may prove essential for giving donors confidence to support this operation.

It may also prove necessary to recruit a small number of international volunteers to assist with deploying bait, if insufficient personnel can be recruited locally. This operation will require living and working on Redonda in very basic conditions for several weeks. Most rat eradications in the Caribbean have involved mixed teams of local personnel and international conservation volunteers, usually appointed through Fauna & Flora International or Durrell Wildlife Conservation Trust. As a principle, however, first priority for all employment and training opportunities should first go to Antigua and Barbuda nationals, in order to build national capacity and reinforce local ownership. This principle is also in strict accordance with national labour legislation.

5.12.1 Helicopter personnel

The helicopter team will require the Helicopter Project Supervisor, pilot(s), engineer and ground crew to undertake the aerial application of bait on Redonda. This should be a team that have been experienced in this type of operation before. The ground crew would be responsible for getting the spreader bucket loaded and ready for deployment. There is the opportunity for the local helicopter companies to be trained in this work by suitably experienced eradication operators to build capacity in the region.

5.12.2 Island-based (bait station) personnel

The island-based team will need a Project Supervisor and at least five personnel (which could be volunteers who have experience on Redonda or on other eradication programmes) that make up the rest of the project team. If using volunteers, it is preferable to have them working for the duration of the programme. All personnel must have their full time committed for the duration of the eradication phase for the project to be successful. Given the terrain on Redonda, it could be useful for at least some of the team members to have advanced climbing skills.

While it may be difficult for local technicians (e.g. EAG and Government of Antigua and Barbuda staff) to commit to spending many weeks on Redonda, it is important to provide opportunities for these staff to be trained during the eradication programme. Build local capacity is particularly important for enabling and encouraging these individuals or agencies to implement the vital role of long-term monitoring after the eradication has ended.

The entire island-based programme will require a minimum of six personnel at all times. This will enable the grid to be established in the recommended timeframe, as well as ensuring that Redonda can be baited, monitored and checked every day as required.

5.12.3 Management personnel (off-island)

It is important to have the support and assistance of management personnel in the stakeholder organisations (e.g. relevant agencies in the Government of Antigua and Barbuda, EAG, FFI and other stakeholders) who are based off-island; in particularly one Project Manager or Coordinator: This post has been incorporated into the project budget and is assumed to be an Antiguan or Barbudan national. This person can assist with organising accommodation and transport on Antigua, transfers to and from Redonda, ordering food supplies, obtaining equipment and other aspects that may arise during the eradication operation. Importantly their role will have managerial, financial and media oversight. It is important that this manager deals with all public enquires, issues media releases and prepares background documents to support the project. Much of this work could be carried out through the offices of the EAG, Department of Environment or other relevant agencies.

It is important that there is also a media spokesperson for the project, from the Government of Antigua and Barbuda or the EAG. Media interest is likely to be high and funding agencies may wish to target media to advocate the project.

5.13 Transport

Equipment and other supplies will be transported to storage areas using transport companies or Government of Antigua and Barbuda trucks.

Project personnel, bait, food and equipment will have to be transported to Redonda by helicopter. Boats may be used to transport people, if the sea is calm and they are willing to climb, but it is not very safe or practicable to carry gear up the access gully (Section 7.2).

All equipment, bait stations and bait must be transported around the island on foot. Bait will be stored at one location close to base camp and the helicopter filling site.

Any eradication personnel (e.g. volunteers) from overseas would travel to Antigua and Barbuda by commercial flights from their home country and travel on Antigua by rental vehicle, bus or taxi.

5.14 Accommodation

For the island-based team, accommodation on Redonda will be in tents around a central camp site. Team members will require an individual tent for sleeping and holding personal gear. There will also need to be a large tent (or cover) for cooking which will be also used as the main meeting area. Another large tent will be required for food and water storage. Bait is also required to be stored under cover. Note that the Offshore Islands Conservation Programme already has much of the necessary camping gear.

A helicopter site will need to be identified on the island where the loading of bait and equipment is undertaken. This will need to be a short distance from camp to ensure easy transfer of gear, but far enough away to prevent damage to tents from downdrafts.

It is also important that there is access for e-mail or telephone contact to the stakeholders of the programme for weekly status reports and general contact for programme discussions. Mobile telephone coverage is available on some parts of Redonda (using networks providers in Montserrat and Antigua) in and as such remote internet facilities may be able to be established.

It is recommended that any foreign members of the eradication team stay at one location while on Antigua, preferably be a house with self-catering facilities and washing machine. Team briefings and analysis and details of the programme are discussed daily during eradication projects. The eradication on Redonda will be an arduous job in hot and difficult conditions and the team must be able to relax adequately on days off. Time off during the eradication operation will be spent on Antigua at this house.

5.14.1 Waste management on Redonda during the proposed eradication

Alternative foods must not be made available to rats on Redonda during the eradication. All waste will be collected by the team and transported back to Antigua for disposal at the landfill or incinerated on the island.

Waste will be stored in rat-proof bins until removal from the island. Waste will be placed in large plastic sacks and triple-bagged prior to helicopter transport. It is very important that the camp site be well maintained and kept clean and tidy.

5.15 Equipment and Costs

An approximate budget covering all stages and requirements of the proposed eradication programme including planning, implementation, monitoring, general expenses and contingencies has been given in Appendix 12.3. These costs cover all requirements for an eradication programme on Redonda using professional operators, helicopter personnel and five volunteers and pre- and post-eradication monitoring. As planning and implementation timeframes for the proposed operation are spread over long period, it is important to ensure that funding arrangements account for this and provide for the effective implementation of all stages of the operation.

The cost of the Redonda black rat eradication is estimated at approximately US$ 630,000 over a four-year period (Appendix 12.3). Funding for the programme will need to be sourced from grants or international funding agencies.

All personnel should provide their own wet weather gear, hiking boots, general outdoor clothing, day packs, headlamps and personal gear. Project equipment will include accommodation, safety equipment (gloves, first aid kits, safety blankets etc.), notebooks, radios, GPS, maps and baiting or monitoring equipment. A list of recommended equipment is given in Appendix 12.4. This includes equipment required for all phases of the proposed operation. There are a number of items that can be used throughout the operation (such as project laptop, radios, first aid kits, notebooks, marking canes, flagging tape etc.). Although the list is detailed, it is likely that a number of other items will be needed, and a 20% contingency cost has been added to the budget. It is possible that many of these items will be able to be provided gratis by partner organisations or other agencies. All products listed are required for the success of the project. It is possible that sponsorship and donations may also reduce costs further.

Approximately $100,000 has been added to the budget to allow for the possibility of rats being detected at the end of poisoning phase or aspects of the project go over the allocated time. This additional contingency funding would allow for a second baiting operation to complete the eradication programme if some rats survive the first operation. Although the proposed Redonda operation is based on similar eradication projects in the Caribbean and around the world, and such additional baiting should not be necessary, it is important to make provisions for every outcome.

5.16 Communication

It is essential that the Government of Antigua and Barbuda is supportive of the proposed eradication programme on Redonda for it to be successful. Government agencies should be properly informed about all aspects and stages of the programme and continually consulted throughout the planning, implementation and monitoring stages of the project. Success is also dependent on the support of the Environmental Awareness Group and all other stakeholder groups, including the fishing communities and government environmental agencies on Montserrat.

We recommend:

- A Communications and Media Plan should be developed by the agencies involved in this project to guide ongoing consultation, media liaison, coordinate the dissemination of information, raise awareness of the proposed eradication to multiple stakeholders and explain the long-term goals and benefits.

- There should be regular meetings to inform stakeholders and interest groups during the development and implementation of the eradication programme, including public meetings and radio phone-in shows on Antigua, Barbuda and possibly neighbouring countries (Montserrat, St Kitts and Nevis).

- Frequently updated fact sheets and progress reports should be provided to stakeholders and interested parties in Antigua, Barbuda and neighbouring countries, outlining key aspects, phases and results of the eradication programme, and contact details.

- Information notices should be erected at the main landing beach on Redonda and on all relevant websites that may be seen by persons thinking of visiting Redonda (Government of Antigua and Barbuda, Environmental Awareness Group, Government of Montserrat, etc.) to notify people of the programme, outline all stages, inform when bait is present on the island and provide warnings and risk information regarding the bait stations and poison. Although Redonda has few visitors due to the difficult access, it is important that any people coming to the island are fully informed about the eradication programme.

- Site visits may be organised for stakeholders to provide information on rats, eradication procedures and progress, and results outcomes. These visits could be extended to media and representatives of funding bodies.

- Regular press releases can be provided to media outlets regarding the purpose, progress and results of the eradication programme.

5.17 Health and Safety

There are significant health and safety risks with the proposed eradication on Redonda, especially with regard to the island's steep and unstable terrain and the necessary use of helicopters.

The health and safety of the project team and any personnel involved with or visiting the proposed eradication must be the primary concern throughout the duration of the project. A detailed Health and Safety plan should be prepared for the project and approved by the relevant participating organisations prior to the eradication operation. This plan must detail all hazards and mitigation to avoid these issues. This should be the responsibility of the Project Coordinator and both Project Supervisors (Helicopter and Island-based). All team members must be given the plan, read and understand it and sign that they have done so. Contact details, next of kin, special requirements and medical conditions of all team members must be held by the Project Supervisors and overall Project Coordinator.

At least half of the field team should be trained in first aid. A member of the team should be designated as the Safety Officer, responsible for addressing any safety issue that arises during the project. Any unsafe practises or problems should be promptly reported to the Safety Officer, Project Supervisors and Project Coordinator and corrected.

During the eradication, daily team briefings should be carried out to raise and address any safety issues. Work programmes would also be discussed daily. All team members should be familiar with the island and work locations. Emergency and safety procedures should be outlined prior to the start of the project.

Any safety issues relating to visitors to Redonda should be addressed in face-to-face meetings with those people or groups concerned when they visit the island. All necessary safety measures to protect visitors will be discussed and in place prior to the eradication operation. Any safety equipment will be supplied to visitors when they arrive on the island. Detailed information on recommended clothing and footwear will be provided to the visitors before they reach Redonda.

Field first aid kits should be provided to all team members and a complete first aid kit should be stored at the base camp on Redonda. An Incident Report Register will be established and kept at the base camp. All personal protective equipment will be supplied to the team (including gloves, overalls, etc.).

6 Pre- and Post-Eradication Monitoring Research

In line with best practice, a number of research projects should be instigated before, during and after the proposed eradication to help inform, improve and evaluate the project.

As a minimum, this research should include monitoring of the island's birds, reptiles, invertebrates and vegetation as well as some specific studies related to the rat eradication. Monitoring should commence one year (two if possible) prior to the actual eradication to enable baseline information to be collected (some of the data presented in this report provide the 'pre-rat eradication' baseline, in particular for the rats, goats, birds and reptiles: see Section 2). This research programme should continue for at least two years after the eradiation phase, and ideally repeated every few years thereafter. Experience from the offshore islands of Antigua show that wildlife populations can continue to rise for more than 15 years after eradicating rats (Daltry *et al.* 2010).

Recommended surveys are outlined below, but a more detailed research plan should be developed in consultation with government and NGO technical personnel, setting out the necessary data collection protocols, data storage and analysis. An accurate map of Redonda should also be acquired or produced to help research planning, data interpretation and presentation. There is still a question mark over the size of the surface area of Redonda, which affects the accuracy of sampling strategies.

6.1 Rats

It would be useful to collect genetic samples from black rats on Redonda as well as black and brown rats from each of the neighbouring islands (i.e. Antigua, Barbuda, Nevis, St Kitts, Montserrat, etc.) to allow the genetic characteristics of individuals of each population to be mapped. This is likely to help identify the source of rats, should any be found on Redonda after the eradication programme has been completed. This will make it possible to determine whether the eradication of black rats failed (if the rats fit the identification and genetic identity of Redonda black rats) or whether the islands have been reinvaded (DNA will help determine where these rats have come from). The genetic material from Redonda should of course be collected prior to the eradication programme.

6.2 House Mice

Although house mice *Mus musculus* have never been recorded on Redonda, intensive monitoring should be undertaken to determine if mice are present prior to the proposed eradication. Monitoring for mice should use a variety of devices (such as wax tags, chew cards and tracking tunnels) and should be established across the island. Mice were not detected during this site visit, but that does not necessarily mean they are absent.

Although mice prefer commensal environments when available, there are a number of well-established house mouse populations that exist with little or no influence from people (Triggs, 1991). However, mice can have difficulty surviving in natural environments when other competitors such as rats and goats are present (Pocock *et al.* 2004). Mice can live in a range of habitats from swamps to mountains and can have home ranges between 10 metres and 2 km (Nowak, 1999).

If mice are detected, genetic (DNA) samples should be collected to allow the genetic characteristics of individuals of the population to be mapped. Samples from the other islands should also be collected. The presence of mice would alter the eradication techniques if mice are also to be targeted.

6.3 Birds

To monitor the seabirds, we recommend the number of nesting pairs of every species is counted regularly, ideally every year (although it would be acceptable to monitor the birds every five years over the longer term). Several persons on Antigua and Barbuda have already been well trained in seabird survey techniques, so there is no need to prescribe methods here. It is however important to allow sufficient time to cover the whole island (the island takes one very long day to walk around, and seabirds nest in almost every part: see Figure 12 to Figure 16), and focus effort on the peak breeding seasons for the various species. Playback calls could be used to detect shearwaters. Nest counts should be replicated at least three times at each location.

Although there are few records of land birds on Redonda, surveys of the distribution and abundance of land bird species should be undertaken on the island annually. The present number of species and individuals is so low that probably the best survey strategy is for an experienced birder or ornithologist to walk all over the island at appropriate times of day (early morning and late afternoon are usually best) and record all species seen. If and when land bird numbers increase, point counts can help provide a standardised measure of diversity and abundance. The point counts could have a fixed radius (e.g. 20 metres used by Daltry, 2010) or not (i.e. distance sampling: see Bibby *et al.* 1992). A random selection of sampling points (i.e. count locations) should be used selected from a grid covering the island. At each sampling point, a standard 10-minute count of bird abundance should be recorded. Count sites should also be marked by GPS and mapped onto a GIS system.

Additional recording of seabirds and land birds can also be undertaken by the island-based eradication team during their day-to-day work. Notes on bird interaction and any interference with bait stations should also be collected as part of the eradication team monitoring procedures (the eradication would coincide with the nesting season for boobies and magnificent frigatebirds).

Long term bird monitoring could be undertaken by the EAG (which has previously conducted several rapid seabird surveys on Redonda) or Government of Antigua and Barbuda personnel, or combination of these. It could also be undertaken as a university project or carried out in collaboration with INGOs (e.g. FFI, EPIC, RSPB). These surveys should continue during and after the eradication operation to monitor the recovery of those species recorded presently on the island and to detect new species (such as shearwaters) that may naturally colonise the island after the eradication of rats. Productivity and recruitment data could also be monitored as the resident populations recover.

6.4 Reptiles

The reptiles of Redonda including several endemic lizards that qualify as globally threatened. Detailed monitoring of the Redonda ground lizards, tree lizards and dwarf geckos should be undertaken during and after the proposed eradication operation, and further surveys conducted for Redonda skinks and (non-native) house geckos.

Before conducting the rat eradication, trials should be carried out to determine whether the lizards are attracted to any of the bait intended for rats. As noted in Section 4, we recommend use of Klerat 20-g waxy blocks for ground-based delivery on the top of the island, but we have not yet determined the optimal bait for aerial distribution on cliffs and steep slopes. The aerial bait must be in smaller pieces or pellets to be distributed using a helicopter spreader bucket, but smaller pieces are potentially more likely to be eaten by lizards. PestOff, which has been successfully used in other aerial rat eradications, is probably too risky to use in areas with endangered lizard species (ground lizards in Anguilla were observed to eat this crumbly bait, albeit not in lethal quantities: Bell, 2012). Further trials should therefore be conducted on Redonda, and other experts and rodenticide manufacturers consulted, to identify a

brodifacoum-based bait that is not attractive to lizards but still appealing to rats and suitable for aerial broadcasting. Potentially the simplest and safest option would be smaller (5 g) blocks of Klerat.

For longer term monitoring, point counts provide an easy and rapid method of monitoring ground lizards and tree lizards: a radius of 10 metres and 5 metres respectively is recommended (see Sections 2.3.2 and 2.3.3 for point count methods). The observation points could be somewhat randomly scattered, or, better, a set of fixed points could be established that are revisited twice annually. Given the highly threatened status of these lizards, and the fact that eradicating rats could have profound effects on their populations, a more intensive mark-recapture study (5-10 days) should also be conducted to provide accurate baseline counts to calibrate the point count data. Daltry (2000a) describes a suitable method for catching, marking and counting ground lizards that worked well in a very similar environment on Sombrero island, Anguilla. Lizards can be permanently marked using passive integrated transponders (as used to monitor the Antiguan racers *Alsophis antiguae* in Antigua) or temporarily marked using small blobs of nail varnish.

