THE FEASIBILITY OF ERADICATING BLACK RATS *Rattus rattus* FROM THE OUTER CHAGOS ARCHIPELAGO

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Cover image: Vache Marine, Peros Banhos, Chagos Archipelago. (G. Harper)

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EXECUTIVE SUMMARY

This feasibility study assesses whether black rats, *Rattus rattus*, can be eradicated from 34 islands, comprising some 1735ha, of the Chagos Archipelago, British Indian Ocean Territory (BIOT), in the central Indian Ocean. The archipelago has *c.* 300,000 pairs of breeding seabird comprised of 18 species, of which ~ 94% nest solely on rat-free islands. There are 10 designated and two proposed IUCN Important Bird and Biodiversity Areas (IBAs) and numerous strict nature reserves and other protected areas.

However, outer islands of the Chagos Archipelago does not meet anywhere near their full ecological and environmental potential due to the presence of black rats on 34 of the 55 islands that form the terrestrial landmass. Invasive black rats should be eradicated in order to improve the archipelago's biological value. The proposed operation would remove rats from 1735ha, or 83% of the total land area (2,100ha), meaning the entire outer Chagos Archipelago would be rat-free.

After an unsuccessful attempt to eradicate rats from 263ha Eagle Island on the western Great Chagos Bank in 2006, a subsequent operation in 2014 successfully eradicated rats from Vache Marine (13ha), and two islets in the Salomon atoll. An archipelago-wide rat eradication operation is now proposed which would be the largest rat eradication carried out on wet-tropical islands to date.

This study concludes that the eradication of rodents will have significant ecological benefits for the archipelago but presents numerous challenges, mainly due to its isolation. There is no guarantee that a rat eradication will be successful on all the islands, especially as tropical islands have had a slightly higher failure rate than for temperate sites (Russell & Holmes 2015).

However, with appropriate focus on pre-operation trials, due care with operational execution, and effective biosecurity across the 34 target islands, the likelihood of a successful eradication appears high. It is suggested that aerial application of rat toxin is the only method likely to achieve success and has a history of being carried out on similar islands elsewhere. An operation would be contingent on chartering a suitable ship and the use of ship-borne helicopters, with a voyage duration of up to two months.

The conclusion of this study is that with adequate planning and implementation and a post-monitoring programme with the ability to deal with unsuccessful islands, the eradication of black rats is feasible. Outcomes can be sustained through the implementation of effective island biosecurity, which will need to be in place well before the operation proceeds. The estimated cost for completing the planning and implementation of the eradication is

US$4,876,530 (including 20% contingency). The cost of on-going biosecurity for the island will be determined when updating the existing interim biosecurity plan.

1. INTRODUCTION

A proposal for an attempt to eradicate the black rat (*Rattus rattus*) on the outer islands of the Chagos Archipelago excluding the southern inhabited atoll, Diego Garcia, is being led by the Chagos Conservation Trust (CCT), by request of the British Indian Ocean Territory Administration (BIOTA), with a feasibility study with an environmental impact assessment and production of an operational plan initially.

The feasibility study is the first step in the planning process for the proposed eradication. CCT commissioned and funded Biodiversity Restoration Specialists (New Zealand) to undertake the feasibility study.

This report documents the findings of the study to determine the feasibility of eradicating black rats from the outer islands of the Chagos Archipelago, central Indian Ocean. It describes the goal, objectives and anticipated outcomes of the project; the importance of the site; the likely benefits and costs of removing the rats; the recommended eradication methodology; strategies to enhance the likelihood of success and sustain outcomes. The report also makes recommendations for the next steps in the planning of the eradication of black rats from the Chagos Archipelago and preventing them from reinvading the islands.

The feasibility study is based on information gathered from CCT, BIOTA, consultation with eradication experts and persons well acquainted with the archipelago, along with several site visits to the archipelago by the author since 2014.

This report will assist CCT, BIOTA and other project partners with their decision-making regarding the proposed eradication. It will also assist with the preparation of funding proposals for the full eradication project.

2. GOAL, OUTCOMES AND OBJECTIVES

2.1 GOAL

The eradication of black rats from all islands within the outer Chagos Archipelago (excluding Diego Garcia) allows natural restoration of native flora and fauna to occur.

2.2 OBJECTIVES AND OUTCOMES

The objectives that this action will achieve and the outcomes that can be expected as a result of achieving these objectives are:

Objectives	Outcomes
1. Eradicate black rats from the Chagos Archipelago	1.1 Removal of rats from 34 islands (1735ha) leaving all of the outer Chagos Archipelago (1865ha) rat free
	1.2 Increased numbers of existing seabird species populations and the re-population of previously rat-infested islands
	1.3 Native plant communities, diversity and structure recover through cessation of rat predation of seeds, fruits and seedlings
	1.4 Recovery of native reptiles (marine turtles) populations through cessation of rat predation on eggs and hatchlings
	1.5 Recovery of coconut crab and other land crab populations on islands due to reduced predation and competition
	1.6 Increased resilience of adjacent coral reef and fish communities through increased nutrient transfer from expanding seabird colonies
2. Biosecurity enhanced on the outer islands of the Chagos Archipelago to ensure they remain rat free	2.1 Eliminate the between-island biosecurity risk within the outer islands
	2.2 Establishment an effective biosecurity infrastructure and methodology for the outer Chagos Archipelago
3. Gain additional experience in regard to eradicating invasive rats on tropical islands and transfer information for other tropical island eradications	3.1 Improved techniques for eradicating rats on multiple small tropical islands using aerial techniques and hand-baiting in mangrove and *Pemphis* shrubland
	3.2 Informing future eradication operations elsewhere of ecological outcomes

3. THE SITE

3.1 THE CHAGOS ARCHIPELAGO

Located in the middle of the Indian Ocean the outer Chagos Archipelago comprises the largest atoll in the world, the Great Chagos Bank, alongside four additional atolls (Carr 2011). On the atolls' rims 55 small islands comprise the terrestrial portion of the territory at some 21km^2 (Harper et al. 2019).

Diego Garcia, the largest island and only inhabited island in the Chagos Archipelago, is on the southern boundary of the entire archipelago (Fig. 1). It has not been included in this proposed eradication as it is large, with a significant human presence including complex infrastructure, which would result in a highly complicated and expensive operation with a high likelihood of failure or reinvasion.

The Chagos Archipelago are low-lying and geologically young which have not had the speciation that has developed on similarly isolated archipelagos such as Hawaii and the Seychelles. The atolls are largely formed from marine sand deposits with some raised rock formations.

The islands were discovered in about 1500 by Portuguese explorers but were not permanently settled until the late 18th century. A substantial copra and coconut oil operation was developed across the entire archipelago and thrived until the middle of the 20th century.

Coconut oil and copra production facilities were initially established at Diego Garcia using slave labour and were soon replicated on the outer atolls (Stoddart 1971a). Many islands had the native forest removed and replaced with a dense monoculture of coconut palms (*Cocos nucifera*). As several seabird species preferentially nest in native trees, this destruction of nesting habitat was probably the first major impact on the previously large seabird colonies that existed there. The settlers also supplemented their diet with seabirds, seabird eggs, turtles and their eggs, and introduced invasive mammals, which hastened the decline in native bird numbers and degraded native forest. Black rats (*Rattus rattus*) and feral cats (*Felis catus*), along with dogs (*Canis familiaris*) and pigs (*Sus scrofa*), were likely to have had the most severe effect. Of these species, only rats are now present in the outer atolls (Carr pers. comm., pers. obs.). Other species like chickens, donkeys and numerous introduced plant species also affected native forest structure and regeneration (Sheppard 2016).
With the decline of the copra industry a permanent military base at Diego Garcia was established in the early 1970s. For the past 40-plus years the outer atolls have had no human settlement following the removal of Chagossians by the UK Government in the 1960s-70s. Since then there has been no permanent population in the entire Chagos Archipelago, but Diego Garcia, the southernmost and largest of the archipelago, hosts a joint UK-US military facility.

The British Indian Ocean Territory (BIOT) is one of 14 British Overseas Territories and was formed on 8th November 1965. The Territory is currently administered from London, with a Commissioner appointed by the Queen, who is assisted by a Deputy Commissioner and Administrator. A Royal Navy Commander represents the civilian Administration of the Territory and is the Commissioner's representative and as such is the highest civilian authority in the Territory.

The BIOT (Constitution) Order 2004 gives the Commissioner power to make laws for the governance of the territory. The BIOT has its own laws and Administration and as such, is constitutionally distinct and separate from the UK.

As part of the governance of the BIOT, the BIOT patrol vessel undertakes regular patrols of the archipelago to police illegal fishing activity there. Access to the outer atolls is only possible by ship, with landings by tender, as no infrastructure, such as wharfs, is present.

The Chagos Archipelago is the wettest of all the Indian Ocean archipelagos. The mean rainfall for Peros Banhos atoll (data from 1950-1966) is approximately 4000mm, distributed bi-modally, with a slightly drier period through the austral winter (Stoddard 1971b). During the summer season approximately 400mm falls each month (range: 40-800mm), whereas June is the driest month with a monthly average of about 150mm (range: 05-270mm). This archipelago has a wet-tropical climate, with similar annual rainfall to Palmyra Atoll (mid-Pacific) where black rats were eradicated in 2011 (Wegman et al. 2012).

3.1.2 Native flora and fauna

Flora

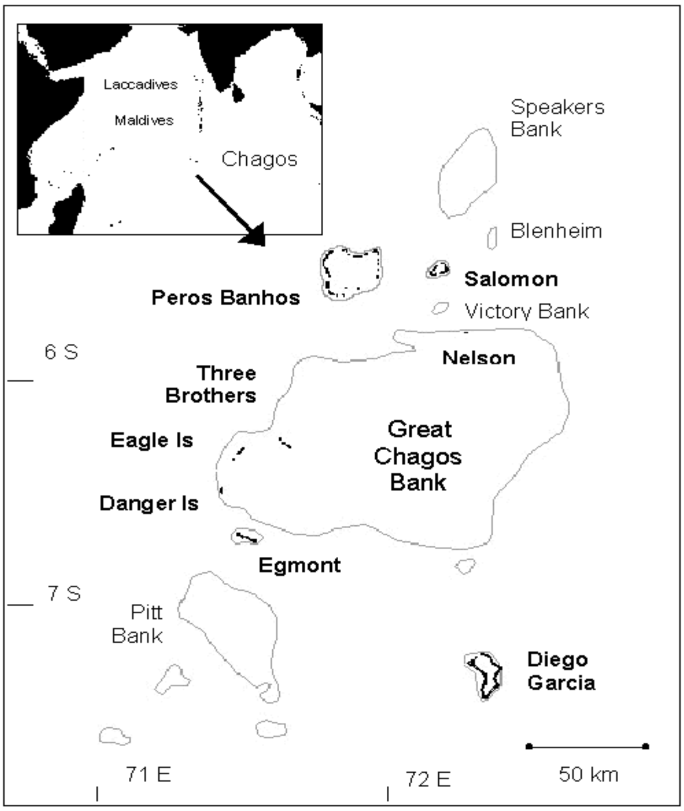
Although there are no endemic native plant species in the Chagos Archipelago, the few islands that were not converted to coconut plantations reveal what the native flora on the islands must have looked like before being settled.

In general, a sand or boulder beach rises to a crest dominated by coastal species like *Scaevola taccada*, *Argusia* (*Tournefortia*) *argentea*, *Guettarda speciosa*, *Morinda citrifolia* and natural coconuts. Behind the crest is either a forest comprised of moist tropical forest trees e.g. *Pisonia grandis*, *Neisoperma* (*Ochrosia*) *oppositifolia*, *Calophyllum inophyllum*, *Barringtonia asiatica* and *Cordia subcordata*, or bare ground and low herbaceous grasses.

