DARWIN INITIATIVE FINAL REPORT ON DPLUS011

ILE VACHE MARINE RESTORATION PROJECT

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1. DARWIN PROJECT INFORMATION

Darwin Ref. Number	DPLUS011
Darwin Project Title	Ile Vache Marine Restoration Project
Country	British Indian Ocean Territory (BIOT)
Award Holding Organisation	Chagos Conservation Trust (CCT)
Partner Organisations	BIOT Administration including HQ BF BIOT (UK FCO), RSPB, RBG Kew, ZSL, Warwick University, G4S LLC.
Grant Value	£32,256.00
Start / End date	01/05/2013 – 30/09/2015
Authors	Peter Carr, Dr. Grant Harper

2. PROJECT BACKGROUND / RATIONALE

Ile Vache Marine is a tiny island of approximately 1.5 km^2 in the Peros Banhos atoll of the British Indian Ocean Territory's (BIOT) Chagos Archipelago (approx. 5° 25` S, 71° 49` E). It is bordered on the atoll rim by deep water, fast flowing channels and the nearest (rat-infested) island is over 4 km away. It lays within a BIOT designated Strict Nature Reserve within the Chagos Marine Reserve and is located in close vicinity of three designated and two proposed IUCN classified Important Bird Areas (IBAs). Despite being near to internationally important populations of breeding seabirds, only miniscule numbers of four species of seabird have ever been recorded as breeding on the island along with one species of introduced passerine. It holds small populations of the critically endangered hawksbill turtle *Eretmochelys imbricata* and endangered green turtle *Chelonia mydas* and the data deficient coconut crab *Birgus latro*. It has an impoverished floral community with 24 species of higher plant recorded prior to the eradication project of which 19 are thought to be either native or probably native.

Throughout the BIOT's Chagos Archipelago, introduced invasive black rats *Rattus rattus* have been recorded as present on 26 islands, absent from 20 and their status uncertain on the remaining nine. Globally, introduced invasive rats have had a devastating impact on oceanic island ecosystems, suppressing populations of both native vertebrates and invertebrates and preventing regeneration of native flora. Rodent (and other mammal) eradication from oceanic islands is recognised by professional conservationists as a standard form of management for improvement of biodiversity and was attempted in the BIOT's Chagos Archipelago in 2006 – an unsuccessful operation to clear rats from the second largest island of the archipelago, Eagle Island.

As part of a long-term strategy to eradicate invasive rats from all of the islands of the BIOT's Chagos Archipelago, (with the exception of Diego Garcia that holds a US Naval Facility), Ile Vache Marine was selected for the second attempt at rat eradication. This "proof of concept" island was selected due to its small size making it affordable and manageable; its distance from the nearest rat-infested island and being surrounded by deep water fast-flowing channels making natural reinvasion improbable; ease of passage across its coral fringe and sandy beaches allowing unloading stores from small boats in surf to be

undertaken in relative safety and that it has had a thorough baseline of ecological data gathered upon it. This baseline knowledge of the flora and fauna of the island informed the project planning team that there were no other organisms on the island that would be collaterally impacted by a mammalian poisoning event.

Crucially, it was selected after a thorough reconnaissance of all islands in the archipelago and was deemed to be one of the easiest to conduct an eradication project upon and therefore increase the chances of success and bolster faith in future similar projects. Further, having small populations of turtles, coconut crabs and being near to IBAs, it offered the opportunity for rapid ecological and biological improvement through recolonisation, recruitment and regeneration. Consummate with any rodent eradication project, for oceanic island native species' ecological rehabilitation, removal of rats must come with invasive vegetation management. Ile Vache Marine was assessed in the early reconnaissance missions as having a manageable invasive plant problem with only the native coconut *Cocus nucifera*, planted as crop but now constituting unmanaged "coconut chaos" needing immediate management.

3. PROJECT SUMMARY

The aim of the project was to restore the ecosystems of Ile Vache Marine by eradicating invasive black rats. This was to be achieved through a four phase operation involving:
1) Vegetation management
2) Operations set up
3) The eradication phase
4) Post-eradication monitoring

This format was (and still is being) followed with some necessary and unavoidable minor adjustments to the finer details of the original operational plan to counter unforeseen circumstances. Critically, one additional phase was inserted, a reconnaissance of the island by the contracted invasive mammal eradication expert who was to be the technical lead of the eradication phase. The failure to identify this requirement in the original operational plan and the Darwin application was a monumental oversight (see further comments on this in section 9, Lessons Learnt).

As a result of the reconnaissance the operational plan was simplified and this both saved money and offered opportunities for exploiting the expertise of the eradication expert to the benefit of the BIOT's Chagos Archipelago.

Table 1 provides a summary of all of the activities undertaken in the preparation for and the execution of the project as measured against project deliverables. Following Table 1 is a detailed narrative of the activities deemed worthy of greater explanation.

Table 1. A summary of activities in the preparation for and execution of Darwin Initiative project DPLUS011 Ile Vache Marine Restoration Project as measured against project outputs.

OUTPUT	ACTIVITY	COMMENT
N/A	Baseline flora and fauna assessment **Completed by 2013 by scientists sponsored by CCT, RBG Kew, RSPB and BIOTA, often supported through Darwin Initiative funding**	This output was not included in the operational plan but is a necessary output to measure future change against. Fortunately, Ile Vache Marine is one of the most comprehensively surveyed islands in the BIOT's Chagos Archipelago from a terrestrial perspective. It has had baseline, pre-rat eradication surveys conducted on avian, mammal, gastropod and invertebrate populations and a full higher plant survey having been completed, from 1996 – 2013.
1.1	Contract mammal eradication expert **Completed by 30 May 2013**	Dr. Grant Harper from Biodiversity Restoration Ltd. New Zealand, was contracted on the recommendation of one of the project partners, the RSPB.
N/A	Mammal eradication expert to conduct reconnaissance of Ile Vache Marine **Completed January 2014**	This output was not identified in the original operational plan. Circumstances of the PI changed that necessitated this unplanned reconnaissance. However, regardless of the reasons why it was originally deemed unnecessary this insertion to the operational plan was critical to the successful delivery of the execution and should be factored in to all future eradication plans in the BIOT's Chagos Archipelago. A report on the reconnaissance trip is in Appendix A.
1.2	Technical liaison between PI and stakeholders / partners **Ongoing**	Technical liaison between stakeholders, partners and other interested organisations has been paramount to the successful delivery of the project. Due to the ongoing requirement for monitoring and the fact that that the island cannot be declared rat-free until two years after the eradication phase, this liaison remains strong and ongoing.
1.3	Contract paid labourers for vegetation management **Not required following reconnaissance**	Following on from the reconnaissance, the extent of the planned vegetation management in the original operational plan was modified and lessened. As a result the requirement for a paid force to undertake the work diminished and following negotiations by the PI with the British Representative of the Territory, it was agreed that the task could be undertaken by British Forces stationed on Diego Garcia, supervised by the PI.
1.4	Calculate rat and crab densities, secure genetic sample **Completed by PI and a Chagossian environmental outreach student in March 2013 as participants on a separate Darwin Initiative funded expedition**	Crucial information in order to calculate bait densities in the eradication phase. Genetic samples (tails) needed collecting in case of project failure – the samples are compared against the existing population to assess if it was an unsuccessful eradication or a new invasion.
1.5	Bait acceptance trial **Not required following reconnaissance**	Following the reconnaissance this trial was deemed unnecessary.
1.6	Vegetation management pre-eradication phase **Completed by PI and Chagossian environmental outreach students in April 2014 and April 2015 as participants on separate Darwin Initiative funded expeditions**	Following the reconnaissance, the original extent of the vegetation management was reduced in scale and the method simplified. As a result, the only invasive plant management undertaken was to fell a 100m x 100m stand of unmanaged (native) coconut and the area sown with native tree seeds and seedlings being planted. The felled trees were left to rot rather than being burnt as was directed in the original vegetation management plan.
1.7	Cut in grid systems for bait stations	This pre-eradication phase activity was critical to the