Monitoring the dwarf geckos is more challenging, because they are tiny, usually hidden from view and appear to be very patchy in distribution. Occupancy surveys could be a useful approach to help determine their distribution and monitor future changes in abundance. It is, however, likely that these geckos will readily use permanent bait stations and rat hotels (as related species of dwarf geckos currently do on Antigua and Saint Lucia), enabling their relatively abundance to be easily monitored as part of the routine long term rat monitoring programme (Sections 5.10, 5.11; Section 8). For example, when the bait stations or rat hotels are checked for signs of rats, the monitors could easily record the number of geckos observed in each station.

Lizard monitoring could be carried out as a student project, by EAG or Government of Antigua and Barbuda personnel, or by researchers from collaborating INGOs or universities. The second author (Jenny Daltry) would be willing to participate in this work.

Note that it is assumed that the Redonda skink and iguana are no longer present on the island. All field researchers should remain vigilant for any sightings of these lizards, however, as their re-discovery would be of immense conservation importance.

6.5 Feral Goats

The feral goats are having a major impact on the ecosystem of Redonda, especially its vegetation and soil. There are large areas of erosion and very limited vegetation growth compared to other islands without goats, and, furthermore, it is clear that plant species richness and abundance is continuing to deteriorate sharply (Section 2.6). If goats remain on the island, there will be limited (or no) recovery of vegetation and many of the current surviving trees, which are extremely important for wildlife, are likely to die off without being replaced.

The entire population in April 2012 was found to number 62-65 individuals, including 37 adult males, 16-17 adult females, and 9-11 kids (Section 2.4.3). It has been noted that the population of feral goats is under stress and many die due to starvation and dehydration throughout drought periods (Morse, 1979; J. Daltry, pers. obs.). Indeed, around a dozen goat carcasses were found on the Plateau in September 2012, having apparently starved to death (J. Prosper, pers. comm.). This suggests the entire herd has now fallen to around 50 or even fewer (assuming there were additional carcasses elsewhere on the island).

We recommend these state-owned animals should be culled or removed as a matter of urgency to prevent their further suffering, to allow the recovery of vegetation, and to prevent further desertification and erosion. While shooting may be the cheapest and easiest method, most of these animals could be removed alive (by trapping them in corrals or using simple snare traps) and taken to an enclosure on Antigua or elsewhere. Goats from Redonda have been taken to Montserrat in the recent past, where local farmers have experience of their husbandry (they are said to be rather wild and difficult to handle: M. Morton,

pers. comm.). Overall changes in vegetation cover, patterns or species composition and evidence of goat browsing should also be noted during and after the removal.

If this recommendation to remove the goats is rejected, the size and composition of the goat population should be monitored regularly (e.g. using methods described in Section 2.4.2) and it would be useful to conduct a more detailed study of the impacts of the feral goats are having on Redonda. Fences could be established to determine how vegetation changes (in terms of species diversity and abundance) when goats are excluded from certain areas.

6.6 Crabs, Beetles and Other Invertebrates

Surveys of the diversity and relative abundance of beetles and other terrestrial invertebrates should be carried out before and for at least several years after the rat eradication operation because their numbers are likely to change significantly. Due to the lack of identification guides for this region, the first round of studies should be undertaken under guidance from an expert entomologist who is familiar with Lesser Antillean invertebrates and can identify any species of particular conservation concern (e.g. alien invasive, endemics, threatened). It would be useful to develop a photographic guide to the species as part of this exercise. Monitoring methods may include hand collecting and the use of invertebrate traps (e.g. pitfall traps, malaise traps, light traps, other traps or a combination thereof), but should be developed under advice from an expert. Prof. Michael Ivie, Montana State University, has expressed interest in being involved in this work.

Once methods are established, and voucher specimens collected to aid identification, future ongoing monitoring could become a routine student project through a suitable national, regional or overseas university.

It could be valuable to obtain a density estimate for the crab population on Redonda to ensure sufficient bait is ordered to successfully complete the eradication. Additional monitoring of crab numbers and behaviour could be undertaken by the island-based eradication team during their day-to-day work. Notes on crab interaction and interference with bait stations should also be collected as part of the eradication team monitoring procedures as this can be used to quantify how much bait was consumed during the eradication which could be valuable information for other eradications in the region and internationally. The estimates of crab density could be used as a baseline for further surveys after the rat eradication to determine recovery or changes to the crab numbers and range across the island.

6.7 Vegetation

As demonstrated by the figures on page 46, photographs can be a powerful way to describe and present changes in vegetation, especially when the same views are repeated (see Figure 30 and Figure 31).

Fixed photo points across Redonda should be established and a series of photographs should be taken at each site to monitor the changes to the island in a wide scale. Standard protocols should be followed and clearly recorded for ongoing and consistent monitoring (e.g. as shown by Daltry, 2010, on Dog Island, Anguilla). To help find the photo points in the future, they can be physically marked with a pole and/or their coordinates recorded using a GPS and mapped. Certain photo points should be taken from the same places as some of the historical photos recorded in Morse (1979) to maintain consistency with these images and show changes over long periods of time. This method can be used by persons without expert botanical knowledge.

Vegetation plots should also be established (e.g. standard 1 m^2 and 10 m^2 plots for small herbs and larger plant species respectively) in a number of locations and habitats across Redonda. Vegetation cover and species composition should be identified in these plots prior to the eradication phase and regularly (ideally

yearly for the first few years, decreasing to every 5-10 years thereafter) afterwards to monitor regeneration, recovery and spread of native and any invasive species. Vegetation plots should also be marked with a pole and/or their coordinates recorded by GPS and mapped to ensure they can be found even after vegetation has grown up. It is particularly important to pay attention to the shifting balance between native and alien plant species. While native species are generally expected to have the competitive advantage, it may be necessary to actively control the more aggressive alien plants.

Finally, further general inventories should be carried out by expert botanists every 5-10 years to detect and identify species of plants on Redonda. With thorough searches, they would be able to verify which species have disappeared since the survey by Howard (1962), and which if any species reappear after rats are removed. There are a number of expert botanists who live or work in Antigua and Barbuda, including Chris Pratt, Carolyn Thomas and Kevel Lindsay, who may be interested in conducting more work here.

7 Risks and Difficulties

There are a number of risks or difficulties that have been identified and quantified that may affect the outcome of the proposed eradication project on Redonda. However, if addressed both before and during the eradication operation, these difficulties should not impact on the success of the project. These are covered below.

A detailed Risk Assessment should be completed for the proposed eradication. All appropriate safety training should be completed by the project team and safety equipment should be available to all members throughout the project.

7.1 Terrain and Topography

The physical features of Redonda pose a challenge for an eradication operation. Sections of the cliffs and coastal areas can only be accessed by boat or rope which makes regular checking difficult and other sections are inaccessible. A detailed access survey was completed by the British Mountaineering Council in 2011 which outlined areas that could be accessed by foot, rope or were inaccessible (Figure 35, Turnbull, 2011). Any rope access work will require suitably qualified and experienced team members as part of the project personnel. The use of a helicopter to spread bait in these inaccessible areas would ensure rats can be targeted in these sites.

The jumble of rocks and scree slopes will make moving around the surface of Redonda difficult and care will have to be taken by the island-based eradication team. This type of terrain may require an increased number of bait stations, but monitoring will detect the presence of rats and action can be taken to target any problem locations.

The high number of ruins and other archaeological structures may also increase the number of bait stations required, but this is unlikely to affect the programme in any way. The presence of these structures may reduce the home range of black rats within these areas, but additional monitoring should be able to detect this and action can be taken to target these locations during the eradication project.

Overall, however, no topographical characteristics on Redonda are unsurpassable and should not inhibit the success of an eradication programme that uses a range of techniques to apply the bait.

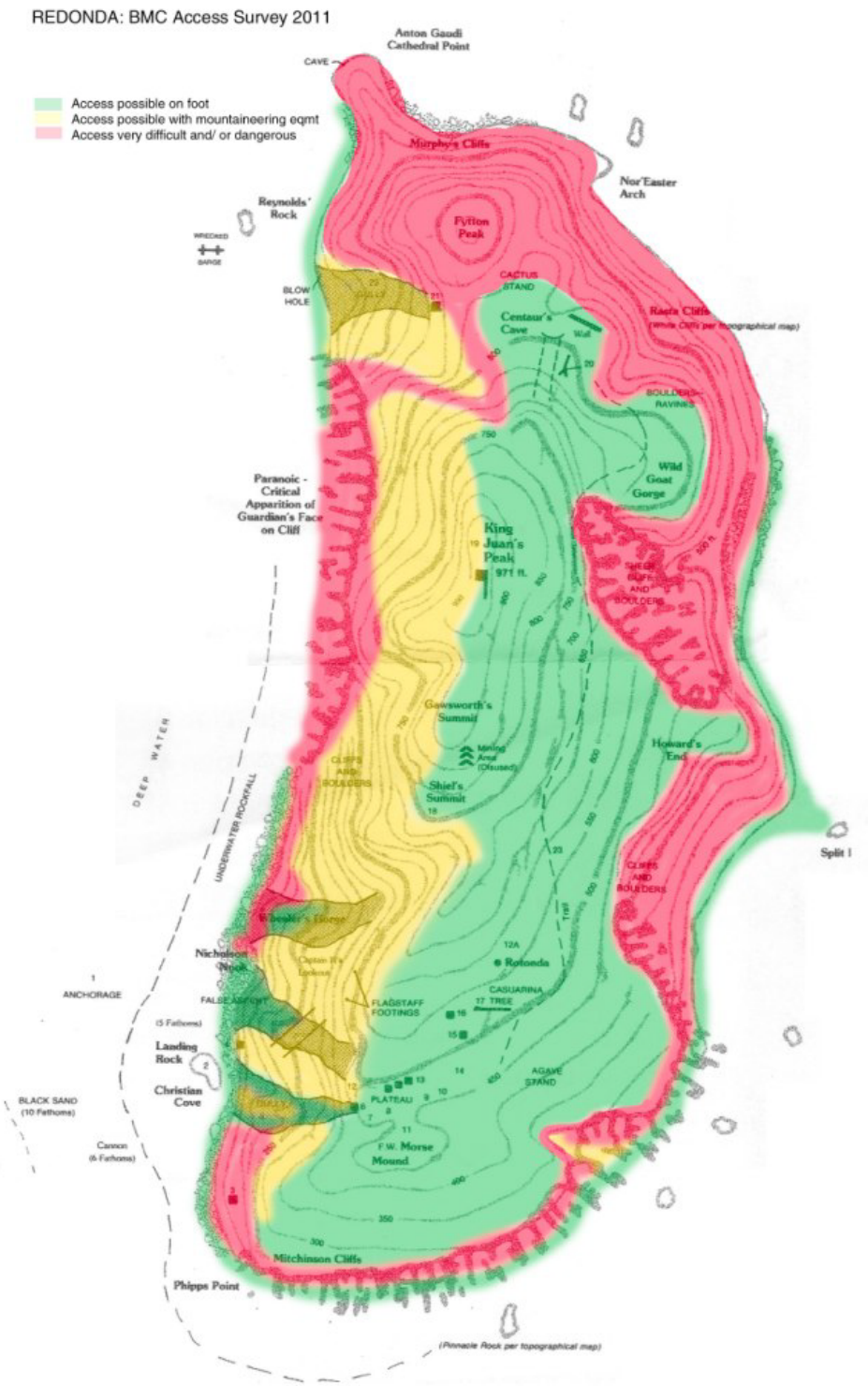
7.2 Transport to Redonda

The eradication of rats from Redonda and most of the necessary preparatory and post-eradication activities will be reliant on helicopter transport to the island to ensure the efficient and safe transfer of personnel and equipment to the island.

Landings from boats are extremely hazardous and the climb to the top of the island is difficult and unstable. It is not advisable to carry gear while climbing up the access gully because both hands are needed to safely climb this route. However, it would be worth consulting a civil engineer on whether this route could be made more stable and easier to climb with back-packs (e.g. by removing all loose boulders and installing hand rails or ropes).

Figure 35. Results of access survey of Redonda by British Mountaineering Council.

■ access possible on foot; ■ access possible with mountaineering equipment; ■ access very difficult, dangerous or impossible. Map reproduced from Turnbull (2011).



If a combination of helicopter and boat transport are to be used to reach Redonda, there are several potential risks to the project: (i) transport not being available; (ii) transport being affected by poor weather or sea conditions, causing delays; and (iii) physical dangers to personnel when getting on and off the boat and onto Redonda and climbing the access gully.

If a boat is to be used to transfer personnel (but not gear) to the island to reduce costs, the Antigua & Barbuda Coastguard would be an excellent option. A small tender would be necessary to reach the shore from the large coastguard vessel. The boulder beach on Redonda also poses a risk and landing will have to be attempted only in suitable weather and seas. Accurate condition reports would have to be relayed to the Coastguard from personnel on Redonda. Project personnel should be briefed on safe boat handling, best practice of entering and exiting a boat and rough shore landings. Life jackets and other safety equipment should be available on the boat.

7.3 Hurricanes

Like the rest of Antigua and Barbuda, Redonda is at risk from tropical storms and hurricanes. The project should been timed to avoid the peak hurricane season (August to November). In the unlikely event of an out-of-season tropical storm, there is an excellent weather reporting system in the Caribbean and warnings would be obtained early enough to evacuate personnel from Redonda if necessary.

7.4 Alternative or Natural Food and Shelter

It is unlikely that there will be a significant amount of alternative or natural food available to rats on Redonda, with the exception of goat droppings and seabird carcasses (or eggs and chicks). Any carcasses will have to be monitored closely to check for rat activity. The proposed eradication is timed for the dry season when vegetation is generally under stress (and fruiting and seeding is reduced or absent); Redonda already has a very depauperate plant community.

It is important that the eradication personnel ensure that all food at the camp site is stored away from rats in rodent-proof containers. The correct disposal of rubbish during the eradication on Redonda is vital, as some rats will not take bait if other ('natural') food types are present. No alternative food must be available to rats. Food and other waste will need to be stored securely (in rodent-proof bins) until disposal on Antigua or incineration on Redonda. The waste area must be clear of debris and well-maintained (i.e. kept clean). Additional bait stations should be placed next to the waste areas (and food storage and accommodation areas) to target rats in these areas.

7.5 Archaeology

Special care needs to be given to archaeological areas, sites and relicts on Redonda. Rats can have a negative impact on archaeological and historic structures; much of this is due to digging burrows underneath. Many of the historic building remains on Redonda have evidence of rats burrowing around the structures and through the walls (E.A. Bell, pers. obs.).

There are a number of potentially important historical sites on Redonda and we recommend that the Historical and Archaeological Society (the Museum of Antigua and Barbuda) is consulted on, and approves of, the proposed eradication project. All important or significant sites should be identified by Historical and Archaeological Society, and team members made aware of them. Whenever possible, bait stations should be placed outside of any recognisable structure (e.g. remnant house etc.) and if this is not possible, the required stations should be placed in areas that would minimise disturbance or damage to the site. Very important archaeological sites would be identified on field maps for the eradication team. Access to all archaeological sites should be limited to work purposes only.

Consultation with Historical and Archaeological Society (the Museum of Antigua and Barbuda) should continue throughout the eradication project. The regular status reports should detail work in and around archaeological features on Redonda, including images, if relevant.

7.6 Bait bittering agents

Bitrex™ (denatonium benzoate) is a bittering agent added to anticoagulant bait to deter human consumption. It is a legal requirement in many parts of Europe that Bitrex™ or an alternative bittering agent is added to all rodenticides.

Rats are not intended to be put off by Bitrex™, although recent research suggests that some rats can detect it even at very low concentrations, and preferentially choose bait that does not contain Bitrex™ (Veitch, 2002; EAB, pers. obs.). Three rats that actively avoided a bait containing Bitrex™ on Lundy Island, UK, were targeted using a special batch of Bitrex-free bait (Bell, 2006).

Standard Klerat bait contains Bitrex™. Based on previous experience in the Caribbean, and especially given the shortage of natural foods on Redonda, this is unlikely to be a problem: we anticipate the Klerat will be readily accepted by the entire rat population. Nevertheless, it would be prudent to purchase a small quantity of a Bitrex-free bait, just in case any rats avoid the Klerat due to the presence of this bittering agent or any other reason.

It is important to monitor bait take and relate it to rat sign and activity to assess whether any rats are actively avoiding any bait. Alternative methods (such as trapping, alternative baits, etc.) may have to be used to target these last surviving rats.

7.7 Resistance

Resistance to rodenticides in rats, particularly brown rats, was first detected following long-term use of warfarin in the UK and has now been found in a range of first and second-generation rodenticide around the world, including bromadiolone and difenacoum (Lund, 1984; Bailey & Eason, 2000; Eason & Wickstrom, 2001; Pelz *et al.* 2005).