The structure of some of the native forest trees allows arboreal nesting by lesser noddies *Anous tenuirostris* and red-footed boobies (*Sula sula)*, whereas the open areas are used by species such as brown booby (*Sula leucogaster)*, brown noddies (*Anous stolidus)* and, the most numerous bird in the archipelago, sooty tern (*Onychoprion fuscatus)*. Small areas of *Pemphis acidula* and mangrove occur in brackish lagoons on two islands (Carr et al. 2013).

Figure 1. Red-footed boobies, Danger Island, Chagos Archipelago (Photo: J. Slayer).

Figure 2. Map of the Chagos Islands showing their location.



Fauna

Birds are the predominant vertebrate fauna of the outer Chagos Archipelago and it holds seabird populations of international importance (Sheppard et al. 2012), the main resident group of birds being seabirds with 38 species being recorded and 18 proven as breeding.

Nine designated and two proposed IUCN IBAs (Important Bird and Biodiversity Areas) exist in the Chagos Archipelago outside of Diego Garcia (the southernmost atoll) and 17 islands are strict nature reserves. The IBA status is due to the presence of breeding populations of seabirds on the islands. Examples of islands with significant seabird populations (Carr et al. *in press*) include;

Petite Ile Bois Mangue: This small island (9 ha) has over 14,000 breeding pairs of lesser noddy.

Longue Island: This medium sized island (20 ha) has an estimated 48,000 breeding pairs of sooty terns.

Danger Island: Danger Island (6 ha) is home to 3,500 breeding pairs of red-footed booby and 2,400 breeding pairs of lesser noddy.

The only native land bird is the striated heron (*Butorides striata*), in addition to one widespread introduced species, the Madagascan fody (*Foudia madagascariensis)*. Numerous vagrants and migrant species have been recorded (Carr 2011, Refer to Section 5.5.2, and the Chagos Black Rat Eradication AEE [Harper 2020])).

Two gecko species, Common house gecko (*Hemidactylus frenatus)*, Mourning gecko (*Lepidodactylus lugubris)*, have been introduced to the outer Chagos Archipelago (Cole 2009).

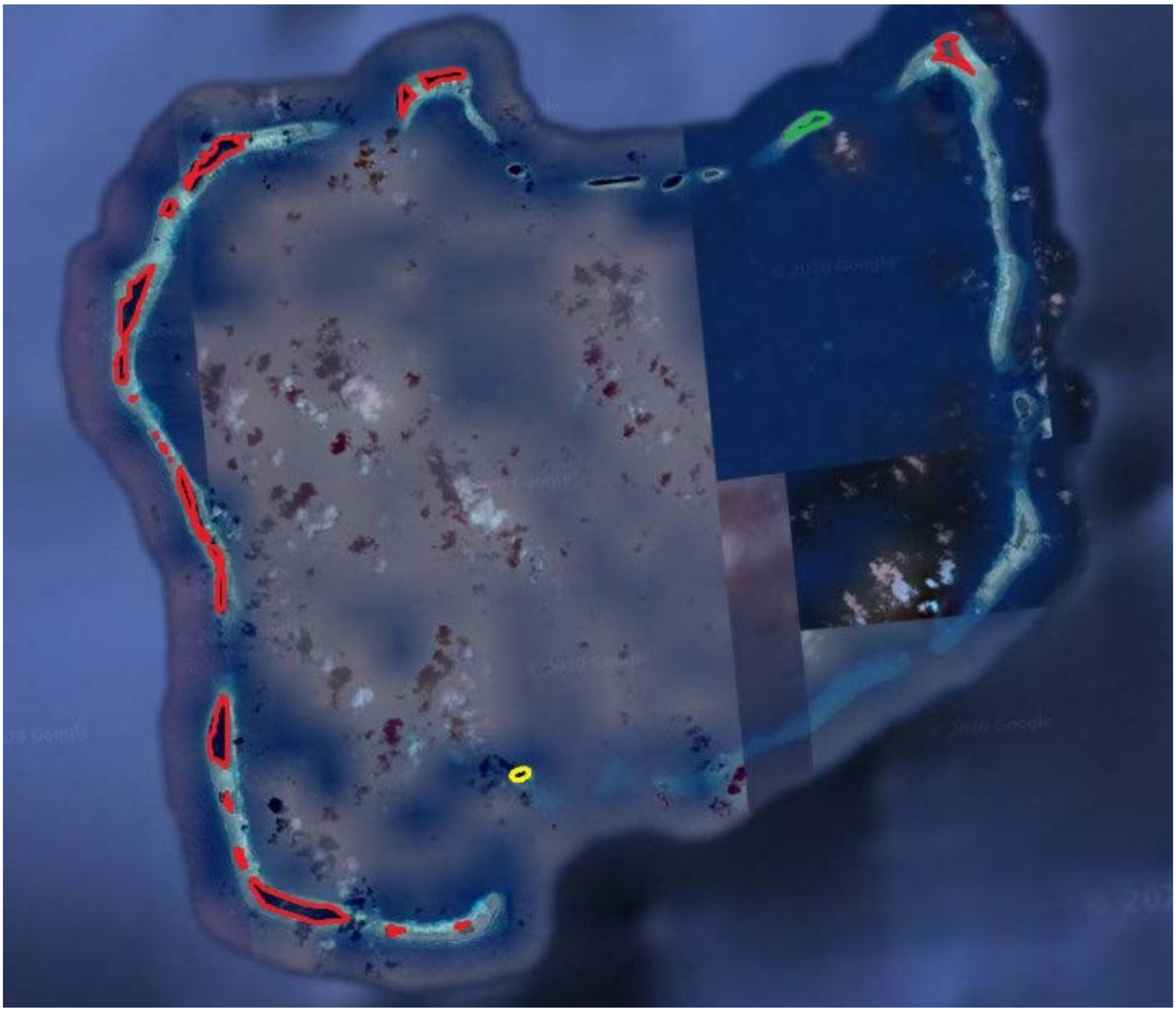
Figure 3. Boobies at rat-free Danger Island, Chagos Archipelago (Photo J. Slayer).

Like other tropical islands, land crabs are the dominant invertebrates, with the coconut crab (*Birgus latro*) being the most obvious. Smaller hermit crab species and the land crab (*Cardisoma carniflex)* are also present (Stoddard 1971d). No native mammals, including bats, exist on the islands. There are populations of endangered green turtles (*Chelonia mydas*) and critically endangered hawksbill turtles (*Eretmochelys imbricate)* that nest on some islands and their populations are slowly recovering since harvesting ceased (Cole 2009).

Of the introduced mammals, black rats are likely to have been present on the Chagos Archipelago for at least 150 years and probably became established during the settlement phase. Black rats are present on all islands that were either settled or used as coconut plantations (Figures 4 –6) & Appendix 2), which comprises over half (61%) of the islands in the outer Chagos Archipelago.

Figure 4. Satellite photo of Salomon Atoll, Chagos Archipelago, showing islands with rats present. Red boundary: rats present; yellow: rats eradicated; unmarked: rat-free.

Figure 5. Satellite photo of Peros Banhos Atoll, Chagos Archipelago, showing islands with rats present. Red boundary: rats present; green: undetermined; yellow: rats eradicated; unmarked: rat-free

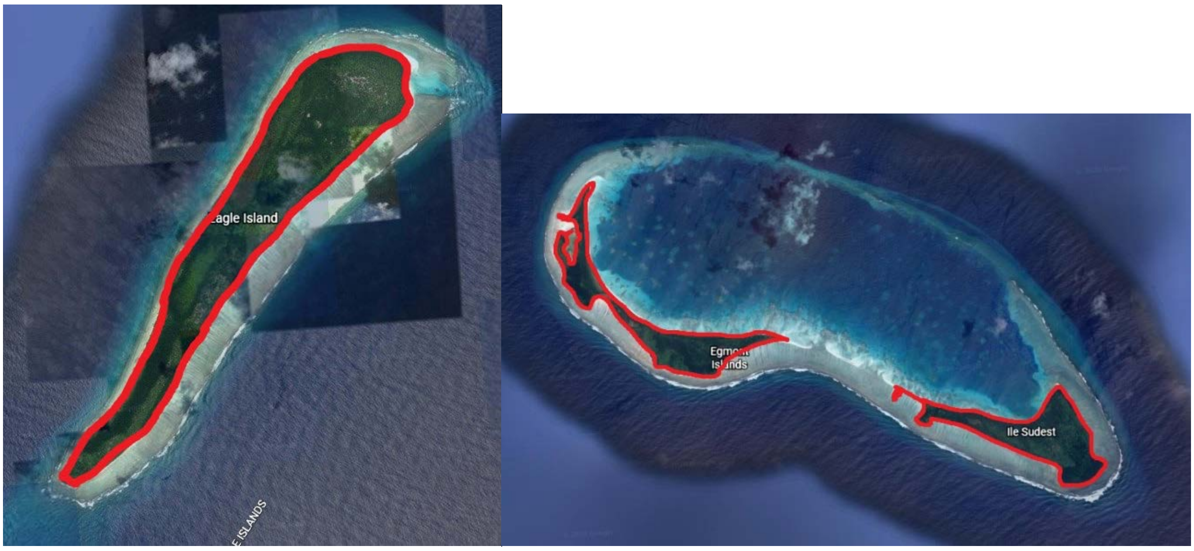


Rats prey on all the seabird species, but particularly the terns and shearwater species, along with land crabs and turtle hatchlings (Harper & Bunbury 2015). The archipelago's seabird population density is approximately 760 times higher on the rat-free islands (Graham et al. 2018). The effect of rats on the plants on the islands is largely unknown but likely to be significant, with fruit, seeds and seedlings being eaten and has probably impacted on the islands' forest structure and plant species composition (Harper & Bunbury 2015).

Rats are present on 34 of the 55 islands of the outer Chagos Archipelago (Appendix 2). Only 4.7% of the terrestrial space on the entire Chagos Archipelago is considered mammalian predator free (Harper et al. 2019).

The Chagos Conservation Trust (CCT) is championing the eradication of rats from the Chagos Archipelago, to allow populations of existing species on the constituent atolls to recover and to allow natural restoration of native flora and fauna to occur.

Figure 6. Satellite photos of Eagle Island & Egmont Islands, Chagos Archipelago, showing islands with rats present. Red boundary: rats present.



The BIOTA (BIOTA 2021) has identified eleven conservation and environmental priorities to ensure the protection of this unique environment for the future. Its vision is that, "The terrestrial and marine biodiversity and ecological integrity of BIOT is protected, enhanced and restored where possible". It recognises that "The terrestrial environment has suffered from human interference, principally though the introduction of invasive species and have compounded declines in island biodiversity".

Their recommendation states that there is a requirement to "To conserve or enhance marine and terrestrial biodiversity and ecosystems including, where practicable, restoration of damaged or degraded habitats".

Specifically they aim to manage, and where possible eradicate, invasive non-native species through active programmes of control; and prevent the introduction of new invasive nonnative species through effective biosecurity measures. Obviously this proposed project to eradicate introduced invasive rats from islands of the Territory aligns seamlessly with the governing agencies priorities and is fully supported by BIOTA.

4. THE TARGET SPECIES, THEIR IMPACTS AND BENEFITS OF CONTROL OR ERADICATION

4.1 TARGET SPECIES: BLACK RATS *RATTUS RATTUS*

Black rats are the most widespread invasive rat species in the world, having been spread by humans during voyages of discovery since at least the 15th Century (Atkinson 1985).