	Completed by June 2014 by members of British Forces BIOT stationed on Diego Garcia, supervised remotely by the PI	successful delivery of the project. In the original operational plan, the PI was to undertake this work with assistance from paid labourers hired from the Base Operations Service Contractor (BOS Contractor) who service the US Naval Facility on Diego Garcia. However, after an unforeseen change of BOS Contractor in early 2013 and the PI not remaining on Diego Garcia to work for the incoming Contractor (G4S / Parsons), this crucial part of the operation had to be rethought. Following discussions with the British Representative on Diego Garcia, it was agreed that British Forces personnel would undertake this work, supervised, remotely, by the PI. The work was undertaken over two weekends in June 2014 by British Forces BIOT, saving money and ensuring the eradication phase could go ahead on the dates planned. See further comments below in the detailed comments that explain the strengths and weaknesses of this approach and in section 9, Lessons Learnt.
1.8	Deploy bait stations **Not required following reconnaissance**	Following the reconnaissance this activity was deemed unnecessary.
2.1	Contract paid labourers to assist the eradication phase **Not required following reconnaissance**	Following the reconnaissance this activity was deemed unnecessary.
2.2	Deliver eradication phase stores to Ile Vache Marine **Completed by 03 August 2014 as part of the eradication phase of the project, not as a separate entity**	This activity took place but not as a separate entity as per the original operational plan. All of the stores required for the eradication phase were delivered to Ile Vache Marine at the same time as the personnel undertaking the eradication.
2.3 – 2.7	The eradication phase of Ile Vache Marine	Following the reconnaissance by the mammal eradication expert the original operational plan was modified and simplified. The following were the important changes: 1) Pre-eradication vegetation management substantially reduced in requirement (1.3); 2) Bait acceptance trial is not required (1.5); 3) Paid labourers not required for the eradication phase (2.1); 4) Eradication plan simplified and modified (2.2 – 2.7). See following narrative for details of the modified operational plan, methodology and execution.
N/A	The eradication phase of Iles du Sel and Jacobin	Surplus time and rodenticide were available to allow the PI and mammal eradication expert to attempt to clear two further islands in the BIOT's Chagos Archipelago. These were in addition to Ile Vache Marine and were not in the original operational plan. See following narrative for rational, methodology and execution.
3.1	Post-eradication monitoring	The post-eradication monitoring plan was modified and extended based on recommendations of the mammal eradication expert. These recommendations, that fit better the internationally accepted time elapses involved in when rats would be detected on tropical islands if the eradication failed, have meant the final outcome of the project, whether the eradication was successful or not, now falls outside of the Darwin Initiative timeframe. See following narrative for details of the modified monitoring plan and of the monitoring results to date.
3.2 – 3.3	Post-eradication academic paper	The academic paper covering the eradication project will not be published until after the final outcome is known.

		The final outcome will be declared no sooner than August 2016, two years after the eradication phase.

PROJECT SUMMARY – DETAILED NARRATIVE

Baseline flora and fauna assessment: A comprehensive baseline flora and fauna assessment of Ile Vache Marine was not part of the Darwin project and was not written into the original operational plan. However, to measure change over time of the entire island's ecosystem this information is essential. Fortunately, previous scientific expeditions to the BIOT's Chagos Archipelago had conducted censuses of the island's terrestrial vertebrate and invertebrate populations and a comprehensive, updated botanical checklist is available. The turtle and avian populations of Ile Vache Marine have been particularly well studied and recorded. This baseline data will be used in the future, not directly as part of this project, to monitor the change over time, if the project was successful in eradicating rats. Further comments regarding pre-eradication baseline data gathering are found in section 9, Lessons Learnt.

Mammal eradication expert to conduct reconnaissance of Ile Vache Marine: Not factoring in a visit to the target island by the mammal eradication expert prior to the eradication phase was the biggest oversight of the entire operation and the most important lesson to learn and to pass on from this experience. Fortunately, happenstance accompanied by the insistence of Dr. Grant Harper that he must be able to reconnoitre the island prior to the eradication phase (an absolutely correct insistence in hindsight) meant that this essential component of the plan was able to occur. Although not budgeted for, the money saved by the recommendations arising from the reconnaissance amply covered the travel expenses.

1.7 - Cut in grid systems for bait stations: Further to the comments in Table 1, the timely execution of this phase coupled with the quality of the work was crucial to the delivery of the follow on eradication phase. The cutting in of grid lines was undertaken by members of the British Forces stationed on Diego Garcia over two weekends in June 2014. This was a voluntary contribution from the then British Representative on island, Cdr. Lee Hardy RN, undertaken by volunteers from British Forces BIOT.

The PI, in consultation with the eradication expert provided written instructions to BF BIOT on how the grid cutting should be executed. In general the grid cutting was carried out well and the lanes were clear and wide enough to move through. It was apparent that the dense *Scaveola* was difficult to navigate through and caused lines to deviate from the desired grid pattern. This was identified on day one of the eradication phase and was rectified within 24 hours before any rodent poison was distributed.

The lesson to be learnt, repeated in section 9, Lessons Learnt, is that vegetation management, especially accurately aligned grid lines for manual bait distribution are critical to the successful execution of the eradication phase. "Wavy" lines could lead to patches of land not having bait deposited in them and therefore lead to an unsuccessful eradication operation. Future vegetation management in preparation of eradication operations should

be supervised on the ground by highly experienced operators with a thorough knowledge of navigating in thick bush and using GPS to mark and possibly cut/lightly cut lines first.

2.3 – 2.7 - The eradication phase of Ile Vache Marine: Although eradications of rats from islands has been successfully carried out since their tentative beginnings in the 1980s, the vast majority of these have been in temperate zones where the technique relies on targeting rats during winter when they are under stress as food supplies are restricted and breeding has ceased. On tropical islands food is freely available and breeding can occur year round. Moreover, non-target species like land crabs are in high numbers and can quickly remove poison bait. For these reasons the failure rate of rat eradications on tropical islands thus far has been higher than on islands in cooler latitudes. Therefore, tropical island eradication planning has to reduce these additional risks to operational success. In order to do this operations are often conducted in dry weather as this affects vegetation production and subsequent food availability for rats, which reduces breeding activity, and also reduces activity in land crabs. Increasing the bait application rates also means that rats can access, even if there is some off-take by land crabs. Hence planning for the Ile Vache Marine operation had to consider these factors well before proceeding in order for the operation to proceed smoothly with the most likelihood of success. Planning and ordering for the eradication operation was carried out during the first half of 2014.

Staff for the operation gathered in Diego Garcia on 31 July 2014 and immediately assembled the equipment and supplies for the eradication operation prior to departure on 1st August. The team, consisting of the PI, sland Invasive Mammal Eradication Expert and members of the UK military on Diego Garcia, landed on the Ile Vache Marine early on 2nd August to allow passage over the coral reef at high tide. Parallel lines had previously been cut at 25m intervals (1.7) on the island, and these were checked and where required were either re-cut or additional lines slotted in between existing lines. Sites for bait throwing were marked at 25m intervals and black plastic bait stations (Protecta LP, Bell Labs, USA) laid at these sites along the cut lines. Thus, by the end of the day there was a 25m x 25m grid of 184 sites across the entire island. The island size was also reconfirmed at 12ha by walking the coast of the island using a GPS (Garmin 62S).