Resistance has been reported throughout the USA, including Puerto Rico (Jackson & Ashton, 1986). Most rats that have been found to be resistant to these second-generation anticoagulants were resistant to warfarin, recognising the genetically-linked relationship, i.e. resistance is transmitted as an autosomal dominant trait (Greaves *et al.* 1982; Lund, 1984; Pelz *et al.* 2005). There is little information on resistance in black rats.

It has also been noted that a higher strength toxin (0.002% rather than 0.0005%) can result in a complete kill of resistant rodents (Lund, 1984; Buckle *et al.* 1994), but this increases the risks to other non-target species and the environment. It is important to note that trials have shown that bait attractiveness and uptake may also affect the effectiveness of the baiting regime rather than assuming it is resistance to the toxin (Quy *et al.* 1992).

There is no evidence of resistance on Redonda, but this could be investigated prior to the eradication operation. There has never reportedly been any use of anticoagulant rodenticides on Redonda, which makes it very unlikely that the rat population has resistance to brodifacoum.

7.8 Presence of House Mice

Although house mice have not been recorded on Redonda, their presence on the island could alter the proposed eradication.

Mice are also susceptible to the proposed rodenticide and, owing to their small size, will not be prevented from accessing neither the bait stations nor the aerially-applied bait on the ground. However, their home range is smaller than the proposed 30 m x 30m bait station grid, which could lead to some mice missing the bait. If mice are detected and are to be targeted in the proposed eradication project a smaller bait station grid size (and alternative bait formulation and possibly alternative bait type) would have to be used to ensure all mice are targeted effectively (i.e. inside the home range of each individual).

7.9 Environmental Impact of Poison

Environmental contamination by brodifacoum can be minimised by the use of well-constructed bait stations and minimum amount of aerially applied bait. In most cases, traces of poison are only recorded at the entrances of the bait stations. Bait stations would not be placed directly next to water sources nor intentionally dropped into the sea.

Brodifacoum is unlikely to be found in water because it is insoluble and as such, does not migrate through the soil (Eason & Wickstrom, 2001). When bait disintegrates, they would most likely remain in the soil, where they may persist for up to a year before being degraded by soil micro-organisms (Eason & Wickstrom, 2001). Brodifacoum is persistent in the system of animals and humans (>250 days), but is slowly excreted (in urine, Eason & Wickstrom, 2001).

Following an accident in New Zealand in 2001 when a large quantity of brodifacoum bait fell into the sea; monitoring was undertaken and brodifacoum residues were detected in shellfish at the immediate crash site (a 100 m^2 area), but these quickly dropped to nothing after several weeks (Primus *et al.* 2005). This is an extreme example of brodifacoum contamination and other studies from standard aerial eradication operations in New Zealand found no observable effects of brodifacoum on marine ecosystems (freshwater and marine species) after aerial bait drops (Empson & Miskelly, 1999; Fisher *et al.* 2011). Fish did not appear to show any interest in the bait, and most pellets disintegrated within 15 minutes, becoming unavailable to marine animals (Empson & Miskelly, 1999).

Regardless of these results, if shellfish or fish are taken off the Redonda coast, it would be prudent to have a no-harvest period linked to post-eradication monitoring to avoid any potential secondary human exposure as a result of consuming shellfish and fish. Bait remnants should be disposed by either burial (at a registered landfill on Antigua) or by incineration.

7.10 Human Health

Direct ingestion of baits or inhalation of bait dust poses a potentially significant health risk. Young children are the most at risk from ingestion, but no children will be present on Redonda during the eradication operation. The recommended bait for the ground-based portion of the eradication, Klerat, has Bitrex™ added. Bitrex is a bittering agent to make the bait unattractive to children and adults. As Klerat are wax blocks, the risk of dust inhalation is also reduced. If large quantities of bait are being transferred between containers, dust mask should be worn.

The ground crew working with the helicopter will be wearing overalls and protective masks and goggles when filling the spreader bucket. PestOff (or any other rodenticide) pellets will be more dusty when poured from the 25 kg sacks.

Another possible way for people to ingest the poison is via the consumption of feral goats. The goats are unlikely to access the bait inside the bait stations, but will be able to feed on the pellets on the steeper cliffs. Although goat hunting rarely occurs on Redonda, it is advised that goats are not eaten for one year following the eradication. Public notices should be placed in local media outlets to inform the general public that goats from Redonda should not be eaten.

Although there are unlikely to be visitors to Redonda, clear warning signs (detailing the eradication, bait station design and danger from bait) should be placed on Redonda at all suitable landing beaches. Warning labels should be placed on all bait stations advising visitors not to touch the stations or bait.

The antidote for anticoagulant poisoning is Vitamin K1. Brodifacoum is relatively slow-acting and several days are available for treatment. In the unlikely event that a person ingests bait, medical advice and aid should be provided on Redonda in the first instance or Antigua if necessary. Vitamin K1 should be available for eradication team members on Redonda. Diagnostic and treatment procedures will be discussed with local medical staff and doctors on Antigua as part of the operational planning process.

A detailed information sheet outlining the hazards associated with brodifacoum should be prepared for the eradication team as part of the Health and Safety plan prior to the operation. As part of the project Health and Safety procedures, to remove any minor risks from handling bait or animal carcasses, all eradication team members should wear protective gloves and protective clothing (i.e. overalls, boots etc.). It is very important to wash and thoroughly dry hands before eating, drinking and smoking after handling bait or carcasses.

7.11 Disease

Rats are known carriers of a number of diseases (including leptospirosis, toxoplasmosis, salmonella and cryptosporidium) and parasites (including mites and fleas).

Most people catch leptospirosis from drinking contaminated water or handling wet vegetation or soil (with the bacteria present after being spread in rat urine) and then transmitted via the hands to the mouth by eating or smoking, rather than by handling rats. The risk from leptospirosis is highest in warm, moist environments. The bacterium dies almost immediately when it dries out. Most people at minimal risk from this disease. Given that Redonda is very dry, and because there are few reports of leptospirosis (Weil's disease) on Antigua and Barbuda, and none from Redonda (Berger, 2010), this risk is low. As the eradication team will be drinking bottled water during the eradication on Redonda and the island is extremely dry, it is unlikely that there is any risk from leptospirosis.

Basic hygiene can greatly reduce the risk of catching diseases carried by rats. It is very important to wash and thoroughly dry hands before eating, drinking and smoking. Any cuts or abrasions should be covered. All rats and other carcasses should be handled using gloves.

7.12 Reinvasion Potential

There are a number of ways a rat can reach an island; these include swimming from neighbouring islands, accidental transport in visiting boats or yachts, accidental transport by visitors in luggage and food supplies or intentional release. Although there are only two likely ways rats could reach Redonda (i.e. by visiting boats and people or intentional release), all these risks have to be identified and managed and are covered separately below:-

7.12.1 Swimming

Redonda is separated from neighbouring islands by a large stretches of deep water (56 km from Antigua, 22 km from Montserrat and 32 km from Nevis) with notorious currents and rough seas. All are well over the maximum known swimming distances of black and brown rats of 1 km and 750 m respectively across open water (Russell *et al.* 2005a,b, 2008). Because it is possible that as brown rats can swim up to 1.4 km/hr and for over 45 minutes, particularly if the water is between 10 and 28°C, scientific opinion suggests that only islands that are separated by over 2 km of open water are safe from incursion by rats (Russell *et al.* 2008). Currents, water temperature and marine predators reduce the chances of rats

surviving longer distance swims (Russell *et al.* 2008) so it is clear that the 22 km distance between Redonda and its closest neighbour is too far for rats to swim. Because there are a wide range of habitats and food sources on the neighbouring islands, there is little pressure for rats to leave these islands in favour of Redonda.

Mice can also swim (Evans *et al.* 1978; King, 1990; Nowak, 1999), but although many studies have shown that mice can tolerate up to three hours of continuous swimming, food, body condition, water temperature (below 32°C) and current can affect orientation, movement and general swimming abilities (Dawson & Horrath, 1970; Dohm *et al.* 1996; Ershoft, 1954). It appears that mice do not swim as a method of dispersing to islands, because all recorded mouse incursions have been via transport of stores and equipment (Taylor, 1978; Russell & Clout, 2005). The maximum swimming distance for mice is only 500 m (Duncan *et al.* 2008) and as such, the distance from neighbouring islands to Redonda would be a definite barrier to mice.

7.12.2 Boats and helicopters

The ways in which visitors (and their food and equipment) are normally transported to Redonda minimising the risk of introducing rodents, because gear is typically placed on vessel on day of travel. Nevertheless, this risk needs to be recognised and mitigated wherever possible.

Visiting yachts pose greater risks because these vessels berth at other islands and wharves which have limited rodent control and then moor close to Redonda. The island is visited by private yachts throughout much of the year, but generally few people go ashore due to the difficult landing. Other boats visiting Redonda are usually chartered transport for people working (or undertaking research) on the island from Antigua or neighbouring islands.

Because all visiting boats constitute a risk for the re-introduction of rodents (however small), it is important that the eradication programme is discussed with any regular visitors and charter operators. An information campaign – possibly using radio, social media, leaflets and posters - regarding the eradication programme could outline the best practices for preventing re-invasion. Permanent bait stations and rodent motels should also be established on Redonda as part of the biosecurity procedures (Section 8).

Usual transport to Redonda is by helicopter, which reduces the risk of accidental transport of rats. The small space and regular checks of equipment and machinery on the helicopter prevents rodents from stowing away.

7.12.3 Researchers and other visitors

Redonda has few regular researchers and/or visitors, many of them linked to conservation agencies, Government departments or the Montserrat Volcano Observatory, but it is important that information regarding the eradication programme is readily available (such as links to websites, project leaflets and posters). The risk is especially high among researchers or other visitors who bring equipment to Redonda or intend to camp here. All food and equipment should be transported in rodent-proof containers and/or checked carefully before being brought onto the island.

Following the successful completion of the eradication, the communication programme could outline raise awareness of the rodent-free status of the island, outline best practices for preventing rodent re-invasion and detail how members of the public can assist. Examples of information leaflets produced following similar eradication projects could be obtained from the relevant agencies (e.g. Anguilla National Trust for Dog Island, RSPB for Lundy Island and National Trust of Scotland for Isle of Canna, Bell *et al.* 2004; 2008).

7.12.4 Intentional release

While there is always a possibility that a malicious person might intentionally release rodents on Redonda, the risk is greatly reduced if sincere efforts are made to ensure all stakeholders understand the purpose of the eradication and are invited to air any concerns or reservations they have before the operation begins.

It is important to continue to include and consult with all stakeholders, locally, nationally and even across the wider Caribbean region, in all stages of the project to ensure that they share ownership of the project and see the benefits for the conservation and ecosystem of Redonda and the Caribbean as a whole.

7.13 Tourism to Redonda and Antigua

The rat eradication should take place during the dry season, between January and April, which also happens to be the most popular time to visit Antigua. Because few tourists visit or land on Redonda, however, the proposed eradication is unlikely to impact tourism.

In fact, the eradication of rats and subsequent recovery of Redonda is likely to have a positive spin off for the tourism industry on Antigua and Barbuda as a whole. Not only is this project bound to attract good international press, but there could be opportunities for developing nature-based tourism on Redonda. Even a boat tour around the island can give visitors excellent views of the seabirds and a very safe and memorable experience without disembarking.

There are many examples around the world of tourism increasing following rat eradications, attracted by the improved opportunities to enjoy wildlife and a healthier natural environment. For example, the enhancement of Lundy island (UK) by the eradication of rats, coupled with a new branding and marketing programme, has resulted in over 20,000 tourists visiting each year (Khamis, 2011). Similarly, after eradicating the prolific population of black rats from Great Bird Island, Antigua, visitor numbers has risen from 17,000 per year to well over 40,000 (Daltry *et al.* 2010), many of them paying over US$100 per head for a catamaran ride to the island.

7.14 Funding

Funding must be realistic and cover all aspects to ensure the project can be completed effectively. Although some aspects of the project could be reduced (such as pre- and post-eradication research monitoring) and savings may be made through discounts or sponsorship deals, inadequate funding of the eradication phase will increase the risk of failure and/or compromise the safety of personnel. The organisations involved in this operation should therefore make a serious effort to secure adequate funding to ensure all planned activities can be delivered to a high standard.

7.15 Non-Target Species

All eradication projects carry a risk that some non-target species will be accidentally harmed by the eradication programme through direct consumption of bait, secondary poisoning by eating poisoned animals, or indirect effects such as trampling and disturbance. Programme planning must identify species at risk and establish preventative measures to minimise this risk.

On Redonda, the feral goats and a range of invertebrates, reptiles and birds could be at risk from primary and secondary poisoning, and the details of this risk and mitigation measures are outlined in Table 16. Every species (or group) is also covered separately below. The principal preventative action for primary poisoning (i.e. direct consumption of bait) is the design of bait station which excludes larger non-target species.

Table 16. Risk assessment for non-target species during the proposed black rat eradication on Redonda.

SPECIES	EFFECT	PREVENTATIVE ACTIONS	RISK
Plants and fungi	Trampling by field workers. Risk of alien plant species being introduced with soiled equipment.	Identify and map locations of rare plants. Screening, cleaning and quarantine of equipment used in rat eradication.	Low
Crabs and other invertebrates	Direct poisoning. Secondary poisoning by eating carcasses.	Bait does not affect invertebrates. Bait station design and bait formulation. Bait station design, bait formulation, bait wired into stations and placement on top of island	Nil
Marine life (i.e. fish, etc.)	Direct poisoning. Secondary poisoning.	Care to prevent bait falling into sea. Rat carcasses collected.	Very low
Reptiles	Direct poisoning. Secondary poisoning by eating invertebrates or carcasses.	Use of bait stations on top of island (where highest reptile populations are present) Bait station design and bait formulation. Retain some of the population in captivity during rat eradication Rat carcasses collected.	Low
Raptors	Secondary poisoning by eating poisoned rats.	(Few scavenging raptors recorded on Redonda) Use of bait stations on top of island Rat carcasses collected.	Low
Seabirds	Direct poisoning (gulls only). Secondary poisoning by eating poisoned rats (gulls). Disturbance	Use of bait stations on top of island. Bait station design, bait formulation and bait wired into stations. Rat carcasses collected. Timing of eradication. Minimise activity in breeding areas.	Low
Land birds (passerines)	Direct poisoning. Secondary poisoning by eating invertebrates which have consumed bait.	(Few land birds recorded on Redonda). Use of bait stations on top of island. Bait station design, bait formulation and bait wired into stations. Rat carcasses collected.	Low
Feral goats	Direct poisoning.	Use of bait stations on top of island. Bait station design, bait formulation and bait wired into stations. Adaptation of grid if interference noted. Temporary or permanent removal of all goats from island	Low to medium
House mice (if present)	Direct poisoning. Secondary poisoning by eating invertebrates which have consumed bait.	Bait type. Bait station design, bait formulation and bait wired into stations. Rat carcasses collected.	Medium

The risk of secondary poisoning of predators or scavengers that eat rats is generally low because most poisoned rats die underground. Three rats were found on the surface in the Lundy Island operation (Bell *et al.* 2004) and three during the Isle of Canna programme (Bell *et al.* 2006; 2008) in the UK. However, 160 rat carcasses were collected from the surface during the Dog Island eradication (Bell 2012) and over a dozen were found during the recent eradication of black rats from Green Island in Antigua. This discrepancy is probably related to rats nesting in the vegetation in the tropics rather than under rocks or in burrows (in temperate countries). It is therefore likely that a hundred or more rat carcasses will be collected on Redonda.

Searches for carcasses must therefore be undertaken as part of the baiting and monitoring grid checks as well as amongst ruins, in caves and optimum rat habitat. Searching for carcases will continue throughout the baiting and monitoring programme. Any carcasses found on the surface will be collected (in plastic bags and brought back to the base), necropsied to assess poisoning symptoms and disposed of safely (by incineration on Redonda).

Despite all preventative methods, it is possible that some incidental loss to non-target species may be inevitable. However, this should be balanced against the long-term benefits to native species and ecosystem recovery.

Through a partnership of agencies, the Royal Society for the Protection of Birds has developed a best-practice leaflet on the use of rat poison and the threats to wildlife (RSPB, 2010). This leaflet outlines methods to prevent rodent infestations, methods to control rats, information on trapping, rodenticides and resistance and the dangers to wildlife (particularly raptors and other birds of prey) for the general public. This leaflet is available from RSPB offices throughout the UK and online.

7.15.1 Crabs and other invertebrates

The recommended toxin, brodifacoum, does not affect invertebrates (Booth *et al.* 2001). Centipedes, slugs, beetles and smaller insects have been recorded eating bait on a number of eradication programmes around the world without losses. Following the eradication of rats the populations of large invertebrates are likely to increase with the removal of a major predator.