Worldwide, introduced rodents have caused 40–60% of all bird and reptile extinctions (Howald et al. 2007). Rats are one of the most destructive of the introduced rodents and are found on more than 85% of oceanic islands and archipelagos (Harper & Bunbury 2015). Moreover, the impact of invasive rats on tropical islands is proportionally worse than at higher latitudes as virtually all tropical islands are biodiversity hotspots with high levels of endemism (Meyers et al. 2000).

Black rats are usually found in forest or shrubland, where they can be highly arboreal. Research on Europa and Juan de Nova atolls in the Mozambique Channel, showed black rats attain high densities in forest in the wet season and lower densities at the beginning of the dry season (Russell et al. 2011). Clark (1980) observed that vegetation density had a positive relationship with black rat population densities and concluded that food was a limiting factor on population size.

In contrast, on more arid tropical islands, or seasonally dry islands population densities are lower probably due to lower primary productivity. Xeric forest and arid shrubland can have net primary productivity substantially less than half of tropical evergreen forest (Melillo et al 1993) and precipitation becomes the principal external driver for population dynamics, by influencing resource availability (Madsen and Shine 1999; Previtali et al. 2009; Russell and Ruffino 2012).

Although breeding by invasive rats can occur year round on tropical islands with little seasonal difference in rainfall (Delattre and Le Louarn 1980, Lindsey et al. 1999), on islands with seasonal rainfall, breeding fluctuates, generally in relation to wet seasons (Russell and Holmes 2015).

4.2 IMPACTS OF BLACK RATS

Rat impacts on native species on the Chagos Archipelago are likely to be significant. Rats are omnivorous, so their diets are highly variable, likely in response to available prey. In general plant material forms the basis of all rat diets, and leaves, stems and fruits are all eaten. Arthropods, usually insects, provide most of the animal protein for rats.

On Europa and Juan de Nova atolls, Mozambique Channel, plants occurred in 90–100% of 220 rats sampled in 2007–2008 (Russell et al. 2011). On Surprise Island, New Caledonia, plant material occurred in 100% of gut samples (Caut et al. 2008). Invertebrates occurred in 72–98% of samples from the Mozambique Channel islands and 38–83% of samples from Surprise Island. Feathers or flesh were found in 0–17% of rats from Juan de Nova, which was tied to the arrival of sooty terns (Feare et al. 2007). On Surprise Island seabird feathers were found in 56% of gut samples, along with skink remains in 13%. Seabird eggs and sea turtle hatchlings were also seen to be taken.

Black rats can have a significant impact on plant population dynamics and rat control operations or eradications can provide strong evidence of the effects of rats on seedlings. In Hawaii only 4% of an endangered lobeliad (*Cyanea superba*) fruit was eaten where rats were controlled in contrast to 47% fruit loss at a non-treatment site (Pender et al. 2012). On Palmyra Atoll, where rats were eradicated in 2005, there was a 130% increase of native seedlings and the first records of native *Pisonia* since monitoring began. Damage to bark and buds tends to follow a recurrent theme of occurring, or becoming more prevalent, during drought or dry seasons (Harper & Bunbury 2015).

Lizards and birds can be severely affected by black rats. Case and Bolger (1991) reviewed the effects of introduced species on island reptiles and concluded that the introduction of predators, with or without exotic reptile introductions, cause extinctions and severe reductions in the numbers of native reptiles on islands.

Since then limited information has supported the supposition that rats on tropical islands have a detrimental effect on reptile species of all sizes. In the case of large reptiles, the rats can impact populations by preying on eggs and young, whereas smaller reptiles can be depredated at all life stages. Mortality in the St Lucia whiptail lizard *Cnemidophorous vanzoi* increased after black rats invaded (John 1999). Populations of reptiles have been recorded to increase rapidly after rat eradication on islands. The Antiguan racer *Alsophis antiguae* population doubled in 18 months after black rat eradication on 10 ha Great Bird Island (Daltry 2006) and a previously un-described gecko species was found on Rabida Island, Galápagos islands, after Norway rats were eradicated in 2011 (K. Campbell, pers. comm., 2012). Moreover, sea turtle hatching success and small crab species are also likely to be adversely affected by black rat predation (Caut et al. 2008, Gronwald et al. 2019, Samaniego et al. 2019).

Meta-analysis of impacts of rats on seabirds concluded that *inter alia* species that weighed less than 300g and those exposed to black rats were most in danger of being extirpated (Jones et al. 2008). However, it appears that almost all species of tropical seabirds up to the size of albatross are vulnerable to rat predation in some form and, unsurprisingly the smaller species such as terns are overly represented. Vanderwerf (2006) and Vanderwerf et al. (2007) noted that the most limiting factor for seabird nesting in the Kwajalein archipelago and Lehua, Hawaii, was the presence of rats, along with other introduced predators.

Although Wirtz (1972) suggested that intensity of seabird predation was positively related to rat density, Woodward (1972) added that predation was exacerbated by seasons with poor plant growth (i.e. dryer years) because rats depended on vegetative matter as the principal component of their diet.

All tropicbirds species are adversely affected by black rats (Schaffner 1988, Ross 2000, Varnham 2001, Daltry 2006, Daltry et al. 2013) and black rats will also depredate bridled tern *Onychoprion anaethetus,* roseate tern *S. dougallii* and least terns *Sternula antillarum* (Witmer et al. 1998 Savidge et al. 2012).

Evidence from black rat eradications suggests population of species as large as brown boobies and brown pelicans *Pelecanus occidentalis* will only increase once black rats are removed from an island (Daltry et al. 2013). Laughing gulls *Leucophaeus atricilla* were entirely absent from islands in Antigua with black rats and only present on islands that have never had rats or have had rats eradicated (Daltry et al. 2013).

In summary, the composition and structure of native forests on the Chagos Archipelago are likely to have been be changed by the selective consumption of seeds, seedlings and fruits of particularly favoured plants.

Seabirds, landbirds and hatchling turtles are also eaten, sometimes leading to their local extinction. It is likely that the extended presence of black rats on the outer Chagos Archipelago has resulted in major changes to the forest and fauna with depressed numbers of many invertebrate and vertebrate species and the likely unrecorded extinction of some species in the past.

4.3 LIKELY BENEFITS OF ERADICATION

Where seabirds have been reduced in numbers or extirpated by rats, rat eradication has resulted in an increase in seabird numbers (Le Corre et al. 2015, Croll et al. 2016, Newton et al. 2016) leading to significantly improved marine diversity through nutrient transfer from seabirds and their colonies (McCauley et al, 2012, Graham et al. 2018) and may promote coral reef recovery following bleaching events (Benkwitt et al. 2019). Recovery of seabird populations will significantly increase the area within the outer Chagos Archipelago where marine diversity and ecosystem resilience is improved.

Responses to rat eradication are highly likely to include marked increases in the numbers, and changes in the species composition, of land crabs, turtle hatchlings and birds, with increased breeding success of noddies and other seabirds (Harper & Bunbury 2015). Over time, native forest structure and composition is also likely to change as fruit, seeds and seedlings previously preferentially eaten by rats become increasingly common (Wolf et al. 2018, Shiels & Ramírez de Arellano 2019).

Currently research and monitoring is undertaken on a variety of species and the reef ecosystem in the outer islands of the Chagos Archipelago through long-term funding by the Bertarelli Foundation. This includes work on seabirds, tuna, sharks and mantas alongside studies on the resilience of coral reef species and habitats. Much of this work will provide baselines to compare ecosystem changes post-rat eradication.

5. CAN IT BE DONE?

5.1 TECHNICAL APPROACH

5.1.1 Management options

A. Do nothing
Maintaining the status quo on the outer islands of the Chagos Archipelago will not address the current significant deleterious impact rats are likely having on the native species there. Furthermore, if no action is taken to reduce the impacts of rats further damage to the islands' ecosystems will occur over time, with possible local or total extinctions resulting. Moreover, the ecological goals for the islands' management will not be achieved as outlined by BIOTA.

B. Undertake long-term control
Undertaking trapping or poisoning to control rats would require maintaining a huge number traps and/or bait stations on 34 islands in perpetuity. Even if the resourcing to maintain the personnel, infrastructure or logistics of running such an operation are discounted the unending cost would be a significant burden for the management agency and would always be subject to the vagaries of budget re-allocations. If funding was cut there would be no lasting ecosystem benefit once the rat population had recovered.

C. Delay eradication until new eradication techniques are available
An additional option is to delay eradication of rats until other control tools are developed. Although there has been a substantial amount of research conducted on other more humane control tools than anticoagulant poison, species specific toxicants, or rat-specific diseases, no commercially viable tools have been forthcoming in recent times and appear unlikely to be available in the foreseeable future (Campbell et al. 2015).

Research on biological control of rats in the field has not achieved any tangible advances recently and no method for applying biological control of rats on a landscape scale is presently available with little likelihood of one being commercially available soon. Moreover, there are considerable issues and risks with possible techniques, such as gene drives. These include the fact that gene drives currently only work in any sense in mice in a laboratory setting and transfer of the technology to rats is fraught with difficulty, possible inadvertent release elsewhere and the extinction of *Rattus* as a genera worldwide, along with significant doubts about deployment into an existing population (Leitschuh et al. 2018, Wilkins et al. 2018, Manser et al. 2019).

D. Eradication
Eradication means the complete removal of the target species from the site of interest, usually an island (Cromarty et al. 2002). Eradication of rats and cats has been successfully conducted at a suite of islands around the world and is a proven and enduring method for protecting the biodiversity values of those islands (Howald et al. 2007). Although eradications can be

expensive, they are conducted within a fixed period with a definite end point, after which only moderate or little additional expense and effort is required, which is usually in the form of biosecurity measures to prevent reinvasion.

Two proven eradication options were considered for the outer Chagos Archipelago, with all using second-generation anticoagulant baits. Other methods such as immunocontraception or trapping have proven to be unproven or unreliable for eradication and have been discounted (Table 2, below). The options were:

1. Aerial application of toxic bait using helicopters guided by GPS navigational systems augmented by ground-based bait application in a few small areas of mangrove or *Pemphis* scrub subject to tidal inundation.

2. Presentation of toxic bait in bait stations and/or hand broadcast on a grid pattern of pre-established tracks over the entire area of all the 34 rat-infested islands.

Although Option 2 has been used on the Chagos Archipelago during the Eagle Island and Ile Vache Marine eradications, both operations required significant effort to establish the track grids and distribute the bait. The larger Eagle Island operation failed, as discussed below.

This bait station operation commenced with an 11 person team arriving on 263ha Eagle Island on 5th February 2006 for three months (Meier 2006). A total of 2864 bait stations were established over a 30x30m grid (~10 bait stations/ha), which involved extensive track cutting. An area of dense mangrove proved problematic and required additional cutting and bridging to enable access. Bait station establishment was carried out over 6 weeks and was complete about 18 March. The bait stations were subsequently filled with 4 x 20g blocks of Talon®-G (0.05 g/kg brodifacoum, with added bitrex) and an additional two blocks were hand-laid between each bait station for a total of 344kg for the initial bait application. Bait stations were serviced daily and bait replaced, along some additional hand-laying of bait, until 21st April, when bait stations were pulled in. The team departed on 24th April. Bait was available for 4 weeks and 5 days and approximately two tonnes was eventually distributed (~7.6kg/ha). The reasons for this eradication failure were likely to have been operational. Bait was only available for a relatively short time, with a low bait application rate, especially considering there was bait loss to hermit and coconut crabs. However, the most telling aspect of the failure was that the personnel left Eagle Island before toxic bait removal by rats from bait stations had entirely ceased (P. Haverson & D. Birch, pers. comm.). Normally, bait station operations are deemed complete until bait take has ceased and no subsequent bait removal attributable to rats has occurred for several weeks. Therefore it appears there were still at least a few rats still present when the operation finished.