On 3rd August poison pellet bait (Bell Labs 25D) was hand spread at a rate of 16kg/ha by the PI and Island Invasive Mammal Eradication Expert. This involved stopping at each of the 184 sites on the grid and throwing 208g of bait in four directions at right angles to each other such that it reached about 10-12m, along with 208g spread at the throwing point. Bait spreading was started at each end of the island by the two operators and lines traversed such that the operators were converging on each other. Bait coverage for almost the entire island was completed in the first day except about a two hectare strip in the centre of the island. This was covered the next morning and a little additional bait was spread above the high tide mark around the coast of the island. All the equipment and empty poison bait containers were removed by the end of the morning. The team departed for Diego Garcia shortly after.

For rodent eradications it is usual for two separate poison bait applications at 7-10 days intervals to ensure all target animals have access to bait, particularly if breeding is occurring and suckling mothers or young animals may have been missed in the first bait spread. Therefore the island was revisited on 14th and 15th August, 10 days later, and a second bait application of poison bait pellets (Pestoff 20R) was hand laid at a rate of 12.5kg/ha. Several recently dead rats were located during the second bait application, suggesting rats had readily consumed the poison bait laid in the first application. The bait stations were also then loaded with wax-based poison baits (Bell Labs) at a rate of three baits secured inside each station. This was to ensure that if heavy rain degraded the bait post-departure or any rats missed the hand-laid bait then poison bait was still available for several months after the operation. The bait stations were raised 40mm off the ground with wooden blocks to reduce interference by hermit crabs. The team departed Ile Vache Marine on 15th August at midday. Subsequently in April 2015 all of the bait stations left in the post-eradication phase were removed by the PI and a Chagossian Environmental Outreach Student as part of a different Darwin funded expedition.

The eradication phase of Ile du Sel and Ile Jacobin: Additional poison bait remained after the Ile Vache Marine operation. This was expected, as a contingency is always allowed for in rodent eradication operations to allow for unforeseen circumstances that may reduce bait coverage, such as bait being lost during a landing or if heavy rain degrades bait on the ground.

As extra time and poison bait was available there was an opportunity to carry out an additional eradication operation on two adjacent islets in the Saloman Atoll, some 30km east of the Peros Banhos atoll. Ile du Sel and Ile Jacobin were selected for their small size and distance from the adjacent larger islands, being at least one kilometre from their nearest neighbours, so they could be covered in one bait application with the remaining bait and there was little likelihood of re-invasion by rats. Obviously there was no time for a pre-eradication reconnaissance of either island, so a quick survey was carried out immediately before each operation was attempted in order to assess any obvious threats to operational success. The small size of each island immediately reduces risk as fewer factors that could compromise an eradication are present.

Ile du Sel (2.2ha) was attempted first on 16 August. The island was circumnavigated and waypoints marked at 25m intervals on each side of the island using a GPS (Garmin 62S). The operators then walked from the first waypoint on one side of the island to the corresponding way point on the opposite side of the island, hand-spreading pellet bait (Pestoff 20R) at 25m intervals, in the same manner as for Ile Vache Marine. Bait was spread at a higher rate of 20kg/ha, as it was a single application. No vegetation cutting was carried out. Ile Jacobin (1.6ha) was attempted in the same afternoon using the same techniques and poison pellet bait. Bait was spread at a rate of 25kg/ha.

Future monitoring of the success or otherwise of these islands will prove interesting to the bigger picture of eradicating rats from throughout the archipelago. The atoll rim of the

Salomon Islands can be exposed at neap tides. Reinvasion of these islands is a possibility. If reinvasion occurs it stresses the importance of any eradication operations considering this eventuality and planning for it - the obvious solution being to conduct an eradication of all islands in the atoll as opposed to individual islands.

3.1 - Post-eradication monitoring: The post eradication monitoring plan was amended by the eradication expert from the original 30, 60 and 90 days to 24 months after the eradication operation. This was to comply with internationally recognised elapsed time for any surviving rats to breed and increase in numbers post an eradication event and for the recovering population to become detectable. Twenty-four months after an eradication operation on a tropical island is also the period deemed necessary after which if no rats are detected, the island can be declared rat-free and the operation deemed a success.

However, post eradication monitoring has been carried out in the interim, primarily as an early warning on any possible eradication failure. This was on the rationale that if rats had been detected on any pre-two year visits, early action to rectify the failure could have been initiated. These visits were funded independent of the original Darwin Initiative funding.

The first check was made in April 2015 by the PI and a Chagossian Environmental Outreach Student. No signs of rat presence were detected. On this same visit further vegetation management was undertaken with the felling of approximately one hectare of coconut planted in previous times in the centre of the island coupled with the planting of a small number of *Intsia bijuga* saplings.

The second check was made in February 2016 by the PI and again no signs of rats were present. Indeed there were positive signs that the operation was successful. A colony of 25 pairs of ground nesting great-crested tern were at the egg laying stage on a sandy headland and several small trees (10 - 50cm high) were noticed around the island. There were no freshly gnawed fallen fruits, no rat runs (obvious trails regularly used) and no rats seen. It should be noted this is not enough evidence to declare the operation a success yet.
It is envisaged that both the PI and the eradication expert will revisit Vache Marine in 2016 after the 24 month period to make a final declaration on the success or otherwise of the operation.

3.2 – 3.3 - Post-eradication academic paper: In the original plan, after the success or otherwise of the operation is definitively known, an academic paper is to be released to share the knowledge gained from the operation and to publicise the outcome. This is still the intent. The paper is likely to be published in Conservation Evidence with a precis of the academic paper being offered to the Chagos News (the periodical newsletter of the Chagos Conservation Trust) and to the Darwin Initiative Newsletter.

It is further intended to publicise the results and lessons learnt, successful or not, at the Island Invasives Conference 2017 to be held in the University of Dundee, Scotland over the period 10 - 14 July 2017.

4. SCIENTIFIC, TRAINING AND TECHNICAL ASSESSMENT

Scientific: The Ile Vache Marine rat eradication was carried out to the standard required to ensure a high likelihood of success for an island of its size with all risks to the operation noted and mitigated for, prior to proceeding. The operation proceeded efficiently with minimum disruption to the planned schedule and was completed on time.

Training: Training was deemed necessary for the British Military volunteers who were assisting with the eradication phase. This training was focussed upon the handling of rat poison and was conducted on the BIOT Patrol Vessel prior to the eradication phase and handling of bait. The training covered the correct use of PPE, the contents of an MSDS and the importance of hygiene when handling rodenticide, focussing upon use of nitrile gloves and thoroughly washing hands and clothes prior to eating and drinking.

Technical Assessment: The first technical assessment was undertaken by the mammal eradication expert, with particular emphasis placed upon assessing the original operational plan against what was actually needed after he had conducted the reconnaissance. A full and valid independent technical assessment can only be undertaken after the 24 month hiatus awaiting the final outcome of the operation. This independent assessment will be undertaken against this final report coupled with the academic paper. Any feedback from independent observers will be valued and if deemed relevant in a Chagos context, will be incorporated into future operations.

5. PROJECT IMPACTS

The project has had a significant positive impact on Ile Vache Marine by using a holistic approach that addressed existing threats but will also lead to future positive impacts that will result in a restored, balanced island ecosystem beneficial to the biodiversity that relies on it.

Habitat impacts: A significant impact of this project is the restoration of the natural habitat of the island. Ile Vache Marine had 35% of its native habitat converted to coconut plantation, which has been left unmanaged for 40 years. The result has been a decline in the island's biodiversity, most significantly the absence of nesting seabirds. Removal of coconut and replacing with native species seed and seedlings will result in a restored natural habitat that will be beneficial to seabird populations that will recolonise the island. A limited amount of coconut has been felled as additional work on this restoration project that was at no cost to the Darwin Initiative. Future ecological rehabilitation of the island is planned involving further coconut management, again, not at a cost to the Darwin Initiative.