It is unlikely that the recommended bait will affect crabs. Pain *et al.* (2000) tested the effects of brodifacoum on land crabs on Ascension Island and found although crabs readily ate the bait, none were killed by the toxin. Low residues were recorded in body flesh, but these were excreted within a month (Pain *et al.* 2000). The main issue will be the amount of bait that crabs may consume which could affect the availability of bait to rats. Preventative measures such as raising or moving the bait stations and increasing the amount of bait sown by helicopter should help reduce the level of crab interference and bait take and ensure bait is available to rats.

As a precautionary measure, people should not eat any crabs (or any other animals) from Redonda, nor use them as fishing bait, for at least one year after the eradication.

7.15.2 Lizards

Lizards are known to be somewhat susceptible to brodifacoum poisoning, but the lethal dose is unknown and probably varies widely between species. Some reptiles feed readily on certain types of bait and a number of species have died during eradication operations around the world (Merton, 1987; Thorsen *et al.* 2000; Eason & Wickstrom, 2001; Merton *et al.* 2002; Bell, 2002; Fisher & Fairweather, 2005; Wedding, 2007). It has also been suggested that consumption of brodifacoum may cause interference of reptile thermoregulation and subsequent death (Merton, 1987). Laboratory trials have also reported mortality in

Caribbean geckos (Garcia *et al.* 2002). Wet baits appear to be more palatable than dry baits to certain lizard species (Freeman *et al.* 1996).

On the basis of published data, it is unlikely that Redonda's lizards would be exposed to a lethal dose using the rodenticide and methods proposed in this report, but the potential effects of sub-lethal doses are not clearly understood. There are at least three endemic lizards on Redonda that are at risk from primary or secondary poisoning: the highly omnivorous Redondan ground lizard *Ameiva atrata*, the largely insectivorous Redonda tree lizard *Anolis nubilus*, and the wholly insectivorous dwarf gecko *Sphaerodactylus* sp.

Significantly, there have been no deaths or conspicuous negative effects on closely related lizards in other parts of the Caribbean during or after eradications using the brodifacoum-based Klerat®, or on islands where there has been long-term use of Klerat. No Caribbean lizards have been found to show interest in eating Klerat, and this bait has been safely used in Antigua and Barbuda for more than 15 years without any demonstrable effects on the native *Ameiva griswoldi*, *Anolis leachi*, *Anolis wattsi, Thecadactylus rapicauda* or *Sphaerodactylus elegantulus* (J. Daltry, pers. obs.). Not all lizards feed in the same way, however, and some forms of bait could be more hazardous than Klerat. Anguilla Bank ground lizards *Ameiva plei* on Dog Island ignored Klerat, but some individuals were observed consuming small, non-lethal amounts of PestOff® (Bell, 2012).

The fact that all of the lizards on Redonda are endemic and qualify as globally threatened means that great care should be taken when using any bait. The Redonda ground lizards *Ameiva atrata* are of particular concern, because they are likely to scavenge dead rats and may directly feed on certain forms of bait. If PestOff® or a similar highly palatable bait is used for even part of the aerial operation, a large sample of the lizards (all three extant species) should be temporarily removed from Redonda while bait is distributed. This is an insurance against the species being significantly affected by direct or secondary poisoning. This will require the construction of properly staffed facilities on Antigua where several hundred lizards can be securely and individually housed for several months. Probably the biggest challenge will be establishing an ample food supply, including tiny live insects suitable for dwarf geckos. This could be one of the most difficult aspects of the rat eradication, and would certainly benefit from bringing in experts on tropical lizard husbandry to provide training and guidance.

Monitoring of all lizard populations should be carried out throughout the proposed eradication to determine whether lizards are consuming or being affected by the bait.

In general, experience from other eradications in the region, the use of Klerat on the top of Redonda (within the green zone on Figure 35, where the majority lizards appear to be concentrated) should pose no risk to reptiles. Following the eradication, the reptile populations are expected to increase with the removal of the rats as both predators and competitors (Towns *et al.* 2006; Daltry *et al.* 2010).

7.15.3 Birds

Some raptors (birds of prey) and gulls could be at risk from secondary poisoning from scavenging dead rats or targeting slower sick rats. However the only raptors found on Redonda in 2012 were peregrines, which would not take rats or carrion, and no gulls have been recorded on Redonda during seabird surveys. It is also likely that most rats will die under rocks or in crevices, making the risk of secondary poisoning of birds extremely low.

Searches for carcasses should be undertaken throughout the eradication programme along the established baiting and monitoring grids as well as around ruins and optimum rat habitat. Any carcasses found on the surface will be collected in plastic bags, necropsied to assess poison levels and incinerated on Redonda.

Despite most baits being dyed green or blue to reduce attractiveness to birds and having some wax content to the formulation, some birds have been recorded eating rodenticide baits during other eradications in the UK (Bell *et al.* 2000, 2006, 2008; Bell, 2004). However, experience on other Caribbean islands, including islands off the coast of Antigua, has found that birds do not eat the wax blocks (Varnham, 2003, 2010). If gulls were to come to Redonda, they might interfere with the bait stations, but alterations (such as extra rocks, wired entrances, hiding the stations etc.) could be made if necessary.

Some passerine birds are at risk from grain-based bait, but there are very few land birds on Redonda (only four zenaida doves recorded during the 2012 survey, which may or may not be resident). Bait will be delivered in bait stations on the top of the island and most passerine species will not enter a bait station. The risk to passerines is reduced further by the bait station design (increased length and additional wires) and the fact that the bait is wired into the stations through the majority of the eradication period (excluding the first two weeks). If any passerines are noted interfering with the bait and/or stations, further adaptations can be made if necessary throughout the eradication programme.

7.15.4 Feral goats

We recommend that the feral goats are removed from Redonda, ideally before the rat eradication is carried out. Any recovery of vegetation and some key animal species following the eradication of rats is likely to be poor if feral goats remain on the island. Goats are having a devastating effect on the vegetation, which will only get worse the longer they are left (Section 2.6). Many of the goats were in poor condition and during recent dry periods, large numbers of goats have starved to death (J. Daltry, pers. obs.). A dozen goat carcasses were found by Junior Prosper (pers. comm.) in September 2012.

The goats currently serve no economic purpose on Redonda apart from occasional hunting by persons from Montserrat. The goats are morphologically different to those on Antigua and Barbuda, and, while they appear superficially similar to other feral 'Spanish goat' stock, they may potentially contain some useful genes or other attributes for the country's farmers. If there is a desire to conserve this island race, it would be possible to live-capture a number males and females in order to preserve, study and use this breed on Antigua or Barbuda.

On the other hand, if the consensus opinion is that at least some goats should remain on Redonda, we recommend leaving only a small bachelor group to help keep the number of goats within the (currently very low) carrying capacity limits of the island.

If any feral goats are to remain on Redonda while the proposed rat eradication takes place, they are at risk if they directly consume the bait. This risk is fairly low because much of the bait will be restricted to bait stations (the whole top of the island). As shown in other similar operations around the world and in the Caribbean (Varnham, 2003; Bell, 2004; Varnham & Daltry, 2006; Witmer *et al.* 2007; Bell *et al.* 2008), goats will interfere with flagging tape, but typically avoid the bait and bait stations. Any such interference will be obvious and the baiting programme can be adapted as necessary. However, the goats do descend the cliffs and gullies where they would undoubtedly encounter smaller pellets of bait broadcast from helicopter. Although the project team should have the antidote (vitamin K_1) should any animals be accidentally poisoned, it would be very difficult to treat the goats due to their suspicious nature and feral status. It is therefore recommended that feral goats are not eaten for 12 months following the eradication.

8 Biosecurity (Quarantine and Contingency)

Once the black rats have been successfully eradicated from Redonda, the priority is to ensure that rats do not become re-established on the islands.

An effective biosecurity plan needs to be developed and fully implemented prior to the eradication phase of the programme. This Biosecurity Plan should also include information on invertebrate and plant pests, parasites and diseases and protocols for Redonda. It will be important to train local staff from EAG, Government of Antigua and Barbuda or any other relevant agencies to ensure that the biosecurity of Redonda can be successfully sustained by these people and groups in the long-term. Data collection and management are very important, particularly if incursions are detected and subsequently eradicated, and all sightings and other rodent-related observations should be recorded and investigated.

The greatest risk of reinvasion is from neighbouring islands (Antigua, Montserrat, St Kitts and Nevis). Rodents can be accidentally transported by a number of means, such as local charter boats, helicopters, visiting tourists, visiting researchers and private yachts. The movement of gear, particularly foodstuffs, provides rodents with the best chance of stowing away and arriving on an island, but it should not be difficult to put effective quarantine measures in place here. Any visitors to the island should be advised of rat-free status of Redonda and asked to maintain vigilance. Quarantine practices from other islands (such as St Kilda, Lundy Island, Isle of Canna, etc.) could be adapted for use on Redonda: for example, advising all visitors to carefully check their bags before venturing onto the island, and enabling charter boats to keep their vessels rodent-free.

The early interception of invading rats is vital and we recommended that surveillance using rodent motels, traps, permanent bait stations, chocolate wax, tracking tunnels, etc. is undertaken at least once per year, and preferably monthly, at the estimated cost of US$ 2,000-3,000 per visit (the main cost being the helicopter flight). Such devices will need regular maintenance, especially after tropical storms or hurricanes. Protocols should be established during the eradication and training given to local personnel. It is important to use a variety of baits (i.e. alternative toxins), lures and monitoring techniques: the same type of bait should not be used long-term. Any rodent caught in a trap should be sent for DNA sampling to determine provenance, i.e. whether it was a survivor of the eradication programme or new incursion from a neighbouring island.

Periodic independent audits and on-going monitoring of these biosecurity measures should be carried out, because it is (understandably) common for people and agencies to become complacent and let standards drop, especially after several years have passed without detecting any rodents. It is important that all involved (e.g. EAG, Government of Antigua and Barbuda, Antiguan community, donors and other relevant agencies) realise that good biosecurity is a wise investment and a vitally important long term commitment.

9 Likely Outcomes of Eradicating Black Rats from Redonda

9.1 Cost-Benefit Analysis

Thanks to the large number of rat eradication projects that have occurred around the world and within the Caribbean, the responses of a wide range of native species, including plants, invertebrates, mammals, reptiles and birds, have become increasingly well monitored and understood (Daltry *et al.* 2001, 2010; Towns *et al.* 2006; Witmer *et al.* 2007; Varnham, 2010).

There are likely to be a number of ecological benefits following the eradication of black rats from Redonda (Table 17), for example:

- Seabird species will have enhanced breeding success and increase in number.
- Prospecting Audubon's shearwater and other bird species will re-establish colonies on Redonda.
- Endemic, globally threatened reptile species will have enhanced breeding success and improved survival.
- Regeneration of plants susceptible to suppression by rats.
- Reappearance of rarely seen or unknown invertebrates.
- Economic benefits through increased revenue from research scientists and tourists.

However, it should be conceded that if feral goats remain on Redonda, some of the benefits may be significantly reduced or not occur at all.

There have been some unforeseen and unintended negative consequences following eradication projects around the world, specifically in terms of other exotic species (usually plants) increasing (Towns *et al.* 2006). It is possible that the following negative impacts could result following the eradication of rats from Redonda:-

- Changes and spread of exotic and problem plant species and invertebrates.
- Increased goat numbers due to improved vegetation cover and reduced competition with rats.
- Mice, if present, could increase in the absence of rats.

It is recommended that pre- and post-eradication monitoring of seabirds, reptiles, invertebrates and vegetation is included in the overall eradication project. This will help quantify impact on or changes to the status and productivity of these species following the eradication. This is important for evaluating how well the eradication has achieved conservation goals, for learning lessons that will benefit other island restoration projects, and for early detection of any other problems or needs that should be addressed.

Research should be conducted to collect baseline information on likely problem species, particularly non-native weeds and invertebrates. It is possible that some alien species whose seeds are eaten by rats may currently be kept at low densities which may cause a problem if weed species spread into vulnerable or important areas. However, many weeds are also spread by rats when they cache fruit and seed. Interestingly the eradication of rats may result in native plants out-competing some alien species.

The removal of rats is expected to benefit the conservation of the island's reptiles, all of which are endemic and qualify as globally threatened. Data in Section 2.3 provide a baseline for monitoring future changes.

Table 17. Summary of consequences of eradicating versus not eradicating rats from Redonda.

Note: Many of the benefits of rat eradication may be reduced or lost if feral goats still remain on Redonda.

ITEM	*RATS REMAIN*	*RATS ERADICATED*
BIODIVERSITY	Suppression or extinction of seabird populations	Expansion of seabird breeding populations
	Reduction of breeding success of seabird populations	Enhanced breeding success of seabird populations
		Establishment of prospecting Audubon's shearwaters and other small seabird species
	Continued, severe dearth of land birds (residents and migrants)	Enhanced and expanded populations of resident land birds
		Increased breeding success of land bird populations
		Potential to re-introduce burrowing owls
	Decline and possible extinction of endemic reptiles	Increases in the globally threatened reptile populations
		Possibility to re-introduce native species (such as iguanas)
	Suppression and extinction of native invertebrate populations	Expansion and increases of native invertebrate populations
		Reappearance of rarely seen or unknown native invertebrates
		Fluctuations in invertebrate numbers
		Possible increase of problem or invasive invertebrates
	Suppression or extinction of plant populations	Regeneration of native vegetation
	Ongoing loss of vegetation (desertification and hence soil erosion)	Improved resistance to soil erosion
	Changes or spread of problem invasive plant species (including heavy production of seeds and fruit) post-eradication	Reappearance of rarely seen or unknown native plant species
		Possibility to introduce rare native species
		Increased production of native seeds and fruit
	House mice (if present) remain very scarce.	Mice (if present) increase, with impacts on native invertebrates, reptiles, vegetation and birds
	Goat population continue to decline through starvation	Goats may increase slightly due to enhanced vegetation growth
HEALTH	Health risks (i.e. disease, ticks, fleas etc.) remain if rats still present	Removal of health risks (i.e. disease, ticks, fleas etc.)
ECONOMY	Limited prospects for tourism if rats remain	Prospects for high-value, low impact tourism, including bird watching.
	Little or no investment of international funding	Significant investment of overseas funding to eradicate rats, build national capacity and monitor wildlife
ENVIRONMENT	Damage to archaeology and historical features	No further damage to historical and archaeological features
	Aesthetics of permanent bait stations around island	No further baiting required (excluding biosecurity requirements)
	Severe soil erosion (due to digging plus loss of vegetation cover)	Reduced rate of soil erosion
	Effects of brodifacoum persistence in ecosystem (and rodenticide resistance)	Limited impacts on environment
		No resistance can develop if rats eradicated

Basic information on the ecology and seabird populations of Redonda has been collected by a number of individuals and organisations (including the present survey, see Section 2.2). The opportunity for both land birds and seabird restoration on Redonda post-eradication is immense. Audubon's shearwaters are likely to be proposing Redonda in low numbers and the natural establishment of this species could occur and it will also provide the opportunity for other seabird species to return to the island. Tropic bird, brown booby and masked booby populations are also likely to increase and spread across the island, as could the red-footed booby, noddy and frigatebird colonies if the number of trees is increased. A greater variety of land birds could recolonize Redonda in the absence of rats, although as long as goats remain on the island, shortage of trees and bushes will likely constrain their ability to survive here.

Islands without rats provide an opportunity for the reintroduction of species that had disappeared, to aid the conservation of endangered species and to repair the damaged ecosystem. In the case of Redonda, for example, it may be possible to reintroduce agaves, native trees, the burrowing owl and iguana.

Evidence from islands around the world suggests that the ongoing effects of rats on biodiversity and the environment alter the visitor perception and experience of that island (Towns *et al.* 2006). In many cases, tourism, as much as conservation, is the main motivation for clearing islands of rats. It is likely that the eradication of rats on Redonda (which are very obvious at present) will raise the profile of the Redonda and could, if desired by decision makers, attract more visitors to Redonda (and hence Antigua and Barbuda), particularly as seabird numbers increase. Most animal species on Redonda are impossible to see on Antigua and Barbuda, and new tourism ventures (such as birding tours, science tourism or combined heritage and nature tours) could be developed as a result. As the most ambitious eradication to be completed in the Caribbean region, this project on Redonda will raise the profile of Antigua and Barbuda around the world.

One of the great advantages of Redonda is that tourism is almost non-existent at present and there is scope to develop and manage this in whatever direction or scale that the country's decision makers see fit.

9.2 Implications of House Mice

House mice *Mus musculus* have never been recorded on Redonda and no sign was found during this feasibility study visit, but it will be important to monitor for mice before, during and after the proposed eradication project. The rats could be suppressing a very small mouse population.

If mice are detected after the rat eradication, a long-term monitoring programme should be instigated to monitor the recovery and possible future impacts of the mice on seabirds, reptiles, invertebrates and plants. It is likely that once rats have been eradicated, any mice present will increase in number, as shown by similar species in other eradication projects (Bell *et al.* 2004, 2011). Alternatively if mice are detected on Redonda *before* the eradication commences, a decision whether they should be eradicated as part of the proposed project should be made. This would require a smaller bait station grid size, possibly smaller bait blocks or type and formulation of bait and a heavy sowing rate during the aerial application of bait.