On the much smaller, but successful Ile Vache Marine operation where hand-broadcast was used, the several days of effort required to distribute bait could have been achieved within minutes using aerial application. Scaling up the Ile Vache Marine operation to 34 other islands would also require a significant increase in personnel and preparatory work, such as track cutting, with a large amount of time, resourcing and ship support required while work was carried out on the cumulative 1735 hectares.

For example, at a track spacing of 50m apart, which would likely be the maximum spacing for effective rat eradication, cutting lines across 1600ha at about 1ha per day per person would take 1600 person days or a team of 10 people about four months to cut. In addition to the wages bill, this estimate does not include the significant costs involved in supporting field teams on highly isolated atolls as touched on above, so the financial cost would be substantial.

For these reasons alone a ground-based eradication on the outer islands of the Chagos Archipelago would require an extended duration at the site compared with an aerial bait application. Moreover, meta-analysis of ground-based operations versus aerial operations on tropical islands has shown the former are markedly less successful (Holmes et al. 2015). Therefore Eradication Option 1, aerial application of bait, would be the most efficacious technique for rat eradication on the outer Chagos Archipelago.

Table 2. Options considered for black rat management on the outer Chagos Archipelago islands.

Options	**Outcome**	**Recommendation**
Do nothing	Continued risk of between islands rat invasion and adverse effect on seabird populations and ecosystem in general.	Not an option if ecosystem recovery is desired. Good cost outcome (nil spent), but no ecosystem benefits. A legal mandate exists to improve the archipelago's environment.
Undertake long-term rodent control	Very expensive and resource intensive exercise, with associated management impacts on the environment. Has to be maintained in perpetuity to ensure any benefits to the local ecosystem.	Not an option if ecosystem recovery is desired at a reasonable cost and within a defined time frame. Both a poor cost and benefit outcome.
Delay eradication until new techniques are available	Continued risk of between islands rat invasion and adverse affect on seabird populations and ecosystem in general. No plausible field-tested technique is	Costs for field delivery are unknown. Not an option if ecosystem recovery is desired within the foreseeable future using a successful technique proven in the field.

	likely to be available in foreseeable future.	
Eradicate the entire rodent population using ground-based techniques	Very expensive with significant investment in time, personnel, logistic support and infrastructure, with possible mixed eradication outcomes (i.e. rats not eradicated on all islands).	Poor option as requires significant medium-term costs with likely mixed ecosystem benefits.
Eradicate the entire rodent population using aerial application of rat toxin.	Relatively expensive, but given the scale and isolation of the islands aerial bait application provides the highest level of confidence that an eradication will be successful.	Good option as short-term costs result in enduring benefit to ecosystem.

5.1.2 Is it an effective & achievable approach?

All eradication attempts require comprehensive planning before implementation and this is particularly true for a rat eradication programme on isolated tropical islands, which present a novel suite of problems when compared to those in temperate regions where many eradication techniques have been developed.

Invasive mammal eradication work on the Chagos Archipelago, in particular, faces both logistical and geographical challenges due to the remoteness and inaccessibility of the archipelago, along with the wet climate and vegetation composition. Ecological challenges, such as accounting for the presence of land crabs and achieving success in complex three-dimensional habitats, such as old coconut plantations, will be difficult to address. However, the same eradication techniques and tools have been successfully used on similar atolls elsewhere so there is a high likelihood this proposed eradication will be successful also.

There have been over 600 successful rat eradications on islands to date but it should be noted tropical islands rat eradications have not been as successful as operations on temperate islands (Russell & Holmes 2015).

The failure of a bait-station rat eradication attempt on Eagle Island (252ha) in the Chagos Archipelago in 2006 is an object lesson in the challenges involved. So, the likely difficulties need to be acknowledged during the planning and execution of the proposed eradication, particularly in light of the logistical challenges of conducting operations in the middle of the Indian Ocean. In spite of the obstacles, the recent ground-based eradication of black rats from Ile Vache Marine (13ha) does show that careful planning and execution can result in a successful outcome.

Rat eradications on wet-tropical islands present the greatest challenge as they present additional ecological risks largely absent on arid islands (Russell & Holmes 2015), such as abundant land crabs and year-round breeding by rats. Thus far, the 2015 black rat eradication on 539ha Banco Chinchorro, near the Yucatan Peninsula, is the largest successful operation on a wet-tropical island (Pinzon Island, Galapagos [1800ha] is the largest tropical island rat eradication, but is arid). At 1735ha, the cumulative area of the proposed eradication would be more than three times the largest wet-tropical island rat eradication to date but on smaller constituent islands, with the largest individual island being 263ha.

As noted below (Table 3 below), several tropical islands with a similar climate and latitude to the Chagos Archipelago have had successful rat eradications carried out on them. Almost all required the transport of equipment, supplies and personnel to the island(s), so similar logistical hurdles were dealt with in order to complete the operation.

Palmyra and Birnie islands, in particular, are hundreds of kilometres from the nearest ports. Therefore the precedence for successful rat eradications on isolated wet tropical islands using aerially applied toxin has been established. In the case of the Chagos Archipelago, the principal hurdle is likely to be logistical, requiring the transport and deployment of the eradication techniques on an archipelago in the centre of the Indian Ocean.

Table 3: Comparative information between the outer Chagos Archipelago and successful rat eradications on other wet-tropical islands
Sources: 1. *Harper et al.* 2019, 2. *Griffiths et al.* 2019, 3. *Samaniego et al.* 2017.

	Outer Chagos (UKOT)[1]	Palmyra (USA)[2]	Banco Chinchorro (Mexico)[3]	Birnie (Kiribati)[2]	Ringgolds (Fiji)[2]	Fregate (Seychelles)[2]
Latitude	6°S	6°S	19°N	3°S	16°S	4°S
Area (ha) & largest island	1735 (263)	235 (98)	539	49	266 (147)	219
Mean annual rainfall (mm)	~4000	4422	1450	1300	2467	2182
Height above sea level (metres)	3	2	6	4	12	125
Landform	coral atoll	coral atoll	sand cay	coral atoll	coral atoll	granite island
Vegetation	*Cocos* & native forest	*Cocos* & *Pisonia*	Mangrove & evergreen forest	Grass & scrub	Scrub & *Cocos* forest	Modified forest
Rat species	*R. rattus*	*R. rattus*	*R. rattus*	*R. exulans*	*R. exulans*	*R. norvegicus*

5.1.3 Recommended Rodenticide

The primary method for eradicating rodents from islands is the use of anticoagulants combined into a highly palatable cereal or wax baits, distributed across every rat territory (i.e. across the whole island) in a methodical and comprehensive manner. This method has been developed and refined over many years and in many different eradication projects.

Anticoagulants cause death in rats by preventing blood clotting and hence, causing internal haemorrhaging. The effects of the anticoagulants are not felt by the rats until a few days after consumption and hence, are unlikely to associate the symptoms with the bait and cause them to stop eating it (i.e. bait avoidance or shyness) before they received a lethal dose.

First and second-generation anticoagulant rodenticides have both been used to successfully eradicate rodent on islands. First-generation anticoagulants are less potent and less persistent but require multiple feeds over several days to reach a lethal dose. By comparison, second generation anticoagulants are more potent and more persistent but do not require multiple feeds, a lethal dose can be attained through a single feed of bait.

This latter characteristic makes them better suited to tropical environments where competition for bait by land crabs and other bait consumers (e.g. ants) can be high and natural food can be available all year around.

Therefore, the use of a second-generation anticoagulant is recommended for the proposed eradication (Table 4). Of the second generation anticoagulants available, brodifacoum is the most commonly used in rodent eradications (Howald et al. 2007, Parkes *et al*. 2011) and the toxicant recommended for the eradication on the outer Chagos Archipelago.

Table 4: Different rodenticides considered for the black rat eradication on outer Chagos Archipelago

Rodenticide	Advantages	Disadvantages	Outcome
First-generation Anticoagulant Rodenticide			
Warfarin	Less likely to result in non-target deaths and secondary poisoning. Not available in pellet form for aerial broadcast.	Multiple applications (4+) over 7-10 days required to provide lethal dose.	Rejected due to requirement for multiple applications of toxin and lack of suitable application method.
Diphacinone	Less likely to result in non-target deaths or secondary poisoning.	Multiple applications (4+) over 7-10 days required to provide lethal dose. Not	Rejected due to requirement for multiple applications of toxin.

		available as pellets for aerial broadcast.	
Coumatetryl	Less likely to result in non-target deaths or secondary poisoning. Not available in pellet form for aerial broadcast.	Multiple applications (4+) over 7-10 days required to provide lethal dose	Rejected due to requirement for multiple applications of toxin and lack of suitable application method.
Pindone	Less likely to result in non-target deaths or secondary poisoning.	Multiple applications (4+) over 7-10 days required to provide lethal dose. Available as pellets for aerial broadcast.	Rejected due to requirement for multiple applications of toxin.
Second-generation Anticoagulant Rodenticide			
Bromadiolone	One feed enough to kill rodents.	Increased likelihood of secondary poisoning or direct non-target deaths. Not readily available in pellet form for aerial broadcast.	Suitable baits for aerial application may not be registered all available for this use.
Brodifacoum	One feed enough to kill rodents. Available in pellet form for aerial application	Increased likelihood of secondary poisoning or direct non-target deaths. Available in pellet form for aerial broadcast.	Acceptable. Efficacious toxin and delivery method. Lack of non-target risk species on Chagos islands.
Difenacoum	One feed enough to kill rodents	Increased likelihood of secondary poisoning or direct non-target deaths. Not readily available in pellet form for aerial broadcast.	Rejected due to lack of suitable application method.

5.1.4 Recommended bait delivery technique

A. Aerial bait application

The rat eradication would involve the delivery of a grain-based bait containing an anticoagulant poison (brodifacoum) into every potential rat territory on each island as this is the most proven poison and in accordance with best practice worldwide (Holmes et al. 2015).

This technique is generally considered to be the most reliable, efficient and successful way of undertaking a rat eradication on larger islands (Russell and Holmes 2015). Aerial broadcasts take substantially less time to implement than other options. However, they involve considerable time for planning and can be costly, particularly where helicopter(s), suitable pilot(s) and associated equipment need to be shipped in, which will be the case on the Chagos Archipelago. This operation will also require the input of highly skilled technical expertise.

The operation should ideally be carried out during driest month (June) when rainfall is relatively low in order to maintain bait integrity as long as possible. It will be carried out using aerial application from a spreader bucket slung under helicopters operating from a support vessel. A support vessel is essential as the islands are widespread and there is no option for operating from a suitable central land base. Two bait applications on each island will be necessary, occurring at least seven to 10 days apart (Keitt et al. 2015).

B. Logistics

Approximately 80 tonnes of bait (1735 ha x 18kg/ha & 14kg/ha applications) would be required. These application rates are derived from trials conducted on Diego Garcia and the bait applications during the successful Ile Vache Marine rat eradication operation at Peros Banhos. This includes 15.6 tonnes likely to be required for coastal swathe application and a contingency amount. The total amount would require approximately 10 x 20 foot containers. A detailed baiting prescription will be drafted during compilation of the final operational plan.