Biodiversity impact: Ile Vache Marine has likely been infested by rats for over a century, which has had severe impacts on the native species with substantial declines in the numbers of seabird species in particular (see Appendix A). It is foreseen, as demonstrated globally

through other rat eradication projects from oceanic islands that a net positive impact is expected with increases in the number of breeding seabirds, invertebrates, nesting turtles and seedling germination and recruitment. An additional positive impact was the baiting of Iles du Sel and Jacobin with excess baits.

Future impact: Habitat restoration and rat eradication is a long term strategy to ensure the future rehabilitation of the island ecosystem to something akin to the situation prior to human permanent settlement in the archipelago (*circa* 130 years ago). To date, two independently funded post-eradication monitoring trips have occurred (2015, 2016) that have found no sign of rats.

Since the project concluded positive signs have been seen including the nesting of 25 great-crested terns and naturally germinating seeds. It is the intention to conduct full flora and fauna surveys every five years, measured against the pre-eradication baseline in order to assess the future impact.

It is envisaged and hoped that as a minimum, breeding seabird and invertebrate numbers will increase. The negative impact of rats upon the successful hatching of nesting turtles is documented. It is thought, though difficult to prove, that hatching success and hatchling to water survival rates will increase in the future as a result of this eradication project.

6. PROJECT OUTPUTS

Habitat management in preparation of rat eradication:

- Four days of pre-eradication grid system preparation by British Forces personnel (voluntary)

Black rat *Rattus rattus* (invasive alien species) eradicated:

- Report on a visit to Ile Vache Marine and other northern Chagos islands in regard to proposed eradication of black rats completed
- 184 sites baited
- 192 kg of pellet bait hand laid during first baiting
- 150 kg of pellet bait hand laid during follow up baiting 10 days later
- 3 wax-based poison baits laid per bait station
- 84 kg of pellet bait laid on subsequent islands

Habitat management post rat eradication:

- Removal of 100x100m stand of unmanaged coconut plantation
- Revegetation of native seed and seedlings

Post-eradication monitoring and reporting:

- Post-eradication monitoring plan developed
- Two independently funded post-eradication monitoring trips completed 2015, 2016

- "*An initial trial to determine an effective rat bait application rate at Diego Garcia, British Indian Ocean Territory*." report submitted to and published in Chagos News, Dec 2015
- "*The Distribution of Ship Rat Rattus rattus in the Chagos Archipelago*" paper submitted to and published in Chagos News, Dec 2015
- Further academic paper planned to announce Ile Vache Marine as rat free after the two-year wait time
- Participation in Island Invasives Conference, 2017 post the two-year wait time

7. PROJECT EXPENDITURE

Total Project Cost

	2013/14	2014/15	Total	**Actual spend**
Darwin funding				
Other funding				
TOTAL	**£ 30,094**	**£ 208,825**	**£ 238,919**	**£237,821.18**

Allocation of Darwin Funds

	2013/14	2014/15	Total	**Actual**	**Variance**	**Reason for variance**
Staff Costs					-100%	The vegetation management was undertaken by military volunteers rather than paid labourers and paid labourers were no longer required to assist Grant Harper and Peter Carr for the eradication phase (application for approval to amend project or budget submitted April 2014)
Consultancy costs					4%	Reconnaissance trip by the rat eradication expert was required (application for approval to amend project or budget submitted Jan 2014)

Overhead costs	£ 2,026	£ 2,181	£ 4,207	**£4207**	0%	N/a
Travel & Subsistence						A reconnaissance trip by the rat eradication expert was required and was scheduled. This was not in the original application for this project as it was not anticipated (application for approval to amend project or budget submitted Oct 2013)
Operating costs						The cost of the rodenticide was saved because a rat bait company donate the product = £4,270 Y1 (application for approval to amend project or budget submitted April 2014)
Capital Equipment						
Other costs						
End of project audit fee						
TOTAL	**£ 15,531**	**£ 16,725**	**£ 32,256**	**£30,678**	**5%**	

8. PROJECT OPERATION AND PARTNERSHIPS

One of the unquestionable strong points of the project operation were the partnerships associated with it. Essential to the successful construction of the original application was discussion between partners and the heeding of their often expert advice. Essential to the successful execution of the eradication phase was communication between the PI and all the active partners. In particular the following partners made major contributions:

a. Chagos Conservation Trust (CCT): CCT was fundamental to the success of delivering the outputs. This UK NGO was the lead organisation, provided the financial conduit

and administrative house for the handling of the Darwin grant; provided the PI with essential administrative support, particularly in the compilation of half yearly and annual reports and provided expertise on grant application construction.

b. British Indian Ocean Territory Administration (BIOTA): This administration provides the governance of the Territory and was the major stakeholder in the project. Without the gifted in-kind use of the BIOT Patrol Vessel (BPV) to deliver stores and personnel to the target island(s) the operation could not have proceeded. The dialogue in preparation of the application was particularly free-flowing and constructive. The continued dialogue throughout the life of the project was constructive. This was demonstrated ably by the exceedingly fast and positive response to the unplanned request to attempt further eradications, originally planned, of Ile du Sel and Ile Jacobin.

c. Headquarters British Forces BIOT: The staff of HQ BF BIOT, in particular the then British Representative, Cdr. Hardy RN, provided outstanding support to the project, above and beyond what was requested in the original plan. The offer of the use of British Military personnel to undertake the grid cutting required prior to the eradication phase was both magnanimous and a project saver. The constant dialogue between the PI, the British Representative and the Training Sergeant (Royal Marines) who led the grid cutting exercise was a model of how operations can be achieved in BIOT when all parties are communicating and cooperating.

d. Royal Society for the Protection of Birds (RSPB): The RSPB were hugely supportive and influential in the preparation of the application. Expert and experienced advice was given freely in the regular meetings held between the PI and RSPB, the most important in hindsight being their insistence on the hiring of a mammal eradication expert and their nomination of Dr. Grant Harper from Bio-restoration Ltd., New Zealand. This decision was without doubt the most important for the successful delivery of the outputs.

e. Royal Botanic Gardens Kew (RBG Kew): The expertise provided by the RBG Kew in the construction of the grant application and their input to the baseline flora and fauna surveys was invaluable and unique.

9. MONITORING AND EVALUATION, LESSON LEARNING

The monitoring and evaluation requirements factored in to the original plan were modified after the reconnaissance by the eradication expert (see section 3, point 3.1 above). Long term monitoring will commence, if the eradication has been successful, from 2016 onwards. The monitoring will focus upon change over time, especially in breeding seabird and vegetation communities. The monitoring frequency will be at five yearly intervals. The long-term monitoring did not form part of the Darwin Initiative funding and will be funded separately, ideally as part of the Terrestrial Action Plan.

There were three major lessons learnt and a general observation made that will be emphasised in the academic paper and incorporated into all future rat eradication operations in the Chagos. These are:

a. Reconnaissance by eradication expert is essential: As highlighted in section 3 and 8.d., the reconnaissance by the eradication expert was a "game-changer" that fundamentally altered many facets of the original plan for the better. The alterations recommended post reconnaissance simplified and reduced costs of many areas of the operation. It is recommended that on all future eradication operations (both plant and animal) that the technical specialist as a minimum, ideally accompanied by the PI, conduct a full reconnoitre of the target area.

b. Cutting of grid lines needed direct supervision: If conducting a hand broadcast operation and using bait stations, the cutting in of an accurately laid out grid is critical to the success of the operation. This is both a timely, strenuous and, if perfection is desired, a specialist task. The British Forces who cut in the grid for the Vache Marine eradication operation produced an outstanding outcome all things considered. However, at the start of the eradication phase when the grid was meticulously checked for accuracy, there were areas in dense *Scaevola* were the grid had wandered off course. If left uncorrected these would have left gaps in the baiting system where rats could have remained and been unexposed to the poison, potentially rendering the overall operation a failure. These potential gaps were mitigated for by the correcting of grid lines and the cutting in of additional lanes. If time or lack of personnel and equipment had been different, this may not have been possible and this would have jeopardised the success of the deliverables.