House mice can have significant impact on a range of species including seabirds, land birds, lizards, invertebrates and plants through direct predation, recruitment reduction and competition (Smith & Steenkamp, 1990; Newman, 1994; Marris, 2000; Jones *et al.* 2003; Towns & Broome, 2003; Cuthbert & Hilton, 2004). It is likely that if the mouse population recovers on Redonda that certain seabird species may not be able to recolonise the island and other species, such as reptiles, invertebrates and plants, may not be able to recover.

10 Conclusions

A well-planned, combined aerial and ground-based eradication programme which is staffed and led by experienced operators with the assistance of volunteers, is adequately funded, and supported by the Government of Antigua and Barbuda, the EAG and other major stakeholders, should result in the successful eradication of black rats from Redonda. Special measures to deal with a number of challenges, including terrain, access, and the safety of non-target species, will have to be adopted and refined prior to the rat eradication programme, but these should not prevent a successful outcome.

With the aid of unobtrusive quarantine measures (costing as little as US$ 10,000 per year), the risk of rat re-invasion is low. There should be significant benefits to the ecology of the island, and particularly seabirds and endemic, globally threatened reptiles, following the rat eradication.

Important and enormously useful though eradicating the rats would be, the eradication will not address all of the problems facing Redonda. While some rare animal species are confidently predicted to increase in the absence of rats, others species, especially plants, could continue to dwindle unless additional actions are taken. Therefore, to achieve a much fuller and impressive recovery, we advise the Government of Antigua and Barbuda, in partnership with the EAG and other conservation NGOs, to consider treating the rat eradication as just one phase of a more holistic site management programme.

Other areas of activity to consider include:- the formal designation of Redonda as a protected area, the partial or complete removal of feral goats to reverse the process of desertification; replanting and re-introduction of species that were historically present on the island; conservation of historical buildings and artefacts of national interest on the island; public education and awareness-raising; development of sustainable funding streams to support management, e.g. through low-impact nature-based tourism.

Such well-placed management actions could, if desired by the Government, lead to this remarkable island earning UNESCO World Heritage Site status for its unique combination of natural and cultural values.

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12 Appendices

12.1 Capture details of black rats caught during index trapping on Redonda (April 2012)

12.2 Brodifacoum safety data sheet

12.3 Budget for the proposed black rat eradication on Redonda

12.4 Equipment list for all phases of the proposed black rat eradication on Redonda

12.5 Selected photographs from Redonda

12.1 Capture details of black rats caught during index trapping on Redonda (April 2012)

Where: M= male, F = female, U = unknown, A = adult, J = juvenile, W = weight (g), HBL = Head-Body Length (mm), T = Tail Length (mm), N-E = Nose to Ear (mm), E = Right Ear (mm), HFr= Right Hind Foot (mm), HFr+C = Right Hind Foot plus claw (mm) and Morph is *frugivorus* = brown/cream; *alexandrinus* = brown/grey or (not present) *rattus* = black/black.

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
10/04/2012	21b	M	A	160	184	210	44	23	31	33	*frugivorus*	bald testes	good body condition
10/04/2012	20a	F	A	155	191	261	50	23	36	38	*frugivorus*	pale oviduct with little blood, perforated	good body condition
10/04/2012	23b	F	A	185	194	267	49	24	33	35	*frugivorus*	lactating	good body condition
10/04/2012	1b	F	A	155	188	242	42	22	31	34	*frugivorus*	lactating	good body condition
10/04/2012	3b	M	A	-	-	225	-	-	30	32	*alexandrinus*	bald testes	eaten
10/04/2012	5a	F	A	150	176		43	22	35	37	*frugivorus*	lactating	good body condition
10/04/2012	8b	M	A	-	-	243	-	-	35	37	*frugivorus*	bald testes	eaten
10/04/2012	21a	M	A	140	167	216	43	22	31	34	*frugivorus*	bald testes	good body condition
10/04/2012	12b	F	A	-	-	236	45	23	34	36	*frugivorus*	lactating	eaten
10/04/2012	11a	F	A	170	184	244	46	22	35	37	*alexandrinus*	lactating	good body condition
10/04/2012	4a	M	A	140	178	230	42	21	33	35	*frugivorus*	bald testes	good body condition
10/04/2012	11b	F	A	105	157	198	37	20	28	31	*alexandrinus*	perforated	good body condition
10/04/2012	5a	M	A	150	182	221	46	24	33	36	*frugivorus*	bald testes	good body condition
10/04/2012	23a	F	A	-	-	196	-	22	34	36	*frugivorus*	perforated	eaten
10/04/2012	24a	F	A	175	175	240	47	24	34	36	*alexandrinus*	pregnant	good body condition
10/04/2012	7a	M	A	115	163	209	41	22	30	32	*frugivorus*	bald testes	good body condition
10/04/2012	22a	F	A	130	172	224	46	24	35	37	*frugivorus*	lactating	good body condition
10/04/2012	14a	M	A	190	185	251	45	24	33	35	*frugivorus*	bald testes	discoloured liver
10/04/2012	26b	F	A	140	165	229	42	22	34	36	*frugivorus*	swollen ovaries	good body condition
10/04/2012	22b	F	A	170	184	240	46	24	35	37	*frugivorus*	lactating	good body condition
10/04/2012	26a	M	A	180	188	238	47	25	34	37	*frugivorus*	bald testes	good body condition
10/04/2012	9b	F	A	160	180	248	45	24	35	37	*frugivorus*	lactating	good body condition
10/04/2012	19a	F	A	170	179	230	42	23	34	36	*frugivorus*	lactating	good body condition
10/04/2012	12a	F	A	-	-	241	44	23	34	36	*frugivorus*	swollen ovaries	good body condition
10/04/2012	6a	M	A	185	198	253	48	24	37	40	*frugivorus*	bald testes	discoloured liver
10/04/2012	4b	M	A	170	184	238	45	24	35	37	*frugivorus*	bald testes	good body condition
10/04/2012	29b	F	A	185	186	250	46	22	34	36	*frugivorus*	swollen ovaries	good body condition
10/04/2012	28b	F	A	-	154	194	41	21	30	32	*frugivorus*	swollen ovaries	good body condition
10/04/2012	27b	M	A	115	157	200	40	22	30	32	*frugivorus*	bald testes	good body condition
10/04/2012	20b	F	J	105	150	201	41	21	32	34	*alexandrinus*	not perforated	J, good body condition
10/04/2012	13a	M	A	165	190	225	43	24	34	36	*frugivorus*	bald testes	good body condition
10/04/2012	20a	F	A	125	159	224	43	24	33	35	*frugivorus*	swollen ovaries	good body condition
10/04/2012	28a	M	A	-	180	203	42	22	30	32	*frugivorus*	testes	eaten
10/04/2012	17a	F	A	-	-	226	-	-	33	35	*frugivorus*	lactating	good body condition
10/04/2012	1a	M	A	-	201	245	45	23	36	38	*frugivorus*	bald testes	good body condition
10/04/2012	18b	F	A	-	-	-	-	21	31	33	*frugivorus*	-	eaten

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
10/04/2012	25b	U	U	-	-	-	-	-	-	-	*frugivorus*	-	only small bit of fur and flesh left, eaten
10/04/2012	3a	F	A	-	-	-	-	-	-	-	*frugivorus*	perforated	eaten
11/04/2012	1a	M	A	-	-	-	-	-	-	-	*frugivorus*	bald testes	eaten
11/04/2012	31a	M	A	205	193	240	45	24	38	41	*frugivorus*	bald testes	good body condition
11/04/2012	31b	M	A	170	178	241	42	22	36	38	*frugivorus*	one testicle (bald testes)	discoloured liver
11/04/2012	38a	M	A	235	204	246	45	23	35	38	*alexandrinus*	bald testes	good body condition
11/04/2012	34b	M	A	150	173	206	45	21	33	35	*frugivorus*	bald testes	good body condition
11/04/2012	32a	M	A	210	199	251	46	24	36	39	*frugivorus*	bald testes	good body condition
11/04/2012	33b	M	A	-	176	226	43	19	33	35	*alexandrinus*	bald testes	eaten
11/04/2012		F	A	155	183	237	45	19	32	35	*frugivorus*	lactating	discoloured liver
11/04/2012	35a	F	A	130	166	232	40	22	31	33	*frugivorus*	swollen ovaries	good body condition
11/04/2012	32b	M	A	170	199	235	45	23	35	37	*frugivorus*	bald testes	good body condition
11/04/2012	33a	M	A	160	187	231	44	23	32	35	*frugivorus*	bald testes	good body condition
11/04/2012	36b	M	A	-	184	222	46	22	34	36	*frugivorus*	bald testes	eaten
11/04/2012	38a	M	A	180	172	232	46	22	33	35	*frugivorus*	bald testes	good body condition
11/04/2012		F	A	120	190	253	46	25	33	35	*frugivorus*	lactating	discoloured liver
11/04/2012		F	A	135	178	231	45	22	35	37	*frugivorus*	lactating	good body condition
11/04/2012		F	A	-	-	194	-	-	31	33	*frugivorus*	-	eaten
11/04/2012		F	A	-	-	213	-	-	32	34	*frugivorus*	-	eaten
11/04/2012		M	A	140	174	222	43	22	33	36	*frugivorus*	bald testes	good body condition
11/04/2012		M	A	170	192	242	46	24	35	38	*frugivorus*	bald testes	good body condition
11/04/2012	19a	F	A	195	197	246	49	25	36	39	*frugivorus*	pregnant	good body condition
11/04/2012	22a	M	A	210	198	273	48	24	36	38	*frugivorus*	bald testes	discoloured liver
11/04/2012		F	A	115	162	207	41	23	30	32	*frugivorus*	swollen ovaries	good body condition
11/04/2012		F	A	150	190	250	46	24	34	36	*frugivorus*	lactating	good body condition
11/04/2012		M	A	-	188	240	44	23	36	38	*frugivorus*	bald testes	good body condition
11/04/2012		F	A	-	-	240	-	-	33	36	*frugivorus*	lactating	eaten
11/04/2012	17b	M	A	-	-	230	-	24	35	37	*frugivorus*	bald testes	eaten
11/04/2012	26a	F	A	160	178	235	45	22	31	33	*frugivorus*	lactating	good body condition
11/04/2012	17a	F	A	-	-	215	-	23	34	36	*frugivorus*	lactating	discoloured liver
11/04/2012		F	A	-	-	-	-	-	30	32	*frugivorus*	lactating	eaten
11/04/2012	24a	M	A	210	216	237	50	24	37	39	*frugivorus*	bald testes	good body condition
11/04/2012		F	A	100	163	202	38	20	28	31	*frugivorus*	perforated	discoloured liver
11/04/2012	23b	M	A	-	-	-	43	23	35	37	*frugivorus*	bald testes	eaten
11/04/2012	24b	F	A	160	170	228	43	21	36	38	*frugivorus*	pregnant & lactating	good body condition
11/04/2012		F	A	160	163	247	44	25	34	36	*frugivorus*	lactating	good body condition
11/04/2012	30a	M	A	140	175	210	43	21	32	35	*frugivorus*	bald testes	good body condition
11/04/2012	20	F	A	-	-	195	-	-	30	32	*frugivorus*	swollen ovaries	eaten
11/04/2012	41	M	A	-	-	-	46	25	33	35	*alexandrinus*	bald testes	eaten
11/04/2012	44a	M	A	170	187	230	46	23	36	38	*frugivorus*	lactating	good body condition
11/04/2012	28b	M	A	210	204	236	47	25	35	37	*frugivorus*	bald testes	good body condition
11/04/2012	18b	F	A	130	176	230	45	24	34	36	*frugivorus*	lactating	good body condition
11/04/2012		F	A	-	-	-	-	-	30	32	*frugivorus*	lactating	eaten
11/04/2012	27	M	A	-	-	206	-	-	33	35	*frugivorus*	bald testes	good body condition
11/04/2012	21a	F	A	130	174	217	44	22	30	32	*frugivorus*	lactating	good body condition

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
11/04/2012	22a	F	J	90	146	205	37	21	32	34	*frugivorus*	swollen ovaries	good body condition
11/04/2012	-	F	A	180	193	245	45	25	35	37	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	-	M	A	130	168	213	44	19	31	33	*alexandrinus*	bald testes	good body condition
11/04/2012	-	F	A	-	-	235	-	22	35	37	*frugivorus*	swollen ovaries	eaten
11/04/2012	-	M	A	150	172	216	44	23	13	33	*frugivorus*	bald testes	good body condition
11/04/2012	-	M	A	160	185	236	46	23	35	37	*frugivorus*	bald testes	good body condition
11/04/2012	44a	M	A	185	187	235	45	25	35	37	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	-	F	A	180	191	245	45	24	33	35	*frugivorus*	lactating	good body condition
11/04/2012	21b	M	A	-	-	228	-	23	32	35	*frugivorus*	bald testes	eaten
11/04/2012	25a	F	A	160	185	236	42	24	35	37	*frugivorus*	lactating	good body condition
11/04/2012	25b	M	A	155	193	231	48	24	35	38	*alexandrinus*	bald testes	good body condition
11/04/2012	46	F	A	185	187	-	46	25	29	31	*alexandrinus*	pregnant & lactating	discoloured liver
11/04/2012	23a	F	A	140	176	230	43	24	34	37	*frugivorus*	pregnant	good body condition
11/04/2012	28b	F	A	160	176	229	45	24	34	36	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	43b	F	A	160	180	232	48	23	31	33	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	45	U	A	-	-	-	46	24	-	-	*frugivorus*	unknown	eaten
11/04/2012	47b	F	A	185	184	235	42	23	35	37	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	28a	F	A	-	-	241	-		33	35	*alexandrinus*	pregnant & lactating	eaten
11/04/2012	30b	F	A	110	157	215	42	23	28	30	*alexandrinus*	swollen ovaries	good body condition
11/04/2012	42	F	A	155	178	-	46	22	35	37	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	49	F	A	180	184	227	47	22	35	37	*frugivorus*	pregnant & lactating	good body condition
11/04/2012	43a	F	J	85	142	193	38	19	28	30	*frugivorus*	swollen ovaries	good body condition
11/04/2012	47a	M	A	-	-	196	41	22	32	34	*frugivorus*	bald testes	eaten
11/04/2012	50	M	A	-	-	-	43	21	28	30	*frugivorus*	bald testes	eaten
11/04/2012	1a	F	A	-	-	-	-	-	-	-	*frugivorus*	lactating	eaten
12/04/2012	31a	F	A	135	172	214	36	22	33	36	*frugivorus*	pregnant	good body condition
12/04/2012	33a	M	A	145	168	214	45	19	34	36	*frugivorus*	bald testes	good body condition
12/04/2012	40a	M	A	200	193	226	45	21	36	39	*frugivorus*	bald testes	good body condition
12/04/2012	37b	F	A	160	173	221	40	23	33	35	*frugivorus*	lactating	good body condition
12/04/2012	40b	M	A	110	157	209	40	22	33	36	*frugivorus*	bald testes	good body condition
12/04/2012	35a	F	A	190	182	238	42	23	35	37	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	36a	F	A	-	-	236	-	22	32	34	*frugivorus*	lactating	eaten
12/04/2012	31b	M	A	-	-	-	45	24	31	33	*frugivorus*	bald testes	eaten
12/04/2012	32b	F	A	-	-	234	-	-	33	35	*frugivorus*	lactating	eaten
12/04/2012	33b	F	A	160	172	218	43	23	31	33	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	34b	M	A	165	178	240	48	22	36	39	*frugivorus*	bald testes	good body condition
12/04/2012	32a	F	A	-	-	236	-	22	33	35	*frugivorus*	lactating	eaten
12/04/2012	6	M	A	120	168	228	43	23	34	36	*frugivorus*	bald testes	good body condition
12/04/2012	5b	M	A	145	176	223	43	22	32	35	*frugivorus*	bald testes	good body condition
12/04/2012	2a	F	A	140	170	231	43	24	32	35	*frugivorus*	lactating	good body condition
12/04/2012	12	M	A	-	-	254	45	24	35	38	*frugivorus*	bald testes	eaten
12/04/2012	5a	F	A	145	180	213	44	22	32	34	*frugivorus*	lactating	good body condition
12/04/2012	10	M	A	-	168	223	39	21	33	35	*frugivorus*	bald testes	good body condition
12/04/2012	15a	F	A	175	193	245	48	23	35	37	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	11	F	A	130	171	223	39	29	33	35	*frugivorus*	lactating	good body condition