In order to transport the bait, helicopters and personnel to the Chagos Archipelago a suitable ship will need to be sourced, preferably from a nearby port to reduce passage costs. The ship will require space for storage of bait, suitable area(s) for storage and operation of two helicopters, and berths for approximately 10-15 staff in addition to the ship’s crew.

Ports for sourcing a vessel could possibly be at Australia, Singapore, the Arabian/Persian Gulf, or South Africa. No support will be forthcoming from the adjacent military base at Diego Garcia. Equipment/supplies would need to be transported to, and depart from, a port on the Indian Ocean periphery, which would take about 10-14 days steaming to reach the Chagos Archipelago. In order to reduce wage costs associated with retaining staff whilst in transit, a possible secondary port for picking up eradication personnel could be Male, the Maldives, some two days steaming from the outer Chagos Archipelago.

The ship would anchor within or in the lee of the atolls (Peros Banhos/Salomon) or islands (Egmont, Eagle) (Figure 7). At this stage it is assumed that the highest priority sites will be Peros Banhos and Salomon atolls as they are the most complicated sites due to the number of islands involved and together comprise about 2/3rds of the total area targeted for rat eradication. Initial analysis of satellite imagery has been used to fix the islands positions and estimate their areas as used within this document. Helicopter baiting operations would then begin, loading bait from the ship and applying bait island by island. There are no sites suitable for operating a helicopter on the islands. Clearance of vegetation for an on-island base(s) within each island or atoll is not feasible as it would be required on at least four locations, and would take too long to establish this number of sites to a suitable standard for helicopter operations and ancillary infrastructure (accommodation, food, water and fuel storage, etc). For three islands with mangrove and/or *Pemphis* forest (2 at Peros Banhos Atoll & 1 at Eagle Island), a small team will need to apply bait to these areas by hand. The total area for hand application across these three islands is 30ha. It may be prudent for this team to also bait the very small islets (<2ha; ~10 islands) to reduce flying time and bait loss into the sea.

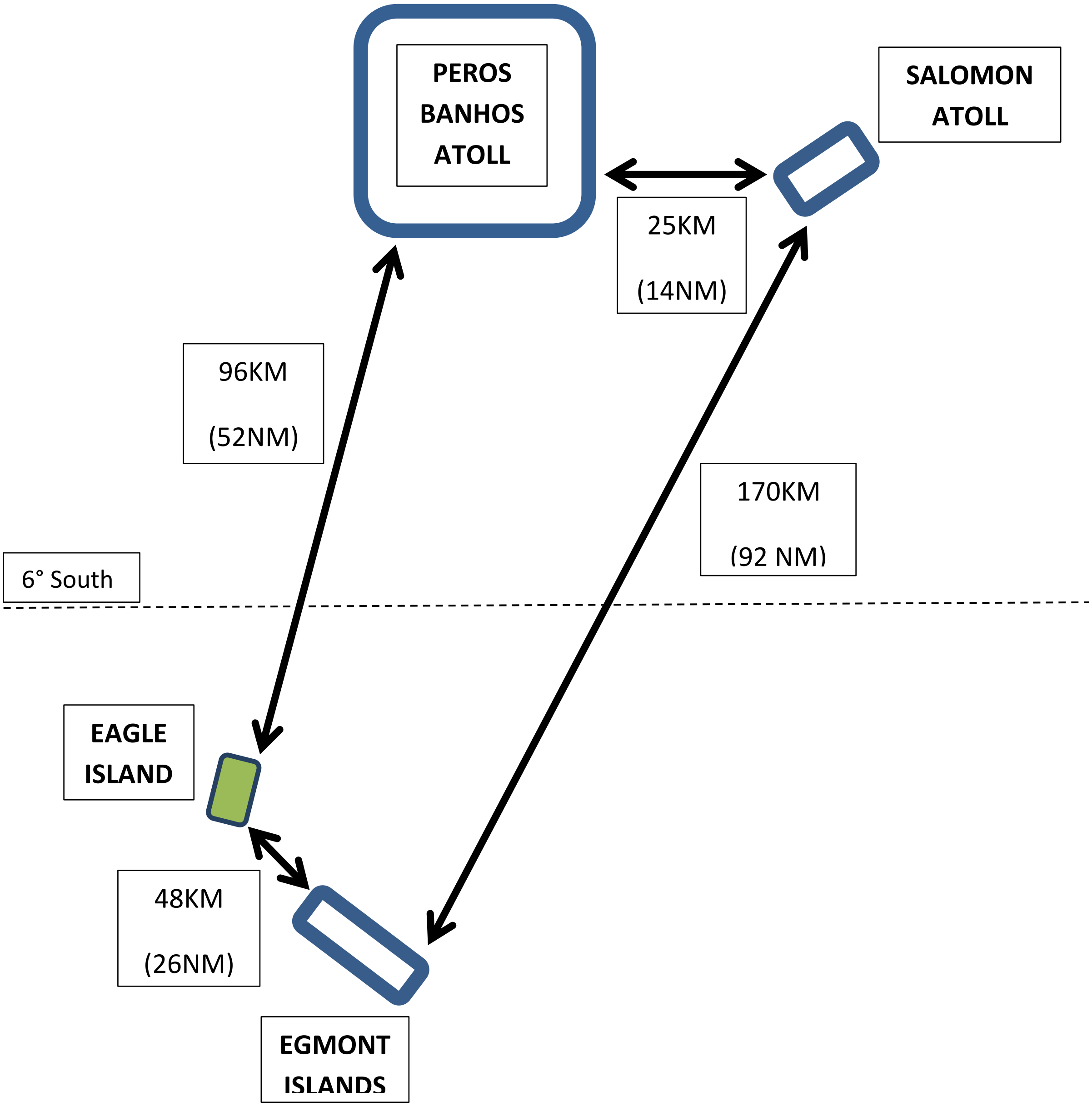
Approximately 1.2 hours are required to distribute 1 tonne of bait, so for 80.3 tonnes about 96hrs, or 12 x eight hour days of flying, will be required for bait application alone. For two helicopters this would translate to about 6 days. However a portion of flying time will also be required for helicopter transit between the ship and the numerous islands at each atoll.

At about 15 minutes transit time for each of the 34 islands, twice for two applications, this would add about 3 hours to the total, or some 99 hrs. This does not include time for flying boundaries of all the target islands to fix their position and area, which is estimated to be about 15-20 minutes average for each island (~8hrs), or some 107hrs in total (13.4 days in total, or 6.7 days for 2 helicopters).

The flying time is in addition to the period required for steaming between the two main atolls, Peros Banhos and Salomon, and Egmont and Eagle Islands further south, although some time will be saved by steaming overnight.

An initial assessment of the time required for flying at the outer Chagos Archipelago, plus steaming between islands, and including about 25% of down-time for poor weather conditions and/or pausing between bait applications, gives a total of about 17-20 days present at the operation site. When combined with steaming to/returning from the Chagos Archipelago, about 37-48 days (~5-7 weeks) would be needed to complete the operation ex-departure.

Figure 7. Schematic diagram of the location and distance between the outer islands and atolls targeted for rat eradication (distances in kilometres and nautical miles)



5.1.5 Key planning issues

A. Logistical Issues
There are likely to be significant hurdles in sourcing and contracting suitably specialist vessel to undertake the operation. It will have to be able to transport and operate two helicopters, along with 80+ tonnes of bait and a number of staff in addition to the ship's crew and be able to operate independently for up to 6-8 weeks.

Moreover, a suitable home port will need to be identified on the Indian Ocean periphery that will suit the operational needs of the project, which include timely procurement of supplies and additional specialist items at a reasonable price. In addition, suitable helicopters will need to be sourced and contracted, and be able to fly to and land on the ship.

B. Ensuring rats encounter and eat bait
Almost all tropical island eradications have to deal with bait removal by land crabs, be they hermit crabs, including coconut crabs, and other species such as *Cardisoma carniflex*, all of which are present in the Chagos Archipelago. Bait removal means there will be less bait available for rats for the suggested four nights after bait application and may reach a point where no bait is available, thus risking the success of the operation (Keitt et al. 2015).

However, evidence from the Chagos Archipelago suggests that bait off-take may be less critical than at other wet tropical islands. For example, a bait application trial (15kg/ha) was undertaken on 2 x 1ha plots in 'coconut chaos' on Diego Garcia and after four days bait was still available despite the losses from land crabs and rats at a population density at ~60/ha.

Similarly, the success of the small-scale Ile Vache Marine eradication despite bait off-take by land crabs (almost entirely by hermit crabs) was carried out at application rates of 16kg/ha + 12.5 kg/ha (Harper et al. 2019).

In spite of the indications that bait application rates at these levels should provide enough bait for rats, these assumptions should be confirmed at selected target islands, by conducting bait loss trials to reduce this risk to the operation.

At this stage, for the planned operation a conservative approach has been to set the baiting rate to 18kg/ha for the first application and 14kg/ha for the second application to give more assurance that bait will be available for at least three days for each application.

C. Timing the operation for the driest month.
The principal climate risk is heavy rainfall. Historical climate records from Peros Banhos and the Salomons suggest that June is the driest month (average ~100mm Stoddard 1971b) although more recent data shows August is drier (See Operational Plan). The bait will need a minimum of four days and nights without significant rain (Keitt et al. 2015).

During the suggested period of the operation in June some rainfall is likely. Pollard baits have been trialled and will begin to lose their integrity with 16mm of rain in one fall (Harper & van Dinther 2014), so there is some likelihood that significant rain will degrade the bait.

Wind is less of an issue as waves from predominant SE trade winds can be circumvented by anchoring within the Peros Banhos, and possibly Salomon, atolls or in the lee of the other target islands.

Therefore, it is planned to undertake operation in June and allow additional time in case of rainfall in addition to significant wind (20kts +) grounding helicopter operations. Securing the services of a weather forecaster, preferably with good knowledge of the area, or assessing online weather forecast sites during the trial period will be required.

The seasonal timing of this operation is critical and cannot be delayed as it needs to coincide with the driest month of the year, to allow for a possible lull or reduction in breeding activity by rats. All planning will need to work towards this period and will need to be in place well in advance. All possible problems that may interfere with the operation timing will need to be considered and mitigated in the Operational Plan.

However, June is still relatively wet, at a mean monthly average of 100 mm. In order to reduce the effect of a possible heavy rainfall event immediately post bait application, the meteorological service at Diego Garcia will be used to provide a five-day rainfall forecast. If significant rain is forecast the operation will be delayed accordingly.

If there is an un-forecasted significant rain event whilst the eradication is being conducted, and it is within the 3 night 'dry period' required for effective bait application, contingency bait could be used to re-apply bait on affected islands. The re-application rate may be at a lower rate if the contingency bait is limited.

Consideration and trials of possibly more weather-proof bait should be conducted in order to confirm the integrity of the bait under likely conditions prior to ordering. Possible contenders would be Pestoff 20R (Orillion, NZ) or Conservation 25W (Bell Labs, USA).

D. Rats breeding during the operational period

If possible, rat eradications are conducted when rats are not breeding and are food-stressed. As a result, the rats are actively foraging for limited food resources and pregnant females or their young are not present.

Associated with the wet climate of the Chagos Archipelago is the likelihood that rats will be breeding during the operational phase of the eradication. Rat breeding on islands is generally tied to primary productivity (Holmes et al. 2015), such that when plants are producing seeds and fruit, rats will respond by breeding.

On tropical islands with seasonal dry periods rat breeding usually ceases with increasing aridity and rat body condition declines (Harper et al. 2015), so rat eradications are timed to exploit this stress period for rats (Holmes et al. 2015).