   In future operations in the BIOT, any pre-eradication vegetation management should be directly supervised on the ground by an appropriately trained and experienced operator.

c. Baseline surveys essential and should be in original plan: Pre-project baseline surveys of the flora and fauna were not factored in to the original operational plan. This was an oversight and in terms of monitoring the long-term benefits of the eradication (if successful) and fortunately this was recognised prior to the eradication phase occurring. Fortunately the PI had visited the island several times previously and conducted ornithological surveys and, specialists in invertebrates, mammals, reptiles and higher plants had visited Ile Vache Marine previously (from 1996 onwards) and a host of disparate information was available. This is being collated by the PI and incorporated into a terrestrial action plan for all islands of the archipelago.

   The take-away point being it is essential when monitoring change over time following a successful eradication operation to have a baseline of data to reconcile

against. This consideration will be factored into all future eradication operations in the BIOT.

d. Ile Vache Marine was a useful operation to inform any further eradication attempts in the BIOT and in other tropical zones: Whatever the outcome, success or failure, this attempt at eradicating rats from Ile Vache Marine has provided a wealth of knowledge and further experience to both the eradication expert and the PI. It is essential that this experience is shared both throughout the United Kingdom Overseas Territories and to the wider biorestoration community in general. This is planned to occur with the publication of the results after the recommended 24 month hiatus post-eradication.

10. ACTIONS TAKEN IN RESPONSE TO ANNUAL REPORT REVIEWS

There were no actions to be taken in response to annual report reviews.

11. DARWIN IDENTITY

The Chagos Conservation Trust is grateful for the investment by the Darwin Initiative into this important project and have promoted it in the following ways:

Video
Three videos have been published showcasing the project's work.
Ile Vache Marine Bird Habitat Restoration Reconnaissance
Ile Vache Marine Rat Eradication
Bring back the birds

Chagos News No.47
"An initial trial to determine an effective rat bait application rate at Diego Garcia, British Indian Ocean Territory."
"The Distribution of Ship Rat Rattus rattus in the Chagos Archipelago"

AGM
'Bringing back the birds' video was shown at the Chagos Conservation Trust's 2016 AGM

CCT Conference
A presentation at the Chagos Conservation Trust's annual science conference on Friday December 5th 2014 at London Zoo

Social media
Video posted on Facebook (over 7,500 followers)

Website
Blog: An expedition blog
News story: Ile Vache Marine Bird Habitat Restoration Project Reconnaissance

Further promotion

Final report: upload to the Chagos Conservation Trust's website and the Chagos Information Portal

E-news: news article written on announcement of Ile Vache Marine as a rat free island

Website: news article written on announcement of Ile Vache Marine as a rat free island

Media release: written for announcement of Ile Vache Marine as a rat free island

Presentation and paper: Island Eradication Conference, Scotland, July 2017

12. LEVERAGE

The success of this project has highlighted that restoration efforts of terrestrial habitats across the BIOT is possible and can have a significant and positive impact on biodiversity.

Initial findings from this project helped garner agreement from the BIOTA and the Chagos Conservation Trust to develop a subsequent application to the Darwin Initiative for a project aimed at creating a terrestrial action plan for the Chagos Archipelago with emphasis upon invasive species management.

13. SUSTAINABILITY AND LEGACY

If successful, the legacy left behind by this project is an entire island of 12 hectares in the Peros Banhos that is rat-free. This may seem completely trivial but, in the case of the Chagos Marine Reserve it is not. Carr and Harper (2015 - attached) when assessing the impact of rats in the BIOT wrote the following:

"The extent of the landmass under consideration, some 50km^2, means these differences [of land mass rat-free versus rat-infested] in percentages as far as conservation is concerned are near inconsequential. The important figure to consider is the **number** of islands that are rat-free….

The second consideration of importance is the location of rat-infested islands…... rat-infested Iles Manoel and Yeye in north-eastern Peros Banhos lie between a cluster of six IBAs. It also shows that eastern Peros Banhos has Strict Nature Reserve (SNR) status, effectively preventing interference of the islands by anyone other than those permitted by the BIOT authorities to visit. The boundary of the SNR at present runs from the eastern point of Moresby to the western tip of Fouquet. Representations have been made to the BIOT authorities to shift this boundary to the eastern tip of Passe to the eastern tip of Fouquet. If this boundary change were to happen there would be two deep water, wide channels either end of a chain of islands and the discrete packages of rat-infested islands of Passe and Moresby and, Manoel and Yeye – Vache Marine already having had its rats eradicated (awaiting final confirmation). This provides ideal conditions for localised rat eradication programmes….."

Therefore, the legacy is an entire island (potentially) being rat-free that is lying amid a cluster of IUCN classified IBAs, the carrying capacity of which is or has already been reached. In addition, Carr *et al* (2013) have proposed that avian tick infestations render IBAs unsuitable periodically. Therefore, a rat-free island in this area provides additional acreage for breeding seabirds and an alternative breeding site to counter the periodic tick infestations that occur in the BIOT.

Sustainability of the legacy, at least short-term appears secure. Ile Vache Marine lies within the Strict Nature Reserve of the Peros Banhos atoll and is therefore a restricted access area where entry on to the island is only generally only allowed to visiting authorised researchers and the authorities that police the enforcement policies of the Chagos Marine Reserve.

14. POST-PROJECT FOLLOW UP ACTIVITIES

The post-project follow up activities will be entirely dependent upon the success of the eradication or otherwise. If the operation has failed full analysis of the reasons why, if detectable, will be required. If successful, periodic assessments of the change of flora and fauna over time (5-10 years) are required, to be reconciled against the baseline surveys and, against islands that remain rat-infested. These surveys will expose the true consequences of eradication operations on tropical islands and inform both the scientific community and the BIOTA of their inherent value.

15. VALUE FOR MONEY

The eradication operation undertaken on Ile Vache Marine was a little more expensive than usual for a tropical island eradication (on a per hectare basis about GBP2000/ha vs ~GBP1000 for other smallish tropical islands) but this was expected owing to the small size of the island and its remoteness. Any further operations in the BIOT would be cheaper as fixed costs per hectare reduce with as larger and more islands are attempted.

As a proof of concept operation for scaling up to larger islands in the Territory it was value for money. It also demonstrated to the BIOTA that these operations can take place in the Territory with a minimum of assistance and disturbance to tempo of other operations that BF BIOT are involved in.

16. ACKNOWLEDGEMENTS

Most importantly our thanks goes to the Darwin Initiative who generously funded this project. This project would not have been possible without the help and support of:

- ACP (NZ) and Bell Labs (USA) for generously donating the Rodenticide.
- British Indian Ocean Territory Administration
- BIOT Commissioner's Representative
- Base Operating Service Contractor (BOSC) on Diego Garcia
- Royal Botanical Gardens Kew
- Royal Society for the Protection of Birds

Appendix 1: Harper, G. & Slayer, J. 2014. Report on a visit to Ile Vache Marine and other northern Chagos islands in regard to proposed eradication of black rats. Unpublished report to the Chagos Conservation Trust, London, UK.

Report on a visit to Ile Vache Marine and other northern Chagos islands in regard to proposed eradication of black rats

Prepared for the Chagos Conservation Trust, UK.
February 2014
Grant Harper PhD, Biodiversity Restoration Specialists Ltd, NZ
Jon Slayer

Background

Black rats (*Rattus rattus*) have been present in the Chagos archipelago for several centuries and are present on 74% of the 58 islands in the group. They have had severe impacts on the native bird populations, with substantial declines in the numbers and distribution of most of the seabird species in particular (Symens 1999). Elsewhere rats also have impacts on insects, terrestrial crustaceans and native plants and are likely to have affected a similar suite of species on the Chagos islands. An attempt to eradicate rats from the largest of the northern Chagos islands, Eagle Island, was carried out in 2006 using poison bait presented in bait stations, but was unsuccessful. An attempt to eradicate rats on Ile Vache Marine (12ha) in the Peros Banhos atoll is planned and a reconnaissance trip to scope the island for vegetation, location, logistics and planning purposes was carried out in late January 2014 prior to proposed rat eradication in mid-2014.