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
12/04/2012	13	M	A	150	186	220	43	22	34	36	*frugivorus*	bald testes	good body condition
12/04/2012	25b	F	A	130	181	235	44	23	33	35	*frugivorus*	-	good body condition
12/04/2012	1a	F	A	185	190	242	49	24	36	39	*frugivorus*	lactating	good body condition
12/04/2012	30	F	A	135	174	237	43	24	35	37	*frugivorus*	lactating	good body condition
12/04/2012	-	F	A	-	-	-	43	22	31	33	*alexandrinus*	pregnant	eaten
12/04/2012	-	M	A	-	-	206	-	-	31	33	*alexandrinus*	small testes	eaten
12/04/2012	19b	F	A	155	176	224	46	20	33	35	*alexandrinus*	swollen ovaries	good body condition
12/04/2012	17	F	A	150	181	226	46	23	32	35	*frugivorus*	lactating	good body condition
12/04/2012	3b	F	A	145	181	236	45	23	31	33	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	9	M	A	155	178	216	45	24	32	35	*frugivorus*	bald testes	good body condition
12/04/2012	21	M	A	140	175	230	42	23	35	37	*frugivorus*	bald testes	good body condition
12/04/2012	23b	F	A	155	194	241	48	23	33	35	*frugivorus*	swollen ovaries	good body condition
12/04/2012	25	F	A	155	178	227	-	25	35	37	*frugivorus*	swollen ovaries	good body condition
12/04/2012	26	M	A	115	166	198	40	22	32	34	*frugivorus*	bald testes	good body condition
12/04/2012		M	A	155	176	233	46	22	35	37	*frugivorus*	bald testes	good body condition
12/04/2012	1b	F	A	125	168	203	42	22	31	33	*frugivorus*	lactating	good body condition
12/04/2012	18	F	A	175	189	240	46	25	35	37	*frugivorus*	lactating	good body condition
12/04/2012	23a	M	J	65	139	181	37	21	30	32	*alexandrinus*	small testes	good body condition
12/04/2012	14a	M	A	200	206	-	46	21	35	38	*frugivorus*	bald testes	good body condition
12/04/2012	24	F	A	130	169	221	42	21	33	35	*frugivorus*	swollen ovaries	good body condition
12/04/2012	13a	F	A	130	178	221	42	20	33	35	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	21a	M	A	-	-	-	-	-	33	35	*frugivorus*	bald testes	eaten
12/04/2012	28a	M	A	-	-	-	-	-	33	35	*frugivorus*	bald testes	eaten
12/04/2012	43a	F	A	175	182	220	47	25	34	36	*frugivorus*	pregnant & lactating	good body condition
12/04/2012	41b	F	A	-	178	232	46	23	33	35	*alexandrinus*	-	eaten
12/04/2012	19a	M	A	155	182	228	42	23	33	35	*frugivorus*	bald testes	good body condition
12/04/2012	43b	M	A	205	193	215	46	25	35	38	*frugivorus*	bald testes	good body condition
12/04/2012	20	F	A	125	168	216	45	21	31	33	*frugivorus*	swollen ovaries	good body condition
12/04/2012	41a	F	A	-	180	226	47	22	33	35	*frugivorus*	lactating	eaten
12/04/2012	4	M	A	95	151	206	41	19	32	34	*frugivorus*	bald testes	good body condition
12/04/2012	7b	M	A	135	175	220	43	23	31	33	*alexandrinus*	bald testes	good body condition
12/04/2012	24	M	A	15	162	216	41	22	31	34	*frugivorus*	bald testes	good body condition
12/04/2012	-	M	A	-	-	-	-	-	32	34	*frugivorus*	bald testes	eaten
12/04/2012	7a	M	A	115	161	216	42	19	30	32	*frugivorus*	bald testes	good body condition
12/04/2012	-	M	A	-	-	-	-	-	32	35	*frugivorus*	bald testes	eaten
12/04/2012	-	F	A	125	162	206	40	21	30	32	*frugivorus*	swollen ovaries	good body condition
12/04/2012	43	F	A	180	184	-	48	23	34	38	*frugivorus*	pregnant & lactating	eaten
12/04/2012	-	U	A	-	-	-	47	20	33	35	*frugivorus*	unknown	eaten
12/04/2012	-	F	A	165	186	237	46	23	34	36	*alexandrinus*	pregnant & lactating	good body condition
12/04/2012	-	M	A	210	190	236	50	25	35	38	*frugivorus*	bald testes	good body condition
12/04/2012	-	F	A	-	-	241	44	23	34	36	*frugivorus*	lactating	eaten
12/04/2012	-	U	A	-	-	-	-	-	34	36	*alexandrinus*	-	eaten
12/04/2012	-	U	A	-	-	-	-	-	33	35	*alexandrinus*	-	eaten
13/04/2012	26b	M	A	135	176	232	42	22	33	35	*frugivorus*	bald testes	good body condition
13/04/2012	9b	F	A	150	185	251	45	24	33	35	*frugivorus*	lactating	good body condition

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
13/04/2012	21a	F	A	145	182	236	45	23	33	35	*frugivorus*	lactating	good body condition
13/04/2012	11a	M	A	155	172	226	43	23	34	35	*alexandrinus*	bald testes	good body condition
13/04/2012	36b	M	A	140	188	247	46	22	34	35	*alexandrinus*	bald testes	good body condition
13/04/2012	-	F	A	160	173	232	45	19	35	37	*frugivorus*	lactating	taken pestoff pellet, good body condition
13/04/2012	14b	F	A	100	164	218	42	21	30	32	*frugivorus*	lactating	good body condition
13/04/2012	23a	M	A	160	195	230	44	22	33	36	*frugivorus*	bald testes	good body condition
13/04/2012	10b	M	A	115	182	246	44	25	31	35	*frugivorus*	bald testes	good body condition
13/04/2012	13	M	A	235	207	269	50	25	39	41	*frugivorus*	bald testes	good body condition
13/04/2012	39a	M	A	230	205	257	50	22	36	39	*frugivorus*	bald testes	good body condition
13/04/2012	26a	M	A	105	158	192	42	18	28	30	*frugivorus*	bald testes	good body condition
13/04/2012	3a	F	A	-	-	254	-	-	33	36	*frugivorus*	lactating	eaten
13/04/2012	36a	M	A	150	178	235	45	22	35	37	*frugivorus*	bald testes	good body condition
13/04/2012	11b	F	A	-	-	235	-	-	34	36	*alexandrinus*	pregnant & lactating	eaten
13/04/2012	31a	F	A	135	173	229	43	21	31	33	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	41b	M	A	-	185	224	43	23	35	37	*frugivorus*	bald testes	eaten
13/04/2012	44b	F	A	160	186	257	50	24	35	37	*frugivorus*	lactating	good body condition
13/04/2012	21b	U	A	-	-	-	42	23	30	32	*frugivorus*	unknown	eaten
13/04/2012	19	M	A	170	185	241	45	24	34	36	*frugivorus*	bald testes	good body condition
13/04/2012	4b	F	A	135	181	224	43	21	31	33	*frugivorus*	lactating	good body condition
13/04/2012	6a	F	A	-	-	-	-	-	36	38	*frugivorus*	pregnant	eaten
13/04/2012	42a	F	A	165	175	225	43	24	33	36	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	24a	F	A	115	179	227	43	24	33	36	*frugivorus*	-	good body condition
13/04/2012	17	M	A	-	-	212	-	-	33	35	*frugivorus*	bald testes	eaten
13/04/2012	24a	M	A	85	152	196	40	20	30	33	*frugivorus*	bald testes	good body condition
13/04/2012	18a	M	A	140	187	234	42	22	35	37	*frugivorus*	bald testes	good body condition
13/04/2012	16a	M	A	130	177	217	46	21	34	36	*frugivorus*	bald testes	good body condition
13/04/2012	32a	M	A	175	185	262	45	25	35	37	*frugivorus*	bald testes	good body condition
13/04/2012	32b	M	A	190	200	233	47	24	34	36	*frugivorus*	bald testes	good body condition
13/04/2012	1b	M	A	145	169	216	44	21	31	33	*frugivorus*	bald testes	good body condition
13/04/2012	1a	F	A	175	191	236	44	24	34	36	*frugivorus*	lactating	good body condition
13/04/2012	22b	F	A	110	176	209	43	22	33	35	*frugivorus*	lactating	good body condition
13/04/2012	18b	M	A	120	175	221	43	22	35	37	*frugivorus*	bald testes	good body condition
13/04/2012	12	F	A	145	177	225	44	23	31	34	*frugivorus*	lactating	good body condition
13/04/2012	22a	M	A	-	-	240	-	-	35	37	*frugivorus*	bald testes	eaten
13/04/2012	4a	F	A	185	195	253	47	23	37	39	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	13a	F	A	160	183	246	47	24	34	36	*frugivorus*	lactating	good body condition
13/04/2012	9a	F	A	165	184	250	47	22	35	38	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	25a	M	A	160	199	228	48	23	33	35	*frugivorus*	bald testes	good body condition
13/04/2012	26b	F	A	135	184	236	50	23	33	35	*frugivorus*	-	good body condition
13/04/2012	35a	F	A	150	183	220	45	23	32	34	*frugivorus*	lactating	good body condition
13/04/2012	33a	F	A	130	190	243	45	23	33	36	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	16b	F	A	-	-	210	-	-	30	32	*frugivorus*	lactating	good body condition
13/04/2012	50	M	A	190	192	242	45	24	34	36	*frugivorus*	bald testes	good body condition
13/04/2012	25b	F	A	160	188	244	47	24	32	34	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	35b	F	A	130	185	252	46	22	34	37	*frugivorus*	pregnant & lactating	good body condition

Date	Trap No.	Sex	Age	W	HBL	T	N-E	E	HFr	HFr+C	Morph	Breeding condition	Notes
13/04/2012	5a	F	A	120	168	218	43	22	32	34	*frugivorus*	lactating	good body condition
13/04/2012	24a	M	J	70	144	196	40	22	29	31	*alexandrinus*	small testes	good body condition
13/04/2012	47b	M	A	170	180	230	46	23	33	36	*frugivorus*	bald testes	good body condition
13/04/2012	38b	M	A	150	173	226	43	21	34	36	*alexandrinus*	bald testes	good body condition
13/04/2012	40b	F	A	155	184	237	43	23	35	38	*alexandrinus*	swollen ovaries	good body condition
13/04/2012	47a	F	A	150	177	237	45	23	34	36	*frugivorus*	lactating	good body condition
13/04/2012	33b	M	A	-	-	215	-	21	33	35	*frugivorus*	bald testes	eaten
13/04/2012	8b	F	A	-	-	-	47	23	34	37	*frugivorus*	lactating	eaten
13/04/2012	8a	M	A	115	167	216	41	23	32	35	*frugivorus*	small testes	good body condition
13/04/2012	39b	M	A	150	178	235	47	20	31	34	*frugivorus*	bald testes	good body condition
13/04/2012	6b	F	A	-	-	219	45	22	30	32	*frugivorus*	lactating	good body condition
13/04/2012	27	F	A	120	186	251	47	23	35	37	*frugivorus*	lactating	good body condition
13/04/2012	37a	F	A	120	185	246	47	22	35	37	*frugivorus*	lactating	good body condition
13/04/2012	28	M	A	150	179	217	44	22	33	35	*frugivorus*	bald testes	good body condition
13/04/2012	23b	F	A	105	161	212	41	23	31	33	*alexandrinus*	lactating	good body condition
13/04/2012	-	M	A	-	-	-	-	-	35	38	*alexandrinus*	bald testes	eaten
13/04/2012	49	M	A	130	169	226	43	21	33	35	*frugivorus*	bald testes	good body condition
13/04/2012	44b	F	A	170	190	245	50	23	33	35	*frugivorus*	pregnant & lactating	good body condition
13/04/2012	43a	F	J	75	143	195	40	21	27	29	*frugivorus*	swollen ovaries	good body condition
13/04/2012	44a	M	A	125	161	207	41	21	34	36	*alexandrinus*	bald testes	good body condition
13/04/2012	43b	F	A	125	166	220	43	22	33	35	*frugivorus*	lactating	good body condition
13/04/2012	45a	M	A	-	-	-	-	-	38	40	*frugivorus*	bald testes	eaten
13/04/2012	35a	M	A	-	-	242	47	22	35	38	*frugivorus*	bald testes	eaten
13/04/2012	46	F	A	140	186	237	48	23	33	35	*frugivorus*	lactating	good body condition
13/04/2012	47	M	A	-	-	235	-	-	33	36	*frugivorus*	bald testes	good body condition
13/04/2012	45b	F	A	-	-	218	47	23	32	34	*frugivorus*	lactating	eaten

12.2 Brodifacoum safety data sheet

The following information covers the safety information for brodifacoum (extracted from the PestOff® sheet). The bait label for Klerat® is available from the following link: Http://www.pestcontrol.basf.co.uk/agroportal/pc_uk/media/migrated/products_1/downloads/rodents/labels_1/KLERAT_WAX_BLOCKS_35KG.pdf).

SECTION I. COMPOSITION

INGREDIENT NAME: Brodifacoum;

MOLECULAR WEIGHT OF ACTIVE: 523.4;

MOLECULAR FORMULA OF ACTIVE: $C_{31}H_{23}O_3Br$

SECTION II. HAZARDS IDENTIFICATION

HAZARD CLASS (HSNO): 6.9 B, 9.1 D

HAZARD IDENTIFIERS:

Priority Identifier: Harmful, ecotoxic, keep out of reach of children.

Secondary Identifier: Harmful substance, Repeated oral exposure may cause toxin to accumulate in internal organs and may affect the clotting ability of the blood.

DANGEROUS GOODS CLASS: Not classified as Dangerous Goods as toxicity falls below Packing Groups III threshold.

SYMPTOMS OF POISONING: No symptoms may be apparent for several days if poisoning has occurred. Can kill if swallowed in large quantities. The active constituent (brodifacoum) is an anticoagulant chemical, which if taken by humans, domestic animals or pets, will reduce the clotting power of the blood. Nausea and vomiting may occur soon after ingestion, however in some cases effects from exposure may be delayed for several days or may not be evident unless checked by a physician. Typical overt symptoms of poisoning include bleeding gums, increased tendency to bruising, blood in urine and faeces and excessive bleeding from minor cuts. Haemorrhagic shock, coma and death may follow in cases of severe poisoning.

SECTION III. FIRST AID MEASURES

Ingestion: In the event of ingestion, do not induce vomiting. Consult a physician and provide an estimation of the amount of product ingested. In the case of very small amounts of product (< 10 grams) being taken, no symptoms may develop but larger amounts may affect blood clotting times. A physician can assess this and provide Vitamin K1 as necessary.

Eye Contact: Wash eyes with water. Skin Contact: Wash exposed area with soap and water.

Contaminated Clothing: Remove contaminated clothing and wash before re-use. Wear gloves and overalls when handling baits. Do not eat, drink or smoke. Clothing and gloves should be decontaminated by washing in hot soapy water.

AS THE SYMPTOMS OF POISONING WILL BE DELAYED FOR SEVERAL DAYS, ALWAYS SEEK MEDICAL ADVICE IF POISONING IS SUSPECTED.

SECTION IV. FIRE FIGHTING MEASURES

The product contains no toxic emissions as vapours, gases or odours. The principle hazard route is via

ingestion**.** Extinguish with water, foam or inert gas

SECTION V. ACCIDENTAL RELEASE MEASURES

In the event of a spill, isolate the spill area and take all practicable steps to manage any harmful effects of a spillage including preventing baits from entering streams or waterways. Scoop spilled baits into secure containers. Recover any undamaged bait for later use by placing in appropriately labelled containers and dispose of spoiled bait as directed in the disposal section below. Use a broom to collect fine material and wash down the spill area with copious water only after all spilled bait has been removed. Give consideration to possible hazards arising from irrigating spill sites. Brodifacoum is not water soluble but fine bait material may pose a risk to people, pets, livestock, wildlife and fish.

SECTION VI. HANDLING AND STORAGE

When handling open containers or baits, wear latex or rubber gloves. When loading aircraft or working in windy conditions, wear overalls, goggles and a dust mask as protection against dust entering the eyes or mouth. Do not eat, drink or smoke when using the product or handling open containers. Wash protective clothing and equipment after use. Remove the outer layer of clothing and wash hands and exposed skin thoroughly before meals and after any contact.

Store in original container, tightly closed and away from feed or foodstuffs. Keep out of reach of children, pets and livestock.

SECTION VII. EXPOSURE CONTROLS AND PERSONAL PROTECTION

Occupational Exposure Limits: Not applicable (not assigned).

Engineering Measures: Decontamination is through microbial decomposition in a biologically active medium.

Personal Protection Equipment: Operators using or handling the product in open containers must wear gloves. When working around aircraft, wear overalls, a dust mask and goggles to prevent the inhalation of airborne particles.

SECTION VIII. PHYSICAL AND CHEMICAL PROPERTIES

Form / Colour / Odour: Pellet and block baits have a solid cylindrical form, are dyed blue or green and may have an odour of cinnamon, fruit flavouring, or chocolate.

Solubility of technical grade brodifacoum Water at pH 5.2 = 0.00, Water at pH 7.4 = 0.38, Water at pH 9.3 = 1.00, Toluene = 0.72, Acetone = 2.30, Methanol = 0.27

SECTION IX. STABILITY AND REACTIVITY

Brodifacoum cereal based baits are stable and non-reactive under normal storage and use conditions.