It is almost certain that on the consistently wet and warm islands of the outer Chagos Archipelago at least a few rats will breed each season. Certainly, during previous site visits, black rats were very abundant on several islands (pers. obs) and have been recorded at densities of about 60 rats/ha on Diego Garcia, where breeding occurs year-round (Harper et al. 2019).

This is a possible unquantified risk to the operation as pregnant or suckling rats may possibly not consume poison baits whilst raising young (Holmes et al. 2015), although this has not been the case where pregnant or suckling females rats were monitored in a recent successful eradication of Pacific rat (*R. exulans*) in French Polynesia (A. Samaniego, pers. comm.). At this stage, trial baiting work at Diego Garcia, and the only successful rat eradication thus far on Ile Vache Marine and two islets, conducted in August, suggest that all rats will consume baits (Harper et al. 2019).

Further trials will be needed to confirm that the proposed application rates will be enough to overcome any risk from rats breeding activity during the operation (5.1.3 above). It is proposed that rat eradication trials are carried out on 4-5 small islands within Peros Banhos Atoll at least two years prior to the operation proceeding. These would also aim to measure overall bait loss and bait removal rates by land crabs to inform the final baiting rates.

E. Rat home ranges are too small to allow them to encounter bait

Rat home ranges in coconut forest, when at high population density, can be as small as 21m in diameter (Howald et al. 2004, Vogt et al. 2006). However, aerial application of toxic bait means that bait is present across the entire area of a target island at a rate roughly equivalent to one bait/m^2 (at an application rate of 18kg/ha = 9000 pellets in 10,000m^2).

Moreover, rats are often diurnally active on these islands (pers. obs.), so on the first day of bait application many rats are likely to encounter a toxic bait before crabs become more active in the evening.

F. Response for eradication failure on individual islands

It is possible that eradication of rats from one to a few of the 34 islands may fail. It is likely not feasible to reinstigate an operation of the same scale due to cost. If this is the case it may be warranted to apply bait by hand, or by drone on each ‘failed’ island, if of a feasible size (estimated to be in the order of <50ha [17 islands]), as costs for transporting and supporting a small ground team or drones and a relatively small amount of bait are highly likely be significantly less than the archipelago-wide operation.

Moreover, the drone and supporting staff and supplies could be transported using the existing patrol vessel. At present it is difficult to estimate the cost of ‘failed island’ response using drones as there are many intangibles involved, with the principal unknown being how many, if any, islands would require re-treatment.

At present the technology and associated techniques are in their infancy they appear promising. Similarly, the cost-effectiveness of the technique in the field is unknown, but the speed at which drone development is occurring suggests there could be significant savings in future, particularly through the economy of scale associated with applying heavier payloads.

In this case, it would be advisable to undertake trials of bait application by existing drones to assess the suitability of this technique. There are a few islands with rats that are isolated enough from other islands to preclude reinvasion where drone trials could be undertaken, particularly Ile Yeye at Peros Banhos.

Note that undertaking an eradication of this size by drone across the entire archipelago is not feasible at this stage. The current stage of technique development has not been proven to successfully eradicate rodents on an island of any size, let alone at the scale of this operation.

Moreover the very restricted payload of current drones significantly prolongs the time to complete an archipelago-wide bait application, in the order of several months. The requirement for a service vessel and staff being present for the entire duration of a drone operation would significantly increase the costs.

G. Response to detection of additional invasive species

Although no sign of cats has been found on the islands of the outer Chagos Archipelago for at least 20 years and mice have never been recorded, there exists the remote possibility that they are present but remain undetected.

It is likely that the planned eradication technique (aerial bait broadcast) would also remove these species through direct poisoning (mice & cats) or secondary poisoning (cats). If they exist and survive the eradication operation they would not become obvious until 1-2 years post eradication and should be detected by the monitoring programme.

Both species require more intensive eradication techniques for their removal, although mice could conceivably be eradicated using the proposed response outlined above (5.1.5 F). Cats would require an additional targeted ground operation for their removal on an island, but as they are highly unlikely to swim from island to island, the biosecurity risk between islands is negligible.

5.2 SUSTAINABLE

Sustainability in this context refers to maintaining the black rat-free status of the archipelago post eradication and hence, safeguarding the outcomes (i.e. species and ecosystem recovery) into the future. This means that is it critical to minimise the risk of re-invasion, both from outside the archipelago and between islands within the archipelago, as a condition of the eradication feasibility.

At present, the eradication of rats on the Chagos Archipelago will protect the currently rat-free islands, particularly at Peros Banhos and Salomon atolls, where the islands are relatively close, at between 40m and 3.8 kilometres apart. The risk from rats swimming from the more distant islands, such as Eagle or the Egmont Islands is essentially nil, as they are separated by at least 20-30km. Diego Garcia, at about 100km from the nearest island would only be a risk for rat reinvasion if assisted by human activity such as research or management visits.

In addition, the risk of introduction and establishment of new invasive species should also be minimised. Managing these risks would require putting in place effective biosecurity measures (or barriers) along a continuum of each pathway which covers; pre-departure to the islands, arrival at islands, and on the islands themselves. Arguably the current departures from Diego Garcia to the outer islands present the greatest biosecurity risk although this is low as there is no civilian population (they are all employed by the military) and any person visiting via Diego Garcia would all be subject to biosecurity protocols.

These measures are detailed in an existing interim Chagos Biosecurity Plan (Harper 2017), but largely pertain to operations carried out by the BIOT patrol vessel itself, occasional research activities and a few visiting yachts.

An additional biosecurity risk is the rare landings by illegal fishing boats operating out of Sri Lanka and the Maldives and it is entirely possible that rodents, and possibly other invasive species, could become established in the outer Chagos Archipelago through this route. The management of this risk needs to be covered in the Biosecurity Plan, and as policing and control of illegal fishing activities is carried out by the BIOT patrol vessel, the management of this risk will largely fall to this vessel and crew.

In order to ensure the gains made by eradicating rats are maintained, it is essential that the recommendations set out in the Biosecurity Plan are put in place and are well embedded in the local governance and operational structures prior to the initiation of the eradication operation.

5.3 SOCIALLY ACCEPTABLE

As the governing body of the British Indian Ocean Territory the BIOTA is the key stakeholder in this project. After CCT successfully eradicated rats from Ile Vache Marine in 2014 it was asked by the BIOTA to lead on the development of a comprehensive archipelago-wide rat eradication programme. As such this proposed eradication operation is fully supported by BIOTA as it will result in completion of some of the priorities set out by the Administration.

5.4 LEGALLY ACCEPTABLE

The Commissioner's Representative will assess and provide the relevant permits for the activities associated with the eradication operation, which include, but are not restricted to, visas for staff, applying toxin, operating helicopters and operating a vessel in BIOT waters.

Permits for toxin application will be subject to the provision of an environmental impact assessment to ensure that the impact on the BIOT environment is minimal and contained. This is currently being drafted. However, it should be noted that the rodent toxin and matrix most likely to be applied was used for the Ile Vache Marine rat eradication in 2014.

In regard to helicopter operations the Commissioner's Representative will provide a permit for the pilots to operate and for the operation of the aircraft so the BIOTA will need full details of the pilots, aircraft, insurance and flight plans. If helicopters are operating around or near Diego Garcia, which is not planned and unlikely, flight plans will need to be approved by the United States Air Operations team. Similarly, helicopter operations off a ship will likely be subject to international guidelines.

Following the normal process for a ship-based science expedition, the Commissioner's Representative will provide a permit for the ship and crew. In relation to visas, staff will be required to supply passport information to the BIOTA. If the vessel is flagged to any state other than the UK or a UK Overseas Territory a further process may be required under the UN Convention on the Law of the Sea, which the BIOTA can assist with if required.

5.5 ENVIRONMENTAL IMPACTS

Rat eradication from islands should only be undertaken once the environmental impacts of the method used are assessed (Empson & Miskelly 1999) and show that the likely benefits outweigh expected costs (Broome et al. 2014). The assessment of the likely impacts and benefits of the proposed eradication of the outer islands of the Chagos Archipelago is discussed below. A detailed Assessment of Environmental Effects has been drafted and should be read in conjunction with this section (Harper 2020).

5.5.1 Flora and fauna persistence and ecological changes

The introduced rats in the BIOT are likely to be having severe adverse effects on almost all the native animal and plant species. The eradication of black rats will eliminate their direct impacts and permit the recovery of the natural communities. Although the immediate recovery stage may not restore the islands to their natural pre-rat condition, it will enable ecosystem recovery.

There are likely to be short-term effects on the ecosystem from the application of a persistent toxin like brodifacoum, at the low application rate and short duration that the poison is present any possible effects will be short-lived as it is broken down by soil organisms with six months (Fisher et al. 2011). This is in contrast to sites elsewhere where long-term anticoagulant use has resulted in residues accumulating in the food chain, particularly at higher trophic levels (Spurr et al. 2005).

5.5.2 Non-target impacts – terrestrial

The goal of eradication of rats from the Chagos Archipelago is to prevent extinction and decline of local native species and to enable species to recolonise and recover. Removal of rats will prevent extinctions or declines in the numbers of native species.

The risks to non-target species will be minimized wherever possible (Refer to Chagos Rat Eradication Assessment of Environmental Effects; Harper 2020). However, in general there is a low risk of significant impacts on native species due to the depauperate state of the terrestrial faunal diversity present on the islands, which is a function of their isolation and young geological history.

Although there may be a risk to *individuals* of some non-target species listed below, this impact should only be considered of critical concern if a species is negatively impacted at the *population* level through lethal or sub-lethal exposure to the rodenticide. As long as the impact is not at a population level or any significant risks can be effectively mitigated (e.g., through timing when species are not present or breeding, or through temporary removal) without compromising the eradication operation then it should proceed.

Following bait application, brodifacoum residues will occur in both sub-lethally and lethally poisoned animals. Residual brodifacoum is stored in the liver of sub-lethally exposed birds, where it can remain for many months, and may be a risk for their predators (raptors or herons/egrets).

However, residues do not appear to persist in invertebrates beyond a few days in most invertebrate species besides crabs (Bowie & Ross 2006, Brooke et al. 2011). It is expected that the largest amount of residual brodifacoum will be present in the tissues of poisoned rodents.

There is high potential for secondary exposure of non-target predators and scavengers, particularly land crabs, which could consume rats after the 3-7 day period that rats take to die. This hazard will remain until rat carcasses degrade. Ground-dwelling invertebrates that feed on baits will also transfer residual brodifacoum in the environment; and secondary risks to insectivores need to be considered. Due to their different blood physiology invertebrates, including crabs, are unaffected by anticoagulants (Pain et al. 2000)

Note that seabirds are highly unlikely to consume poison bait whilst on land. The birds most likely to consume bait or be subject to secondary poisoning through consumption of non-target species such as crabs or by scavenging dead rats, are listed below.

Red Junglefowl (Domestic chicken): An introduced species, that is present on Eagle Island, so are likely to consume bait. As millions of chickens exist, their extirpation from the Chagos Archipelago will have no appreciable effect on the global population. However, their local extinction is unlikely unless the populations are very small, although there may be a significant local reduction in numbers, albeit temporarily.

Striated heron: This native species are present throughout the archipelago, including Diego Garcia and are therefore unlikely to be extirpated on all islands.

White-breasted waterhen: This species is most common on Diego Garcia where no poison application will occur.

Common moorhen: Again, very common on Diego Garcia where no poison application will occur.

Cattle egret: Found most often on Diego Garcia where no poison application will occur.

Madagascar red fody: This is an introduced species and is present on Diego Garcia in large numbers where no poison application will occur. Present in low numbers through the outer islands, but are a granivore so less likely to consume pellet baits.