Itinerary

Jon Slayer (contracted to the Chagos Conservation Trust) and I flew onto Diego Garcia in the late afternoon of 24 January 2014 and immediately boarded the 'Pacific Marlin' for a 6pm departure for the Peros Banhos atoll. We spent three days in the northern Chagos archipelago and returned to Diego Garcia on the morning of 28 January. We departed Diego Garcia on 29 January.

Ile Vache Marine

We landed on Ile Vache marine about 0830 on 25 January. The initial work was to walk the circumference of the island on the beach with a GPS to ascertain the island area for planning and bait ordering. After this we walked several transects across the island to assess the relative amount of the various vegetation types on the island and difficulty of cutting lines for bait spreading. Further time was spent searching for non-target species and for recent signs of rats.

Results

The area of Ile Vache Marine was calculated at 11.94ha using the 'Area calculation' function on a Garmin 62s GPS.

Transects across the island showed that the northern and coastal portions of the island were dominated by coconut palms, with some native hardwoods, and the southern side of the island was largely covered in thick *Scaevola* thickets. The centre of the island was a mix of open lightly grassed areas and *Scaevola*.

Besides hermit crabs, one gecko (mourning gecko(?)) and several Madagascan fodies were seen, along with noddies. Some rat sign was located, although it appeared that rat numbers were not excessively high.

Other islands

Ile Manöel in the Northeast Peros Banhos was visited on the afternoon of 25 January. We also calculated its size by walking around the island with a GPS. Ile Manöel was calculated at 31.5ha. The island apparently has rats and our observations confirmed this.

Two to three hawksbill turtles were seen in the shallows at Ile Manöel.

Ile Yeye was visited on the morning of 26 January. We also measured its size by walking around the island with a GPS and it was calculated at 61.1ha. The island apparently has rats and our observations confirmed this.

Eagle Island was visited on the morning of 27 January. We landed at about 0830 at the northern tip of the island and had seen a rat within 5 minutes, in coconut litter. We walked the exposed east coast to about a third of the way down the island, crossed over the island to the other side and returned to our landing site. Numerous coconut and hermit crabs were noted and several chickens heard.

Sea Cow Island was visited late in the morning of the 27th. The contrast with the rat-infested islands visited previously was evident, as innumerable seabirds were seen wheeling above the island or nesting in trees before we even landed, which hadn't been seen on any of the other islands. On landing we walked across the island to the south coast, noting large numbers of nesting red- footed boobies and noddies in particular, especially in hardwood trees and on *Argusia argenta* bushes. Numerous butterflies were also recorded. One rooster was seen as well. On the southeast coast was a recent wreck of a fibreglass fishing boat of some 20m in length, capsized at the high tide mark. We were later told this wreck was less than month old.

Danger Island was visited on the afternoon of 27 January. We traversed the island and returned along the south coast, again noting the large numbers of nesting red-footed boobies and brown boobies, which appeared to confirm the island's rat-free status. Numerous caterpillars and moths were seen on *Argusia argenta* bushes. Some chickens were seen and one hawksbill turtle was found digging a nest on the west coast during the day.

Discussion

The proposed rat eradication on Ile Vache Marine should be a fairly straightforward operation, although it will be expedited if assistance is provided by personnel from Diego Garcia with cutting lines in the vegetation before the bait spreading is carried out in late July-August (Appendix 1). It is expected the operation will take 1-2 days to spread bait, followed by a two-week break, then a second distribution of bait and the placement and loading of bait stations, taking some three weeks in total.

If any justification for the proposed rat eradication was needed then the subsequent visits to rat-infested and rat-free islands elsewhere in the Chagos group provided the evidence, with a stark difference in numbers of birds in particular. The substantial reduction in available breeding sites within the archipelago due to the presence of rats must be severely reducing population numbers of seabirds and argues for ongoing efforts to rid the islands of rats.

When carrying out eradication operations an accurate measure of island area is essential for planning of required bait quantities, so the discrepancy between the sizes of three islands checked using a GPS and the sizes as listed in Symens (1999) was of some concern. Symens (1999) listed Ile Vache Marine as 8.0ha, where as we measured it at 11.9ha and similarly for Ile Manöel, listed at

50ha, versus a GPS measurement of 31.5ha and Ile Yeye at 58.5ha, which we measured at 61.1ha. If possible, accurate measurements of the island areas should be undertaken where possible, especially if further rat eradications are planned. A shortfall in bait distributed on an island due to inaccurate area measurements could mean the difference between success and failure.

Apparent plans for restoration of islands after rat eradication, by the reduction in cover of coconut palms and planting or encouraging native hardwoods, needs to be planned and budgeted carefully. It appears that native seabirds prefer native hardwoods and shrubs for nesting, but the effort involved will be substantial and should be part of a larger restoration plan for the islands.

The planned eradication on Ile Vache Marine is understood to be part of a larger plan to eradicate rats on most, if not all, of the islands in the northern Chagos, although we understand that some initial thought has also been given to eradication of rats on Diego Garcia itself, which is a substantially more difficult operation. We discussed these plans during our visit and came to the conclusion that an eradication operation of some six weeks using aerial application of rat poison bait to all the 35 rat-infested islands of the Chagos archipelago would probably be cheaper, a more efficient use of resources and more likely to succeed over all the islands in the long run, in contrast to a series of ground-based eradications carried out over a decade or more. In light of these discussions we have drafted a suggested basic plan and indicative budgets for the eradication of rats on all the Chagos islands except Diego Garcia (Appendix 2).

An eradication operation on Ile Vache Marine will provide an example of what can be achieved on other small islands within the Chagos group and should also show that in situations where rats re-invade an island a ground-based eradication operation can remove them. The recent wreck of a fishing boat on Sea Cow Island, a rat-free island, highlights how vulnerable these islands are to re-invasion and it is hoped that no rats were on that boat when it came ashore.

Recommendations

1. Carry out the planned eradication of black rats on Ile Vache Marine in July-August 2014, using a ground-based hand-spread of rat bait with a follow-up of the establishment of bait stations.
2. Approach British Forces Headquarters on Diego Garcia to ask for assistance with cutting tracks within the thick vegetation on Ile Vache Marine before mid-July to expedite the eradication (Appendix 1).
3. Carefully consider the attached plan (Appendix 2) for eradication of rats using aerially-applied rat poison bait on all the Chagos Islands, except Diego Garcia.
4. Endeavour to accurately measure the area of all the islands within the Chagos archipelago to assist with future planning of rat eradication attempts and other management actions.

Acknowledgements

We would especially like to thank the British personnel on BRITOPS and the crew of the BIOT Patrol Boat for the substantial amount of assistance they provided during our stay, which was done cheerfully and enthusiastically, it was great working with them. The crew of the *Pacific Marlin* were at all times helpful and pleasant company which made for a successful trip.

Thanks also to the team at the Chagos Conservation Trust for their assistance with planning and funding for the trip.

References

Symens, P. (1999) Breeding seabirds of the Chagos Archipelago. *In*: Ecology of the Chagos Archipelago, Sheppard C.R.C. & Seaward, M. R. D. (eds) Linnean Society, London.

Appendices

Appendix 1. Plan for preparation of Ile Vache Marine for rat eradication in mid-2014.

Appendix 2. Proposal of the eradication of rats from all islands in the northern Chagos archipelago.

Appendix 1.

Vache Marine Rat eradication preparation

Rationale: preparation for rat eradication beginning in late July 2014.

Timing: Please prepare before mid-July 2014.