SECTION X. TOXICOLOGICAL INFORMATION

The baits present a very low hazard to operators unless taken orally.

TOXICITY DATA FOR THE ACTIVE INGREDIENT - VARIOUS SPECIES*

White laboratory rat (oral) LD50	0.26 mg/kg B/W
Dog (oral) LD50	3.56 mg/kg B/W
Cat (oral) LD50	25.0 mg/kg B/W
Mouse (oral) LD50	0.4 mg/kg B/W

SECTION XI. ECOLOGICAL INFORMATION

Use the products only for the purpose indicated and in the manner prescribed by the product label.

Brodifacoum may persist for many months in the fatty tissue, liver and kidneys of sub-lethally poisoned animals. Mortally poisoned animals may present a secondary poisoning risk to carnivorous birds and mammals and in addition a tertiary poisoning risk where for example feral pigs eat poisoned possums and are subsequently taken and eaten by pig hunters. Take steps to mitigate any potential non-target exposure by wildlife, domestic animals or humans. Studies have shown that brodifacoum concentrations will decline within decaying carcasses.

Improper disposal of unwanted pesticide is unlawful. If wastes cannot be disposed of according to label instructions, contact your local hazardous waste advisor for guidance.

SECTION XII. DISPOSAL CONSIDERATIONS

Product which is surplus or spoiled should be disposed of by burying with other organic material on the active tip face of an appropriately managed landfill or buried within the biologically active layer of soil elsewhere within a secure area. Ensure that a good covering of earth is applied over the bait immediately to prevent access by scavenging birds. Avoid deep disposal.

Alternatively, burn unwanted bait material in a suitably constructed and appropriately located incinerator and bury any residues as above. As the smoke and fumes produced by burning is irritating and potentially harmful, ensure wind does not carry smoke plume towards populated areas.

Treating the baits through a sewage oxidation facility or other chemical treatment facility is also an acceptable means of disposing of unwanted bait material where this is allowed by local by-laws and regulations.

Burn empty bags or bury in a suitable location at a landfill. Do not use the empty container for any other purpose.

SECTION XIII. TRANSPORT INFORMATION

Proper Shipping Name: Not Applicable – Not classified as Dangerous Goods due to low toxicity

U.N. NO: Not Applicable Class: Not Applicable

Packing Group: Below PG III threshold for Dangerous Goods

Maximum transport quantity when for use as tools of trade = No limits

SECTION XV. OTHER INFORMATION

Do not use poisoned or contaminated animals for food or feed.

This product is toxic to most wildlife. Birds and mammals feeding on carcasses of contaminated animals may be killed. Take measures to minimise the chance of baits entering any body of water. Apply the product only as specified by its label directions.

Where practicable, the exposed bodies of all poisoned animals should be collected and destroyed by complete burning or deep burial at a landfill approved for hazardous wastes.

12.3 Budget for the proposed black rat eradication on Redonda

The following costs cover the entire project; planning, pre- and post-eradication research, implementation and monitoring. The eradication programme will need professional operators, helicopter personnel and at least seven volunteers.

	ITEM	EXPLANATION	No.	COST (US$)	TOTAL COST (US$)	NOTE
PRE- and POST-ERADICATION MONITORING (4 years)	RESEARCH STAFF	Bird monitoring, twice annually (pre- and post-eradication)	30 pd	150	4,500	1
		Reptile monitoring, twice annually (pre- and post-eradication)	30 pd	150	4,500	
		Invertebrate monitoring, twice annually (pre- and post-eradication)	30 pd	150	4,500	
		Vegetation monitoring, twice annually (pre- and post-eradication)	30 pd	150	4,500	
	TRAVEL	Return travel Antigua to Redonda, 4-8 researchers, pre- and post-eradication, sharing the same helicopter when possible.	10	1,350	13,500	2
	ACCOMMODATION	Camping facilities for 4-8 researchers for several days per year, pre-and post-eradication monitoring	40 pd	0	0	3
	SUBSISTENCE	Food for 4-8 researchers for several days per year, pre-and post-eradication monitoring	40 pd	30	1,200	4
	EQUIPMENT	For all research projects (as per Appendix 12.4)	1	16,629	16,629	5
	REPORTING	Data entry, analysis and reporting, pre-and post-eradication monitoring, 1 week per research team per year	8 pwk	500	8,000	6
				Sub-total	**US$ 57,329**	
BIOSECURITY PLAN	STAFF	Project Supervisor 1 - Island-based	1 mo	4,000	4,000	6
				Sub-total	**US$ 4,000**	
OPERATIONAL PLAN	STAFF	Project Supervisor 2 – Helicopter	1 mo	4,000	4,000	7
		Project Supervisor 1 - Island-based	1 mo	4,000	4,000	
				Sub-total	**US$ 8,000**	
ERADICATION AND INTENSIVE MONITORING	ISLAND-BASED STAFF	Project Supervisor 1 – Island-based	4 mo	4,000	16,000	8
		Field Rat Eradicators/ Volunteers	5 pm	800	4,000	9
	HELICOPTER STAFF	Project Supervisor	4 mo	4,000	16,000	10
		Pilot, engineer and ground crew, 4 personnel	2 mo	4,000	8,000	11
	TRANSPORT	International Travel (for international member to Antigua)	11	1,000	11,000	12
		Rental car on Antigua	3	1,000	3,000	13
		Helicopter transport (to Redonda)	12	2,025	24,300	14

	ACCOMMODATION	On Antigua, for up to 11 personnel	3	1,000	3,000	15
		On Redonda, for up to 11 personnel	15	500	7,500	16
	SUBSISTENCE	Food for 11 personnel	3	3,300	9,900	17
	BAIT (WAX BLOCKS)	Brodifacoum (Klerat), ½ tonne, 10 kg buckets	0.5 t	110	5,500	18
	BAIT (PELLETS)	Brodifacoum (pellets), 1 ½ tonne (in 25 kg sacks)	1.5 t	7,900	11,850	
	STATIONS	Bait stations, 1.5L plastic drink bottles	250	0	0	19
		Wires (c. 95 for 200 m, 2 rolls) for keeping bait in stations	500	0.48	240	
		Wooden boxes (stained), rodent motel, hinged and lockable, individually numbered, warning labels, etc.	25	50	1,250	
		Monitoring points, wires (c. $95 for 200 m, 2 rolls)	500	0.48	240	
	EQUIPMENT	As listed in Appendix 12.4	1	15,500	15,500	20
	HELICOPTER (BAIT APPLICATION)	Transport for bait and bait application, 8 hours per day per application (up to 6 applications), plus 2 contingency days	64	1,350	86,400	21
	FREIGHT	Freight costs (equipment to Antigua)			5,000	22
				Sub-total	**US$ 228,680**	
EX-SITU FACILITY FOR LIZARDS (to be confirmed)	STAFF	Herpetocultural Adviser to design facility, train keepers and address any problems, approx. 5 months including accommodation and subsistence on Antigua	5 pm	5,000	25,000	23
		Assistant keepers x 2	6 pm	1,500	9,000	
	TRANSPORT	Return helicopter, Antigua-Redonda to collect and release lizards (may require several trips)	5	1,350	6,750	
	CONSTRUCTION	Secure, purpose-built building to house lizards and live food supply	1	10,000	10,000	
	EQUIPMENT	Vivaria (>300) and other items, as listed in Appendix 12.4.	1	40	16,260	
	SUPPLIES	Food and other supplies for lizards.	3 mo	2,000	2,000	
				Sub-total	**US$ 69,010**	
TWO-YEAR MONITORING	STAFF	Monitoring for surviving rats, one day/month for 18 months	18	100	1,800	24
	TRAVEL	Helicopter transport (to Redonda), 1.5 hours per trip	18	2,025	36,450	
	EQUIPMENT	As listed in Appendix 12.4	1	4,450	4,450	
	REPORTING	Data entry, analysis and reporting	4	300	1,200	
				Sub-total	**US$ 43,900**	
FINAL CHECK	STAFF	Project Supervisor 1 – Island-based	3	4,000	12,000	25
		Volunteer	4	800	3,200	

	TRAVEL	International Travel	3	1,000	3,000	
		Helicopter transport (to Redonda), 1.5 hours per trip	3	2,025	6,075	
	ACCOMMODATION	On Antigua, for up to 4 personnel	1.5	1,000	1,500	
		On Redonda, for up to 4 personnel	1	0	0	
	SUBSISTENCE	Food on Redonda, 4 people	4	284	1,136	
	EQUIPMENT	As per long-term monitoring (see Appendix 12.4)	1	0	0	
				Sub-total	**US$ 26,911**	
QUARANTINE AND CONTINGENCY (establishment costs only)	STAFF	One day per two months, check of permanent bait stations and rodent motels, including data entry, analysis and monthly reporting	12	[100]	[1,200]	26
	TRAVEL	Helicopter transport (to Redonda), 1.5 hours per trip	6	2,025	12,150	27
	EQUIPMENT	As listed in Appendix 12.4	1	2,350	$1,850	28
				Sub-total	**US$ 15,200**	
CONTINGENCY (Repeat operation if required if any rats survive)				**Sub-total**	**$ 100,000**	29
GENERAL ADMINISTRATION (direct project costs only)	STAFF	Project Coordinator. May be a largely part-time role over 4 years, but full time immediately before and during the eradication.	40 mo	1,500	60,000	30
	COMMUNICATIONS	Telephone, internet	48 mo	50	2,400	
	STAKEHOLDER CONSULTATIONS	Including catering for workshops and meetings	16	300	4,800	
	OFFICE SUPPLIES	Paper, printer toner, other stationary.	48 mo	50	2,400	
	OUTREACH AND AWARENESS	Brochures, posters, social media etc to communicate project	4	1,500	6,000	
				Sub-total	**75,600**	
		TOTAL			**US$ 628,630**	31

Budget notes

1. The pre- and post-eradication monitoring should be undertaken by suitably trained and qualified personnel to determine recovery (or changes) in birds, reptiles, plants and invertebrates after the eradication phase has finished. Number of person-days on the island will vary, and most of these taxa will require a two-person

team. Staff costs are an average estimate: actual daily rates may range from $0 (e.g. visiting academics, students) to >$500 (consultants). Includes data analysis and report writing.

2. Transport to and from Redonda will be by helicopter. It is assumed there will be 1 trip per researcher per month (for either four or six months of the year depending on study species). It is assumed all four researchers will share the same charter trip to complete their research. Estimated costs of the helicopter are US$1,350 per hour.

3. Assumes researchers will have their own tents or use OICP tents/ other camping gear for accommodation on Redonda during their research.

4. US$30 per person per day, for food, water and miscellaneous (e.g. insect repellents, sunscreen, first aid supplies).

5. The required equipment is listed in Appendix 13.6. This list will need to be confirmed with individual researchers and may need addition items.

6. This covers one month of the office-based time of the Project Supervisor for the preparation and production of the Biosecurity Plan. This also includes estimated company overheads (for usual ongoing expenses of operational office such as office maintenance, rent, accounting fees, advertising, depreciation, insurance, legal fees, repairs, supplies, taxes, utilities, etc.).

7. This covers one month of the office-based time of the two Project Supervisors (Helicopter and Island-based) for the preparation and production of the Biosecurity Plan. This also includes estimated company overheads (for usual ongoing expenses of operational office such as office maintenance, rent, accounting fees, advertising, depreciation, insurance, legal fees, repairs, supplies, taxes, utilities, etc.).

8. The Project Supervisor (Island-based) would be involved for 4 months which includes preparation time, time on Redonda and final report production and is in charge of overall ground-based eradication operation.

9. This is a monthly stipend of $50 per week for volunteers to assist with living expenses while absent from paid work. It is recommended that five volunteers should be involved in the eradication programme. It is preferable to have volunteers who have previous experience on Redonda or eradication operations. Volunteers would be involved for 2 months.

10. The Project Supervisor (Helicopter) would be involved for 4 months which includes preparation time, time on Redonda and final report production and is in charge of overall helicopter eradication operation.

11. The Helicopter pilot, ground crew and engineer would be involved for 2 months which includes preparation time and time on Redonda.

12. This covers international airfares and travel for the eradication team (up to 11 personnel).

13. This covers the monthly costs of hiring a rental car or van. There will be in the need to have a vehicle for the duration of the operation (i.e. 3 months).

14. It is expected that there are four trips per month (for team movements, visitors, supplies etc.) from Antigua to Redonda totalling 12 trips. This may be altered due to weather and other factors.

15. The accommodation on Antigua should be in a rented self-catering house that can hold up to 11 people (or fewer, if most of the field personnel are Antiguan). This will be used for briefings and storage of equipment prior to the eradication and for time off during the operation. This accommodation would be required for three months.

16. The accommodation on Redonda will be temporary; in tents. A chemical toilet and shower tent (or location) will also have to be provided.

17. The cost for food is based on previous experience of projects of this size (approximately $300 per person per month) with a similar number of personnel. This food covers all personnel throughout the 3-month operation (including preparation and debriefing time on Antigua). Much of the food can be bulk ordered (non-perishables).

18. These are maximum prices for the bait that is presently available from wholesalers. It may be possible to get a discount for a large order, or get the bait donated as this is a conservation project. It would be good to get the wax block bait provided in 10 kg buckets as it can be stored securely and transported around the island easily. The pellet bait should be in 25 kg sacks so that it can be easily put into the spreader bucket. The project would require 4 tonne of pellet bait and 1 tonne of wax blocks.

19. This is the cost for all 250 bait stations including wire. Wooden rodent motels will also be constructed by the project team. The cost of marking poles, flagging tape and poison labels are covered in the equipment section.

20. These costs are estimated and are likely to be able to be reduced. All the equipment listed in Appendix 22.8 (Table 16) is vital for the programme, and other equipment may be required as the preparation of the programme continues. Some equipment (i.e. GPS, distance range finder etc.) may be able to be borrowed from other agencies for the duration of the project.

21. It will be required to use a helicopter to apply bait to the inaccessible slopes and cliffs. It has been estimated that it will require 8 hours of flying per day to complete one application, and that there may need to be up to 6 applications. Two contingency days have been included. The helicopter costs are estimated at US$1,350 per hour.

22. This is an estimation of freight costs and it may be possible to get freight companies to waive or reduce freight costs as a donation to the project.

23. It may be possible to subcontract an experienced reptile curator gratis from a reputable zoological collection in the US or Europe.

24. The long-term monitoring will be a continuation of the intensive monitoring, but limited to coastal zones and high-risk areas. This work may be done by local EAG or Government of Antigua and Barbuda staff which could reduce the overall costs. It is assumed that this will require only a day trip to the island to check the permanent stations.

25. The Project Supervisor and up to three volunteers would visit Redonda for four weeks to undertake a final intensive monitoring check over the entire island prior to rat-free declaration; covers preparation time, time on Redonda and reporting.

26. The quarantine and contingency (biosecurity) requires a person checking permanent bait and monitoring stations on Redonda. It is assumed that this will be undertaken by the Project Coordinator or other EAG or Government of Antigua and Barbuda staff member, and no additional staff costing has been added to the budget (it is likely to take one day per two-months (up to 6 days per year) plus another day per two-month for data entry (6 days), analysis and reporting; approximately $1,200 per year for staff costs). These checks will have to be undertaken permanently and regularly (preferably every two months).

27. It is assumed that this will require only a day trip to the island to check the permanent stations for the quarantine and contingency aspect.

28. These costs are for the establishment costs only (and first year of checking). This is an ongoing requirement to ensure Redonda remains rat-free. The quarantine and contingency equipment will need to be stored on Antigua. This will have to be bait stations, monitoring points, bait (50 kg), notebooks and pens, rodent teethmarks and footprint detection information and maps of permanent stations. It should be noted that the bait will only last for up to 3 years. It can be used on an uninhabited island or one of the other inhabited islands prior to expiration (and replacement). The permanent wooden rodent motels and bait stations will be constructed and put into place during the eradication programme.

29. This covers a contingency operation should there still be surviving rats at the end of the proposed eradication. This contingency fund could also be used in case of delays to the original project, increased costs for travel, fuel, food, additional equipment requirements and other unforeseen items or aspects of the project. See earlier notes for information on individual items. Much of the equipment can be used again for this extension to the project.

30. The direct costs include a Project Coordinator (mostly part-time) and the estimated additional costs of managing this project within the offices of the EAG, the Department of Environment, or a combination of national agencies. It does not include office rental.

31. This does not include any indirect costs that EAG, Government of Antigua and Barbuda, FFI or any other stakeholder may incur during the proposed eradication – these are liable to increase the overall cost by 10-15%. However, savings may be made on several of the items in the budget through sponsorship, donations and better estimates from suppliers in Antigua. If cuts must be made, it is better to reduce spending on the wildlife monitoring components than to compromise the actual eradication operation.