Indian pond heron: Occasional visitor only, so will not be affected by poison at a population level.

Several wader species (plovers, sandpipers, godwit, whimbrel, turnstone, sanderling, ruddy turnstone etc) are present during the austral summer, but all are highly unlikely to be present during the operation, taking place in the winter, so are therefore not at any significant risk of direct or secondary poisoning, except for any juveniles that may not migrate. Ruddy turnstones *Arenaria interpres* may be affected if they consume any invertebrates with residual toxin during the summer post-eradication, but this will be some 4-5 months post-operation, so unlikely.

House gecko: There are two gecko species that have been introduced to at least some of the islands of the outer Chagos Archipelago. As they are widespread throughout the tropics, and there has been no noticeable impacts on small lizard populations in other tropical island rodent eradications there is unlikely to be any detectable effect on this population.

In all other operations worldwide the recovery of native species has been quick and substantial (Smith *et al*. 2006, Witmer *et al*. 2007, Towns 2009). Land crabs, in particular, do not appear to be affected by the poison bait operations and quickly recover to levels higher than when rats were present (Parrish 2005, Towns *et al*. 2006, Samaniego & Bedolla-Guzmán 2012). Indeed, it is possible that some presently rare crab species may become markedly more common after the removal of rats (Samaniego et al. 2019).

Poison bait pellets break down rapidly in water (< 2 days) and as brodifacoum has extremely low solubility in water, uptake by plants or contamination of ephemeral ponds or the few mangrove/*Pemphis* areas is very unlikely to be a reservoir for residual brodifacoum.

Similarly, soil residues are likely to reach low levels within a few months as it is degraded by soil organisms (Ogilvie et al. 1997, Fisher et al. 2011), although degradation of poison pellets is very dependent on local conditions, particularly rainfall. In the prevailing damp conditions in the archipelago, pellets will probably only last a few weeks on land at most.

However, as most pellets will be consumed by either rats or land crabs (Harper et al. 2015) dead rats are likely to be the largest reservoir of toxin and monitoring the movements and fate of radio-tagged rats and the process of degradation of rat carcasses in pre-operation trials could provide information on the rate of toxin decay. Monitoring the rate of degradation of baits in pre-operation trials could provide information on the decay of the baits in the environment, or they may be inferred from the other study on a tropical atoll at Palmyra (see below).

5.5.3 Non-target impacts – marine

It is likely that some toxic pellets will enter the coastal waters around target islands and may be detectable in some marine species, such as molluscs, immediately post-eradication. However, the toxin's persistence is likely to be short-lived. For example, after a coastal road accident at Kaikoura, New Zealand, approximately 18 tonnes of brodifacoum bait entered the inter-tidal zone forming a plume of particulate matter of about 100 x 500m in area.

Monitoring of the marine invertebrates and fish at the site revealed that brodifacoum was not detectable in the water column or sediment within three and nine days respectively. Marine fish species had barely detectable levels of brodifacoum after two weeks. Some invertebrates still had very low residues a year after the accident and one particular mollusc species 31 months later (Primus et al. 2005).

At tropical Palmyra Atoll, although brodifacoum was detected in fish, invertebrate, lizards and crab species 60 days after the eradication, by three years post-eradication no residues were detected in the same species (Wegman et al. 2019). A similar result was obtained in fish on Wake Island, three years after aerial application of brodifacoum pellets there in 2012 (Siers et al. 2016).

It should be noted that the Kaikoura example is an extreme case of toxin application and the Palmyra operation also applied brodifacoum bait at significantly higher rates than the proposed operation (155kg/ha vs 32kg/ha, Pitt et al. 2015) due to the extremely abundant land crab population, so the degree of exposure for non-target species in the Chagos Archipelago is likely to be substantially less.

Indeed, in a New Zealand rat eradication with comparable bait application rates, sampling of the marine environment showed only a few individuals of fish and mollusc species had consumed bait and none at a level that was likely to cause mortality. Furthermore, brodifacoum residues subsequently fell below detection levels within a matter of weeks (Masuda et al. 2015).

Additional precautions will be required with regard to ballast water and suitable biosecurity protocols will need to be followed to avoid importing of non-native marine organisms.

Although these results do not obviate the eradication practitioners from undertaking due care with bait application, it does suggest that any impact of brodifacoum in the marine ecosystem at the proposed application rates will be limited and short-lived.

5.5.4 Ecosystem response to rat removal

It is possible that there will be an irruption of Lepidoptera or other invertebrate species (e.g spiders) with removal of rats, which has been observed on several islands, including Henderson Island (Shiels et al. 2017, pers. obs.). However, it was not seen on Ile Vache Marine post-eradication (Carr, pers. comm), so may not occur in the Chagos Archipelago.

There are likely to be changes in the numbers and species composition of crabs post-rat removal as recorded on Mexican islands after rat eradications there (Samaniego et al. 2019), particularly as the crab fauna appears to be relatively diverse on some islands such as Moresby (pers. obs.).

Vegetation recovery is highly likely to be substantial (Wolff 2018) with the removal of rats and predation on fruit, seeds and seedlings. An example on the outer islands of the Chagos Archipelago was significantly increased numbers of *Intsia bijuga* seedlings noted on Ile Jacobin and Ile du Sel (Salomon Atoll) after rats were eradicated there (Harper et al. 2019).

There are few weed species on rat-free islands within the Chagos Archipelago and most are grass or grass species in the few forest-free sites, which suggests that weed species are unlikely to be a significant problem post-eradication. Pre- and post-monitoring of the response of possible weed species is a suggested action.

The comprehensive research and monitoring of native species and coral reef ecosystems carried out at present will provide valuable pre-eradication baseline data and ensure measuring the ecosystem response after the operation will accurately assess the positive impacts and likely biological recovery.

5.5.5 Pollution

The humans, ship and tenders associated with the eradication operation will potentially have short-term adverse pollution impacts on land and seawater. However, the duration of operation in and near the target islands will be a matter of days.

There is some risk of fuel spills from the use of the ship/tenders. Suitable mitigation techniques should be in place to deal with possible fuel spills, including bunding and sorbents on board, with booms and a skimmer for marine spills.

All shipboard rubbish will need to be retained as per Annex V (Regulations for the Prevention of Pollution by Garbage from Ships) of the MARPOL Convention in 1998.

There will be significant but short-term effects of helicopter noise at target islands, lasting a few hours at most for larger islands, while bait is being applied. The response of seabirds to over-flights can depend on the species and stage of breeding season (Carney & Sydeman 1999), and as some seabird species can breed at any time during the year it is difficult to foresee what affect helicopter flights will have. However, as most islands with rats have very few seabird species, the affects will likely be limited.

5.6 CAPACITY

The proposed eradication operation will require persons with specialist skills to complete the task. The current stakeholders do not possess the specialised staff for an operation of this nature and will need to contract the various suitably experienced personnel to undertake the eradication (Table 6).

5.6.1 Initial steps

An obvious first step is to source a suitable vessel and crew to transport the staff, equipment and supplies to the island. The entire operation depends on this action. In addition, experienced and suitably qualified helicopter pilots will need to apply the bait to the required standard and have associated engineers and technicians to service the helicopters and provide GIS skills.

5.6.2 Staffing

Management staff should comprise a Financial Controller, Programme Manager, Operations Manager and Technical Advisor, along with crew that have experience in both aerial and ground-based baiting techniques for carrying out the helicopter work along with baiting a few small areas of mangrove/*Pemphis*. All these skilled personnel will need to be sourced and recruited from a small pool of international operators.

5.6.3 Governance and technical oversight

The overall project governance should be provided by a Steering Group comprising members from CCT, BIOTA and stakeholders. Oversight of the technical portion of the eradication will require the formation of a Technical Advisory Group, comprised of persons with experience of rodent eradications on isolated islands, with preferably some tropical island experience.

There are suitable persons available to fill these roles, but they often have commitments at least 12 months in advance, so contact with possible candidates should be made soon after sufficient funding is secured for the project. This is particularly true for management staff such as the Programme Manager and Eradication Manager.

5.6.4 Ship charter and determining the port for departure

In addition, as the entire programme depends on the availability of a suitable vessel. Therefore identifying and entering negotiations to charter a ship in the Indian Ocean periphery, or perhaps further afield, will be an essential task as soon as funding is available.

An associated task will be identifying a suitable port to operate from that has the facilities to support the vessel and operational and procurement tasks prior to departure. Due to the extended period isolated from supply chains identification of equipment required for the eradication and sourcing spare parts or components that are critical for operation completion will be an essential part of the procurement process.

5.6.5 Sourcing a suitable toxic bait

Identifying a suitable toxic bait and initiating discussions with the supplier will also be needed early in the planning process.

5.6.6 Helicopter charter and associated permitting

Securing the use of helicopters and bait spreading buckets that can perform the required tasks, along with pilots and ancillary staff, will also be one of the initial steps the programme will depend on.

Associated with developing the programme will be identifying the legal requirements to operate within the Chagos Archipelago, operate helicopters and distribute toxic bait. There may also be additional regulations and permitting required for expat pilots working within the UK Overseas Territories.

Permitting issues need to be resolved early to ensure there are no delays once the operation reaches the point of departure from the home port and provide surety that the helicopters, pilots and ship can operate at the Chagos Archipelago, and the selected bait be distributed, well before they arrive.

5.6.7 Detailed planning

A significant amount of additional planning remains to be initiated or completed in order for the operation to run smoothly and achieve its eradication goals. In addition to this study, the overall Project Plan, and the Assessment of Environmental Effects, the current Operational Plan will evolve and expand as various components of the operation are finalized prior to implementation. Similarly, a Monitoring Plan to assess any impacts and the benefits of the operation, a Communications Plan to manage the public face of the operation, and a

Restoration Plan to guide the long-term management of the islands post-eradication, will all need drafting.

Table 6. Skills required for proposed outer Chagos Archipelago Rat Eradication Operation

KEY SKILL	PURPOSE	METHOD TO OBTAIN SKILLS
Financial & Project Controller (FC)	Manages administrative and financial aspects of the project, reporting to CCT/BIOTA, Steering Committee, and funders. Liaison with stakeholders. Manages external communications with media etc. Is responsible for the successful delivery of the project.	Fixed term contract from within CCT or contractor.
Programme Manager (PM)	Oversees and organises eradication operation logistics and contracts including ship and helicopter hire. Liaison between ship's captain and operation staff.	Fixed term contract for appropriately experienced contractor.
Shipping Agent	Agent at Port of Departure. Provides assistance with customs clearance, local logistics, ship loading and associated tasks.	Fixed term contract for appropriately experienced contractor.
Operations Manager (OM)	Technical planning and management of eradication operation, including bait acquisition. Directly oversees all aspects of the eradication operation and is responsible for the delivery of the eradication phase. Directly controls all air operations. Deputises for PM if required.	Fixed term contract for contractor.
Technical Advisor (TA)	Provides technical advice and is directly responsible	Fixed term contract for contractor

	for delivering all aspects of ground-based operations e.g. mangroves. Deputises for OM if needed.	
Technical advice (TAG)	Technical advice with most recent developments	Island Eradication Advisory Group (NZ).
Steering Group (SG)	Provide overall programme oversight.	Stakeholders
Helicopter company	Aerially sowing cereal baits	Fixed term contract for contractor
GIS expertise	Mapping of aerial and ground operational components	Fixed term contract for contractor.
Communications/Media manager	Advises/assists with external media requests/press releases	Part-time contract for local company or in-house.
Ship Operation	Running ship to, during and from the northern Chagos	Fixed term contract as part of ship charter
Weather expertise	Weather predictions for eradication operation.	Meteorologist on Diego Garcia or contract meteorologist/website
Medical & Health & Safety Officer	Provides medical care and first response to medical emergencies. Oversight and delivery of safety components of operation	Fixed term contract as part of eradication staff.
Bait loaders & ground-baiting crew	Loading bait for aerial baiting & applying bait on ground sites. General duties associated with supporting eradication logistics.	Fixed term contracts for all staff
Genetic analysis	Collection of rat samples pre- & post operation. Analysis of samples	EM for collection during pre-operation trials. Commercial lab for sample analysis. Technical expertise for genetic analysis if required.