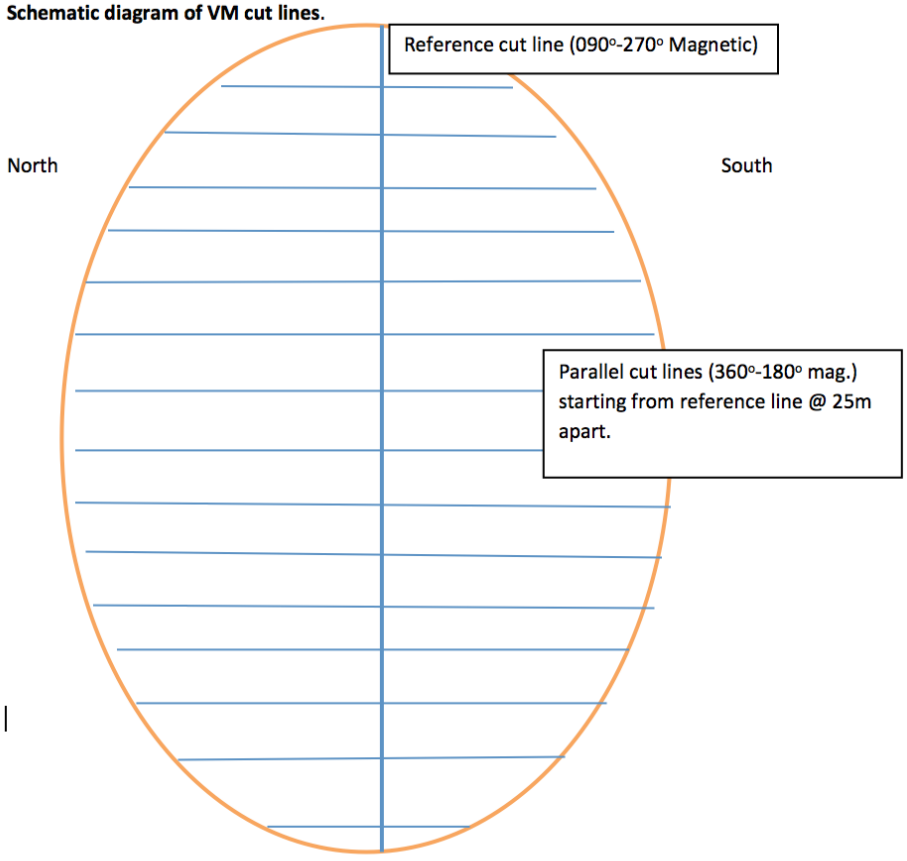
Note: Island is approximately 500m by 300m (12ha) and a mix of coconut grove, *Scaevola* thicket and open ground. Cutting of parallel lines has to be very accurate at 25m apart to allow effective spread of poison rat bait across the entire island without any gaps in bait coverage.

Reference line: The reference cut line is used as a reference for all other cut lines to be cut from. It is the first line to be cut, at 270° or 90° mag. Mark line at 25m intervals. Use a 25m string line to mark points rather than a GPS as GPS can be a little coarse for accurate distance marking.

Cut lines: From the reference line cut lines on bearings of 360° mag and 180° magnetic. The cut lines only need to be wide enough to move through, not 2m wide for example. There is no need to cut through areas of coconut palms, only *Scaevola* thickets and other hardwoods. We will mark all the lines at 25m intervals before we carry out the eradication operation.

For an island this size we expect there will be about 25-30 lines needing to be cut which should take a team of six personnel about 1-2 days to cut (25 lines/6 = 4 lines per person).

Schematic diagram of VM cut lines.



Appendix 2.

Chagos rat eradication proposal

Eradicate rats from all 35 rat-infested islands in the Chagos Archipelago, except Diego Garcia (total area approximately 1400 hectares), by aerially spreading rat poison bait by helicopter flying from helicopter-capable ship.

Background

Black rats (*Rattus rattus*) have been present in the Chagos archipelago for several centuries and are present on 74% of the 58 islands in the group. They have had severe impacts on the native bird populations, with substantial declines in the numbers and distribution of most of the seabird species in particular (Symens 1999). Elsewhere rats also have impacts on insects, terrestrial crustaceans and native plants and are likely to have affected a similar suite of species on the Chagos islands. An attempt to eradicate rats from the largest of the northern Chagos islands, Eagle Island, was carried out in 2006 using poison bait presented in bait stations, but was unsuccessful.

Except Diego Garcia (2700ha), all the islands of the Chagos archipelago are uninhabited, of which some 1400ha in total area have rats present. Worldwide, over 300 islands have had rats successfully removed, with particular success when using aerially spread poison rat bait from helicopter.

Proposal

To operate a civilian helicopter from ship and deposit rat bait aerially onto all rat-infested islands within Peros Banhos group, Saloman group and on Eagle Island. This will entail two bait drops about 3-4 weeks apart and take about one week for each operation including transit time from Diego Garcia.

Several options are presented. These involve varying degrees of support from the US/UK military based at Diego Garcia and therefore have varying levels of funding required.

At present helicopter-capable COMPSRONUS Military Pre-position (COMPSRON) ships are present in the lagoon at Diego Garcia and are required to exit the lagoon every month for 3 days for operational reasons. Options 1 and 2 suggest using these trips twice for about a week each time to assist with a rat eradication attempt using a helicopter operating from a COMPSRON ship. These options would greatly reduce the cost of an eradication operation as ship charter is usually the largest cost component of aerial rat eradication operations on islands.

The advantage of this proposal is that the entire rat eradication operation for the Chagos archipelago (except Diego Garcia) would be completed within six to seven weeks in contrast to likely multiple years for a series of ground-based operations to achieve the same outcome, which is a rat-free archipelago. Aerial operations have a higher success rate than ground-based operations (Russell & Holmes 2013) and problems with rats living in coconut trees is overcome as aerially sown bait is deposited in the tree tops as well as on the ground. There are also associated savings in travel and planning costs as the staff and planning involved is only done once rather than on multiple occasions for a series of ground based operations. In addition, once all the islands are rat-free the chances of re-invasion from neighbouring islands are virtually nil, which is less likely if rats are eradicated from islands piecemeal.

At this stage it is not envisaged that Diego Garcia would be attempted as there are several major hurdles to overcome before that operation can be initiated, including substantially improved biosecurity, shut-down of current rat control operations for several years before an eradication is attempted, closure of the landfill site, education of staff on the island about the reason for the eradication and improved control of rubbish disposal to name a few. In contrast an eradication of rats on the other islands in the Chagos group could be undertaken within 1-2 years of the approvals and funding being obtained.

Options for rat eradication at the Chagos Archipelago

Option 1.

Operate from a COMPSRON (US Military Pre-position) ship. Civilian Helicopter brought in by military C-17. Bait brought in by military C-17. Five civilians required with assistance from personnel on Diego Garcia.

Estimated cost: GBP 400K (GBP 286/hectare)

Advantages:

Helicopter bait-spreading has higher likelihood of success than ground-based eradication operation.
Low cost option with more likely by-in from probably funding bodies.
Short time frame for operation of about 6-8 weeks at Chagos archipelago, in contrast to several years of ground based operations.
Small team required for operation of approximately five persons with support from BIOT.

Disadvantages:

Possibility of support being withdrawn at short notice if US and /or UK military require ship or Diego Garcia for more pressing commitments.
Require permission for use of COMPSRON ship for two one-week periods.
Require permission of use of civilian helicopter to operate from military vessel.
Require permission to store and load rat poison from COMPSRON ship.
Require financial in-kind support from US and/or UK military to bring in helicopter and bait.

Option 2.

Operation from COMPSRON (US Military Pre-position) Ship. Civilian helicopter and bait brought in by MV Mohegan supply vessel. Five civilians required with assistance from BRITOPS staff.