12.4 Equipment list for all phases of the proposed black rat eradication on Redonda

The following equipment is required to undertake the pre-and post-monitoring, preparation, implementation of the eradication operation, intensive monitoring and long-term monitoring on Redonda. This is not a complete list. Other equipment may be needed throughout the project or recommended by the researcher(s) who undertake the pre- and post-eradication monitoring aspect, and prices are liable to increase with inflation. As such, a 20% contingency amount has been added to the budget. Equipment requirements and costs should be reviewed carefully when preparing the Operational Plan.

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
PRE- AND POST-ERADICATION MONITORING (seabirds, reptiles, vegetation and invertebrates)					
Notebooks	Lined, field notebook, 4 per researcher per year, 4 years (2 years, pre- and post-eradication monitoring)	-	64	8.99	575.36
Pencils	Pencils, 2 per researcher per year, 4 years (2 years, pre- and post-eradication monitoring), 32 pencils	12 pack	3	2.86	8.58
Pens	Pens (biros; blue, black and red), 1 of each per researcher per year, 4 years (2 years, pre- and post-eradication monitoring)	12 pack	4	2.86	8.58
Marker pens	Blue, black and red	12 pack	4	8.99	35.96
Flagging tape	Hazard tape	75 mm (500 m)	16	9.49	151.84
Marking poles	8 ft bamboo poles to mark monitoring points (to be cut in half)	3 m x 100 mm diam. (100 pack)	10	77.98	779.80
Maps	Laminated	OS Map	16	6.99	111.84
GPS	To record waypoints for GIS-linked maps and database (e.g. locations of nests, photo points, etc.), 1 per researcher (such as Garmin e-trex)	-	4	89.99	359.96
Cell phone	Prepaid, for maintaining contact with mainland (one per researcher)	-	4	35.00	140.00
Letter paper	Letter paper for reports or maps, 1 ream per researcher per year, 4 years (2 years each pre and post-eradication monitoring)	Ream (500 pages)	16	2.29	36.68
Laptop	For data entry, storage, analysis and reporting, one for all researchers to share for Redonda project purposes.	-	1	600.00	600.00
Cameras	For vegetation fixed point monitoring and recording wildlife. Model should be water resistent and rugged (e.g. Lumix Panasonic)	-	1	250.00	500.00
Bird monitoring equipment	Specifications to be decided in consultation with researchers. Likely to include binoculars (potentially available from EAG), spotting scope and plastic tags for numbering nests	Various	1	1,500	1,500.00
Lizard monitoring equipment	Specifications to be decided in consultation with researchers. May include minnow traps, calipers, PIT tags and scanners, etc.	Various	1	3,000	3,000.00

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
Invertebrate monitoring equipment	Specifications to be decided in consultation with researchers. May include pitfall traps, malaise traps, light traps, collection jars, preservatives, etc.	Various	1	3,000	3,000.00
Plant monitoring equipment	Specifications to be decided in consultation with researchers. May include plant press, microscope and identification guides.	Various	1	3,000	3,000.00
First aid kit	First aid kits, field type, one per research team (x 4)	-	4	12.30	49.20
				Sub-total	**13,858**
				Contingency (20%)	**2,772**
	ESTIMATED TOTAL (PRE- AND POST-ERADICATION MONITORING)				**US$ 16,630**
LIZARD EX-SITU FACILITY (to be confirmed pending further research on risks to lizards)					
Vivaria for lizards	Commercially available clear plastic vivaria, various sizes, to house ground lizards, tree lizards and dwarf geckos. Species and, in most cases, individuals should be housed separately	Glass or clear plastic vivaria with good ventilation	300	40	12,000.00
Vivaria for live prey	Commercially available vivaria suitable for rearing non-flying fruit flies, crickets and other prey. Biscuit tins may suffice for mealworms and other species.	Glass or clear plastic vivaria with good ventilation	20	40	800.00
Other supplies	May include specialist antiseptic cleaners and other supplies for cleaning cages and rooms; pest control; cloth bags for transporting lizards; veterinary supplies, etc	Various	1	750	750.00
				Sub-total	**13,550**
				Contingency (20%)	**2,710**
	ESTIMATED TOTAL (LIZARD EX-SITU FACILITY)				**US$ 16,260**
ERADICATION OPERATION PHASES:					
ERADICATION PHASE					
Rat traps	Kill traps or DNA sample collection (available from OICP)	-	50	0.00	0.00
Marking poles	8 ft bamboo poles (to be cut in half)	3 m x 100 mm diameter (100 pack)	5	77.98	389.90
Flagging tape	Hazard tape, red and white striped	75 mm (500 m)	20	9.49	189.80
Marker pens	Permanent marker pens, good quality, to number tags	12 pack	2	8.99	17.98
Spray paint	Orange, red and blue, to mark bait stations	orange, red and blue (6 of each)	18	5.00	90.00
Nitrile gloves	Nitrile gloves, thick surgical gloves, 100 per box, for handling bait and rats	1 box (100 gloves) of each (mixed sizes)	3	5.52	16.56

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
Vitamin K_1	Vitamin K_1, both injections and tablets (antidote for brodifacoum)	10 doses	5	19.00	95.00
Notebooks	Waterproof notebooks	4 per person	40	8.99	359.60
Pencils	Pencils, HB, 4 per person	12 pack	5	2.86	14.30
Pens	Pens, biros, blue, black and red, 1 per person	12 pack	5	2.86	14.30
Cell phone	For contact between team and with mainland	-	10	35.00	350.00
GPS	GPS, for GIS linked maps (from earlier research monitoring phase)	-	1	0.00	0.00
Headlamps	1 for each team member	-	10	39.95	399.50
Batteries	Rechargeable AA and/or AAA batteries for headlamps etc., including recharge unit	4 batteries plus charger	10	12.49	124.90
First aid kits	First aid kits, field type for team members	-	10	12.30	123.00
Safety blankets	Emergency or safety blankets	-	10	3.95	39.50
Laptop	Data entry, data storage, GIS mapping, analysis and reporting (from earlier research monitoring phase)	-	1	0.00	0.00
Printer and toner	Production of daily bait take maps, information etc.	-	1	150.00	150.00
A4 paper	A4 paper, for reports, information, letters or maps	ream (500 pages)	5	2.29	11.45
Map	Enlarged maps of Redonda	OS Map	10	6.99	69.90
Whiteboard	Whiteboard for team notices and field locations		1	29.00	29.00
Whiteboard pens	Whiteboard pens for team notices and field locations	4 pack	2	10.00	20.00
Whiteboard eraser	Whiteboard eraser		1	5.00	5.00
Deb Skin Safety station	Deb Skin Safety station, for cleaning hands after using bait and handling carcasses	-	1	89.32	89.32
Deb Skin Safety station refills	Deb Skin Safety station refills, for cleaning hands after using bait and handling carcasses	3 of each	3	51.27	153.81
Stuff sacks	1 per team member, for carrying all emergency equipment	Outdoor designs (lrg)	10	3.49	34.90
Tools	For construction of wooden rodent motels; handsaw ($16), hammer ($16), nails ($2.86 for 100), hinges ($10.75 for 12)	-	10	29.61	296.10
Whistles	1 per team member, 'referee' type, for safety	-	10	3.35	33.50
Hi-visibility vests	1 per team member, for safety	-	10	1.65	16.50
Pocket knives	1 per team member, for scrapping wax blocks clear	Spartan	10	19.95	199.50
Thermos	1 per team member	500 ml	10	14.95	149.50
Lunch boxes	1 per team member	-	10	11.95	119.50
Generator	Honda EU200i	-	1	1,150.00	1,150.00
				Sub-total	**4,752**
				Contingency (20%)	**950**
	ESTIMATED TOTAL (ERADICATION PHASE)				**US$ 5,702**

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
ERADICATION OPERATION PHASES:					
INTENSIVE MONITORING PHASE					
Notebooks	Waterproof notebooks	4 per person	40	8.99	359.60
Pencils	Pencils, HB, 4 per person	12 pack	2	2.86	5.72
Pens	Pens , biros, blue, black and red, 1 per person	12 pack	2	2.86	5.72
Marking poles	8 ft bamboo poles (these will be cut in half) (100 pack)	3 m x 100 mm diam	5	77.98	389.90
Flagging tape	Hazard tape, red and white striped	roll	15	3.00	45.00
Marker pens	Permanent marker pens, good quality, to number tags	12 pack	2	8.99	17.98
Plastic bags	Self sealing, 25 ml, to collect unclear monitoring items	3.5" x 4.5" (1000 pack)	10	22.98	229.80
Chocolate wax	Candles (table), white & unscented	50 pack	100	21.99	2,199.00
	Cocoa powder	250 g	25	2.18	54.50
	Pot (saucepan)	12 cm, 0.7 L	3	25.00	75.00
	Muffin trays	24, mini	10	12.00	120.00
	Gas cooking ring	single	2	21.60	43.20
	Gas bottles	9 kg	2	17.85	35.70
Candles	Candles, 50 mm lengths or tea lights	50 pack (tea lights)	50	8.50	425.00
Soap	Soap, small hotel type	144 bars per box	15	15.36	230.40
Chew sticks or cards	Commercially available (connovation.co.nz)	20 pack	100	3.20	320.00
Vegetable oil	Vegetable oil or used cooking oil from local businesses	1 L	10	6.00	60.00
Tracking tunnels	Tracking tunnels	Trakka (with wires)	100	10.00	1,000.00
	Tracking cards	Trakka (50 pack)	50	31.00	1,550.00
	Tracking ink	Black track (100 ml)	5	9.00	45.00
Waxtags	Commercially available (connovation.co.nz)	peanut flavoured	1000	0.50	500.00
Chew sticks or cards	Commercially available (connovation.co.nz)	20 pack	50	3.20	160.00
Cordless drill	Rechargeable drill, for making holes in all monitoring items (such as chew cards, chocolate wax, soap etc.)	18 V	2	52.99	105.98
Drill bits	6 mm	6 pack	2	19.99	39.98
Safety equipment	Stuff sacks, high-visibility vests, whistles, first aid kits, torches, etc. (from earlier eradication phase)	-	10	0.00	0.00
General equipment	Pocket knives, lunch boxes, thermoses, drink bottles, etc. (from earlier eradication phase)	-	10	0.00	0.00
				Sub-total	**8,017**
				Contingency (20%)	**1,604**
	ESTIMATED TOTAL (INTENSIVE MONITORING PHASE)				**US$ 9,621**

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
TWO-YEAR MONITORING (AND FINAL TWO-YEAR CHECK)					
Tracking tunnels	Tracking tunnels (from earlier intensive monitoring phase)	Trakka (with wires)	100	0.00	0.00
	Tracking cards	Trakka (50 pack)	50	31.00	1,550.00
	Tracking ink	Black track (100 ml)	5	9.00	45.00
Candles	Candles, 50 mm lengths or tea lights	50 pack (tea lights)	50	8.50	425.00
Soap	Soap, small hotel type	144 bars per box	10	15.36	153.00
Chew sticks or cards	Commercially available (connovation.co.nz)	20 pack	50	3.20	160.00
Vegetable oil	Vegetable oil or used cooking oil from local businesses	1 L	5	6.00	30.00
Chocolate wax	Candles (table), white & unscented	50 pack	50	21.99	1,099.50
	Cocoa powder	250 g	10	2.18	21.80
	Pot (saucepan) (from earlier intensive monitoring phase)	12 cm, 0.7 L	3	0.00	0.00
	Muffin trays (from earlier intensive monitoring phase)	24, mini	5	0.00	0.00
	Gas cooking Ring (from earlier intensive monitoring phase)	single	2	0.00	0.00
	Gas bottles	9 kg	5	17.85	89.25
Notebooks	Waterproof notebooks		10	8.99	89.90
Pencils	Pencils, HB	12 pack	1	2.86	2.86
Pens	Pens , biros, black	12 pack	1	2.86	2.86
Cell phone	For maintaining contact with EAG (from earlier eradication phase)	-	1	0.00	0.00
GPS	GPS, for production of GIS linked maps (from earlier monitoring research phase)	-	1	0.00	0.00
Equipment	Back packs, lunch boxes, pocket knife, thermoses, etc. (from earlier eradication phase)	-	1	0.00	0.00
Safety equipment	First aid kits, emergency blanket, whistle etc. (from earlier eradication phase)	-	1	0.00	0.00
Laptop	Data entry, storage, GIS mapping, analysis and reporting (from earlier monitoring research phase)	-	1	0.00	0.00
				Sub-total	**$ 3,669**
				Contingency (20%)	**734**
	ESTIMATED TOTAL (LONG-TERM MONITORING & FINAL CHECK PHASES)				**US$ 4,403**
QUARANTINE AND CONTINGENCY (ESTABLISHMENT COSTS ONLY)					
Permanent Bait stations	Plastic commercially available lockable station, individually numbered, etc.	-	20	16.90	338.00
Rodent Motel	Wooden boxes (stained), hinged and lockable, individually numbered, warning labels, etc. (from earlier eradication phase)	750 mm x 20 mm x 20 mm (approximately)	20	0.00	0.00

ITEM	*EXPLANATION*	*UNIT*	*NUMBER*	*EST. UNIT PRICE US$*	*EST. TOTAL US$*
Tracking tunnels	Tracking tunnels (from earlier intensive monitoring phase)	Trakka (with wires)	100	0.00	0.00
	Tracking cards	Trakka (50 pack)	10	31.00	310.00
	Tracking ink	Black track (100 ml)	2	9.00	18.00
Candles	Candles, 50 mm lengths or tea lights	50 pack (tea lights)	10	8.50	85.00
Soap	Soap, small hotel type	144 bars per box	2	15.36	30.72
Chewsticks or cards	Commercially available (connovation.co.nz)	20 pack	25	3.20	80.00
Vegetable oil	Vegetable oil or used cooking oil from local businesses	1 L	2	6.00	18.00
Chocolate wax	Candles (table), white & unscented	50 pack	10	21.99	219.90
	Cocoa powder	250 g	5	2.18	10.90
	Pot (saucepan) (from earlier intensive monitoring phase)	12 cm, 0.7 L	3	0.00	0.00
	Muffin trays (from earlier intensive monitoring phase)	24, mini	5	0.00	0.00
	Gas cooking ring (from earlier intensive monitoring phase)	single	2	0.00	0.00
	Gas bottles	9 kg	1	17.85	17.85
Bait	Brodifacoum wax blocks, 10 kg buckets	10 kg	5	68.00	340.00
Notebooks	Waterproof notebooks, one per two-month period	-	6	8.99	53.94
Pencils	Pencils, HB	12 pack	2	2.86	5.72
Laptop	Data entry, storage, GIS mapping, analysis and reporting (from earlier monitoring research phase)	-	1	0.00	0.00
				Sub-total	**1,528**
				Contingency (20%)	306
	ESTIMATED TOTAL (QUARANTINE & CONTINGENCY)				**US$ 1,834**

12.5 Selected photographs from Redonda

Figure 36. Masked booby and chick (Adam Long, BMC)

Figure 37. Newly fledged boobies (J. Daltry, FFI-OICP)

Figure 38. High cliffs and scree slopes after rain (Adam Long, BMC)

Figure 39. Redonda ground lizards scavenging the booby chick carcass (J. Daltry, FFI-OICP)

Figure 40. Feral goats, with Montserrat behind (J. Daltry, FFI-OICP)

Figure 41. Mine manager's house (J. Daltry, FFI-OICP)

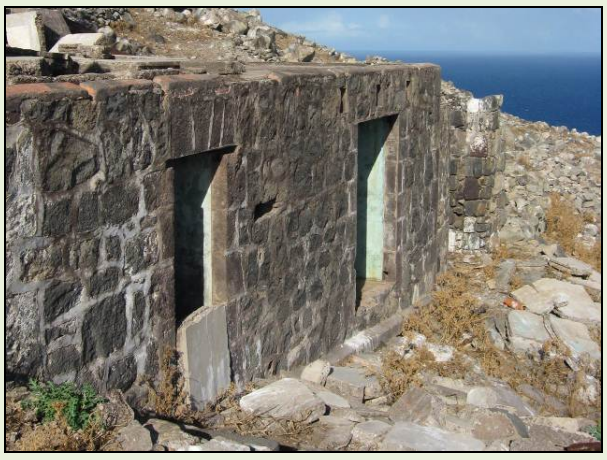

Figure 42. Team inside Centaur's Cave (Tom Aveling, EAG-OICP)

Figure 43. Fig tree, frigatebirds and red-footed boobies on the Western cliffs (J. Daltry, FFI-OICP)

Figure 44. Rat on *Opuntia* – note white scars from prickly pear moth (T. Aveling, EAG-OICP)

Figure 45. Another badly damaged patch of *Opuntia* (Ruleo Camacho, EAG-OICP)

Figure 46. Single patch of *Aloe vera* (J. Daltry, FFI-OICP)

Figure 47. Project camp on the Plateau – the main helicopter landing site (J. Daltry, FFI-OICP)