5.7 AFFORDABILITY

As the proposed operation will take place on a very isolated archipelago and all the equipment and supplies required will need to be shipped to the site the associated costs will be substantial. Moreover, there will need to be pre-operational trials to inform planning and fine tune aspects of the operational plan and budget to ensure there are a minimum of issues once the eradication operation is on site.

An indicative budget, as at late 2019, is tabled below (Table 7). It may need re-adjustment if proposed trials suggest that significant changes to the operational plan or costs are required. It would be advisable to re-visit the budget figures when funding bids are being drafted.

Table 7. Indicative budget for the proposed outer Chagos Archipelago Rat Eradication.

Item	Details	Cost (US$)
Project Design Stage		
Production of Feasibility Study, Operational Plan, Environmental Impact Assessment, Project Plan		Already contracted.
Meetings costs		500
Travel for PM/OM		4000
Project Design Stage, Expected cost		**4500**
Operational Planning Stage:		
Financial & Project Controller	Contract for 24 months. Operation administration management and financial oversight. Obtaining consents (24 months). Reports, public relations/media, political aspects, legal aspects, provides liaison between stakeholders, funders and science agencies involved. An essential component will involve contracting a ship broker to source and charter a suitable ship for the operation.	138,000
Programme Manager	Contract for 24 months. Management and oversight of the project, including recruitment and operations in the field. Conducts and oversees all procurement,	100,000

	transport, storage and maintenance of equipment. Assist FC obtaining consents.	
Operations Manager	Contract for 12 months (part time for 6 months). Sourcing staff / recruitment, further refinement of Operational Plan, Monitoring plan, assist PM obtaining consents. Direct control of field operations.	35,000
Technical Advisor	Part-time contract for 6 months. Provide advice for PM/OM. Plan and assist with on-island trials at Chagos.	15,000
Meeting costs	Flights / accommodation for PM and OM while sourcing vessel / helicopters / port / staff / meetings with stakeholders / Steering Group	20,000
Pre-operation trials at Chagos	Contract for 2 months for Drone Technician PM/EM/TA: Flights to Maldives, trial equipment, bait trials, and write-up. Trials of drone on selected small island. Assume boat costs part of usual Fisheries Patrol operation.	100,000
IEAG/IC advice	Travel expenses and time for IEAG/IC to oversee and critique planning documents.	10,000
Consents / permits	Costs for permit processing, flights for meetings with BIOTA/FCO	15,000
Operational Planning Stage, Sub-total		432,300
Operational Planning Stage, Contingency (10%)		43,230
Operational Planning Stage, Expected cost		**475,530**
Implementation Stage:		
Vessel charter	Ship (60 days @ $40,000/day)	2,400,000
Helicopter hire	2 helicopters x 60 days @ $2800/day hire + $450 per hour when flying. Inclusive of spreader bucket, engineer etc	381,000
Bait	80.3 tonnes at $2800/tonne (rounded)	225,000
International bait transport to port of departure (PoD)	Will depend on port location. At this stage working on Singapore as interim PoD	30,000
Domestic bait transport	For 10 containers from factory to port of export (including silicon sticks)	15,000

Fuel	107hrs @ 120L/hr @ $1.50/L	19,260
Staff	Contract for FC for 6 months	34,500
"	Contract for PM for 6 months	25,000
"	Contract for OM for 6 months	25,000
"	Contract for TA for 4 months	18,000
"	Chief Pilot (3 months)	40,000
"	Pilot for 2 months	16,000
"	GIS technician for 4 months	18,000
"	Field Staff for 2 months (8 @ 12,040 each)	96,320
Return flights for staff	18 staff @ $2000 each	36,000
Accommodation in port of departure	18 staff for 2 weeks	25,000
Port costs	Storage, stevedoring, Customs costs etc,	40,000
Car hire at port	Two weeks pre- and one-week post-operation, including fuel.	2,000
Equipment procurement	Technical and PPE, including computers, VHF radios, satellite phones, protective clothing	35,000
Signage	Weather-proof warning signs at usual landing sites for yachts	8,000
Biosecurity advocacy	Pamphlets for visiting yachts, ship's crew explaining eradication and need for biosecurity measures	10,000
Implementation Stage, Sub-total		3,499,080
Implementation Stage, Contingency (20%, rounded)		700,000
Implementation Stage, Expected cost (rounded)		**4,200,000**
Sustaining the Project Stage:		
Confirmation of eradication success	1 year post- eradication. Will need to check all 34 islands. 20 days including planning & travel time at $1800/week per person for 2 people. Report compilation. Does not include vessel costs.	20,000
Reacting to failed islands	Drone capability and toxic bait to respond to any island where rats survived. To be	100,000(??)

	present with monitoring teams on Year 1. Does not include vessel costs.	
Confirmation travel	Flights & accommodation for 2 staff	7,000
Independent rodent detection team	To include rodent detection dogs to enhance detection ability and reduce time on islands. Visit all 34 islands at Year 1.	20,000
Rodent monitoring equipment	Snap-traps/chewcards/chewsticks/wax-tags/lures	1,500
Monitoring of ecosystem response	For first five years. Vegetation plots and seabird counts at selected islands. Monitoring at years 1, 3 and 5. Three 10 day visits at $10,000/visit	30,000
Sustaining the Project Stage set-up and running costs for 2 years		178,500
Sustaining the Project Stage Contingency		18,000
Sustaining the Project Stage, Expected 2-year cost		**196,500**
PROJECT TOTAL		**4,876,530**

6.0 SUMMARY

The proposed Chagos Archipelago rat eradication operation is feasible, and with careful planning and execution the operation has a high chance of success. There is a record of successful operations completed on similar islands elsewhere in the tropics, with the caveat that reasons for the few failures are not well understood. A rat eradication will almost certainly result in significant biodiversity gains for the archipelago, both terrestrially, for seabirds and land crabs, and also for the marine ecosystem, with increased nutrient outflow from more abundant, larger seabird colonies, improving coral reef resilience and marine species diversity.

Two overarching issues will need to be resolved for the eradication to proceed, which are the significant logistical hurdles of carrying out an operation on this highly isolated site and funding the substantial associated cost.

Careful management of operation logistics will be required to ensure success, and focussed trials will be needed to inform and amend the associated Operational Plan. Operational implementation is contingent on sourcing a ship suitable for transporting a large amount of bait, and flying two helicopters. If successful and appropriate biosecurity measures are established and adhered to, then the rat eradication should be sustainable. The considerable distance of the outer islands of the Chagos Archipelago from any other land precludes unassisted rodent reinvasion.

Indeed, the isolation of this archipelago and the difficulties it poses for mounting this operation show how it will assist in maintaining enduring eradication outcomes. However, this does not obviate the island managers of the requirement for effective biosecurity and it will need some development before the operation proceeds.

An initial review suggests few environmental risks with the project, which will be covered in an associated Assessment of Environmental Effects. There are very few direct or secondary poisoning risks for a few bird species, but as these are either only summer visitors (and therefore not present during the operational window) or still present at Diego Garcia, in the southern Chagos Archipelago, the risk is at an individual level, rather than for entire populations.

The expense incurred through mounting this operation is considerable and there is always some risk of failure inherent in eradications, particularly on wet tropical islands. Therefore, eradication validation within 12 months is essential, as is an instantaneous response to any post-eradication rodent detections.

Developing drone technology to accompany monitoring teams to react and deal with any subsequent rodent detections is relatively expensive at present, but logistically manageable, realistic for smaller islands, and it would be prudent for an eradication operation encompassing 34 islands for a 'rapid response' contingency to be included and funded in the original bid.

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9.0 APPENDICES

9.1 Appendix 1. Site visits

The author has visited the outer Chagos Archipelago three times, twice in 2014 and again in 2016, including landings on several islands in the Peros Banhos (Ile Moresby, Ile Parasol and Petite Ile bois Mangue, Grande Ile Coquillage) and Salomon Atolls (Ile de Passe, Ile Takamaka, Ile Boddam, Ile Poule) and on Nelson's Island, Eagle Island, Sea Cow Island and Danger Island. During the visits he has undertaken invasive species research or eradication work on five islands in the Peros Banhos and Salomon Atolls: Ile Vache Marine, Ile Jacobin, Ile du Sel, Ile Manoel and Ile Yeye.

Internal reviewer, Pete Carr, has visited every island in the Chagos Archipelago and has conducted management and research activities throughout the Chagos Archipelago since 1996.

9.2 Appendix 2. Detailed table of the outer Chagos Islands

Table 1. Islands with black rats present, and targeted for eradication, in the outer Chagos Archipelago (Carr & Harper 2017. Refer to Figure 4 for a schematic location map of the islands).

Atoll / Island	Island	Area (ha)	Combined Area (ha)	Rats present (✓) or absent (-)
Peros Banhos			779.1 (with rats)	22 islands with rats
	Mapou de Ile de Coin	7		✓
	Ile de Coin	130		✓
	Ile Anglais	16		✓
	Ile Montpatre & Ile Gabreille	13		✓
	Ile Poule	93		✓
	Ile Petit Soeur	50		✓
	Ile Grande Soeur	59		✓
	Ile Pierre	124		✓
	Ile Petite Mapou	1		✓
	Ile Grande Mapou	20		✓
	Ile Diamant	89		✓ (Mangroves present)
	Ile de la Passe	23		✓
	Ile Moresby	34		✓ (Mangroves present)
	Ile St Brandon	0.2		-
	Ile Parasol	8		-
	Ile Longue	22		-
	Petite Ile Bois Mangue	9		-
	Grand Ile Bois Mangue	13		-
	Ile Manoel	32		(✓?)
	Ile Yeye	64		✓
	Marlin’s Island	0.1		✓
	Ile Petite Coquillage	19		-
	Ile Grande Coquillage	21		-
	Ile Fouquet	3		✓
	Ile Mapou Ile de Coin	8		✓
	Ile Finon	2		✓
	Ile Manon	3		✓
	Ile Verte	4		✓
	Unnamed island	1		✓
	Unnamed island	3		✓
	Ile Vache Marine	13		Rat free in 2014

Saloman			296	7 islands with rats
	Ile Boddam	117		✓
	Ile Anglaise	76		✓
	Ile Takamaka	51		✓
	Ile Fouquet	48		✓
	Ile Sepulture	2		✓
	Ile Poule	1		✓
	Ile Jacobin	2		Rat free in 2014
	Ile du Sel	2		Rat free in 2014
	Ile Diable	1		✓
	Ile de Passe	29		-
	Ile Mapou	4		-
Egmont			397	4 islands with rats
	Ile Carre Pate	6		✓
	Ile des Rats / Ile Sipaille	59		✓
	Ile Tattamucca / Ile Sudest	212		✓
	Ile Lubine	120		✓
Eagle	Eagle Island	263	263	✓ (Mangroves present)
	Total		1735 with rats. 130ha without rats.	34 islands with rats 10 islands rat-free