Estimated cost: GBP 600K (GBP 428/ha)

Advantages:

Helicopter bait-spreading has higher likelihood of success than ground-based eradication operation.
Low cost option with more likely by-in from probable funding bodies.
Short time frame for operation of about 6-8 weeks at Chagos archipelago, in contrast to several years of ground based operations.
Small team required for operation of approximately five persons with support from BIOT.

Disadvantages:

Possibility of support being withdrawn at short notice if US and /or UK military require ship or Diego Garcia for more pressing commitments.
Require permission for use of COMPSRON ship for two one-week periods.
Require permission of use of civilian helicopter to operate from military vessel.
Require permission to store and load rat poison from COMPSRON ship.

Option 3.

Operate from civilian helicopter-capable ship. Helicopter and bait brought in by civilian helicopter-capable ship. 12 civilian staff required.

Estimated cost: GBP 1025K

Advantages:

Complete control of the operation, so unlikely to be compromised by requirement for support from military.

Helicopter bait-spreading has higher likelihood of success than ground-based eradication operation.

Short time frame for operation of about 6-8 weeks at Chagos archipelago, in contrast to several years of ground-based operations.

Disadvantages:

Cost is likely to be in the order of GBP 1 million (GBP 733/hectare)

Substantial by-in from several funding sources is required, with associated lag in securing funding and possible withdrawal of funding if project delayed to period outside funding period.

Likely permission required to operate ship/staff from Diego Garcia.

A larger team (~12) may be required if support is not forthcoming from personnel on Diego Garcia.

References

Symens, P. (1999) Breeding seabirds of the Chagos Archipelago. *In*: Ecology of the Chagos Archipelago, Sheppard C.R.C. & Seaward, M. R. D. (eds) Linnean Society, London.

Russell, J., Holmes, N. (2013) Preliminary results from historical rat eradications. Tropical island rat eradication workshop, August 2013. University of Auckland, NZ.

Appendix 2: Carr, P. & Harper, G. 2015. The Distribution of Ship Rat *Rattus rattus* in the Chagos Archipelago. Chagos News 47: 21-32.

The Distribution of Ship Rat *Rattus rattus* in the Chagos Archipelago

PETER CARR* AND GRANT A. HARPER†

*Chagos Conservation Trust, London, UK
†Biodiversity Restoration Specialists, PO Box 58, St. Arnaud, New Zealand

Abstract: The first comprehensive survey for invasive rats in the Chagos Archipelago occurred in 1996 and reported detecting the presence of Ship Rats *Rattus rattus* on 36 of 45 islands surveyed. Incidental observations from a 1975 scientific research expedition increased this figure to 37 of 47. Presently the Chagos Archipelago has 58 named and two unnamed landmasses. These have accreted in to 55 islands, islets and cays (hereafter termed islands). Extensive surveys for invasive mammalian predators post 1996 have revealed that *Rattus rattus* is actually present on 26 islands, absent from at least 20 and their status uncertain on the remaining nine. Six islands reported as rat-infested in 1996 have subsequently been proven to be rat-free and a further three islands have had rat eradication projects' undertaken on them. Due to the miniscule size of the islands involved the total landmass free of rats in the Chagos Archipelago has not increased dramatically though crucially, the number of rat-free islands has. This new information on *Rattus rattus* distribution when combined with the locations of the internationally important breeding seabird colonies strategically informs the future prioritisation of islands for ecological rehabilitation.

INTRODUCTION

The catastrophic impact of introduced invasive species on fragile island ecosystems is now well recognised. One of the most widespread invasive families is Rattus, of which three commensal species have been introduced to over 80% of the world's island groups (Atkinson, 1985), where their serious deleterious effects through predation and competition on tropical islands are well documented (Harper & Bunbury, 2015).

In the tropical Chagos Archipelago, central Indian Ocean, rats were present in numbers enough to ruin crops by 1786 (Wenban-Smith & Carter, in press). They were most likely accidentally introduced during the first attempts at permanent settlement by the French and British in the late 1700s, though Portuguese mariners had been prospecting the area two centuries prior and may have been the perpetrators.

To counter the negative impact of "swarms" of rats on crops and the living quarters, at the height of the plantation era in the early 20th Century, children on the largest island of Diego Garcia were paid three cents per rat corpse collected in an attempt to control numbers (Scott, 1961). In more recent times, a scientific research expedition to the Chagos in 1975 recognised the potential for increasing biodiversity through eradicating rats on the second largest island in the archipelago, Eagle Island (06° 11´ S, 71° 19´ E) (Hirons, Bellamy & Sheppard, 1976; Bellamy,1979). This visionary plan was brought to fruition in 1996 with a dedicated eradication attempt, though unfortunately it was unsuccessful (Daltry, Hillman & Meier, 2007).

At the same time as the failed eradication attempt on Eagle Island, as part of the first scientific research expedition for two decades Barnett & Emms (1998) undertook surveys of various taxon, including mammals and located *Rattus rattus* "on most islands". During the same scientific research expedition Symens undertook the first survey specifically on the distribution of rats, recording *Rattus*

rattus on 36 of the 45 islands of the archipelago surveyed; this research also demonstrated the skewed bias of breeding seabirds towards rat-free islands (Symens, 1999).

Varnham (2006) produced a database of invasive species from across the United Kingdom Overseas Territories (UKOTs) and her Chagos records were based primarily on Symens' 1996 data. Hilton & Cuthbert (2010) assessed the impact of invasive mammalian predators on avian populations throughout the UKOTs. They noted that rats were present on 95.3% of the Chagos landmass, cats were present on 62% and that only 4.7% of the entire Chagos terrestrial space was mammalian predator free. They also calculated that seabird density ≈20x greater on rat-free islands, again based upon Symens' (1999) data.

In 2010 in the Chagos itself a second *Rattus rattus* eradication project was being drawn up. As the success rate of rat eradication operations on tropical islands had to that date been substantially less successful than similar operations on islands with temperate seasonal climates - recently substantiated in print by Russel & Holmes (2015), the second attempt at eradicating rats was deliberately planned to be a much smaller operation than the previous endeavour. This ensured it came with consummately scaled down risks, operational and logistical burdens and costs. Eleven hectare Ile Vache Marine in Peros Banhos (05° 25 S, 71° 49E) was selected as the target island. (Two other tiny islands [>2 ha.], Jacobin and Sel in the Salomon Islands were included in the same project). The eradication phase of this project was executed in August 2014; the success or failure of these operations will not be determined until August 2016.

The latest analysis of the impact of invasive mammals in the UKOTs has been by the RSPB, who prioritised Ile de la Passe in Peros Banhos as the 25th island in the entire UKOTs in need of ecological intervention - in this case rat eradication (RSPB, 2014). At low tide Ile de la Passe has a 5m wide shallow channel between it and rat-infested Moresby Island and therefore would be reinvaded following any eradication operation unless the two islands were cleared of rats concurrently. A Territory-focussed analysis using an expanded RSPB methodology would likely produce a different outcome of which islands are the highest priorities for ecological intervention in the Chagos (RSPB, pers. comm.).

The distribution of *Rattus rattus* in the Chagos was revisited in 2011 as part of a review of the Important Bird Areas of the region (Carr, 2011a) and, two years later as part of a Masters by research project analysing the factors impacting the breeding island selection of Red-footed Booby *Sula sula* throughout the archipelago (Carr, 2013). It became apparent during this research that their distribution was not as published by Symens (1999), which had been widely accepted and used for analysis.

Knowledge of the distribution of invasive mammalian predators is critical to any biological management plan and this is especially so on oceanic islands where their impact, particularly on breeding seabirds, is amplified. To better inform future terrestrial environmental management plans, especially if they propose ecological intervention and island environmental rehabilitation, this paper reviews and updates the distribution of *Rattus rattus* in the Chagos Archipelago.

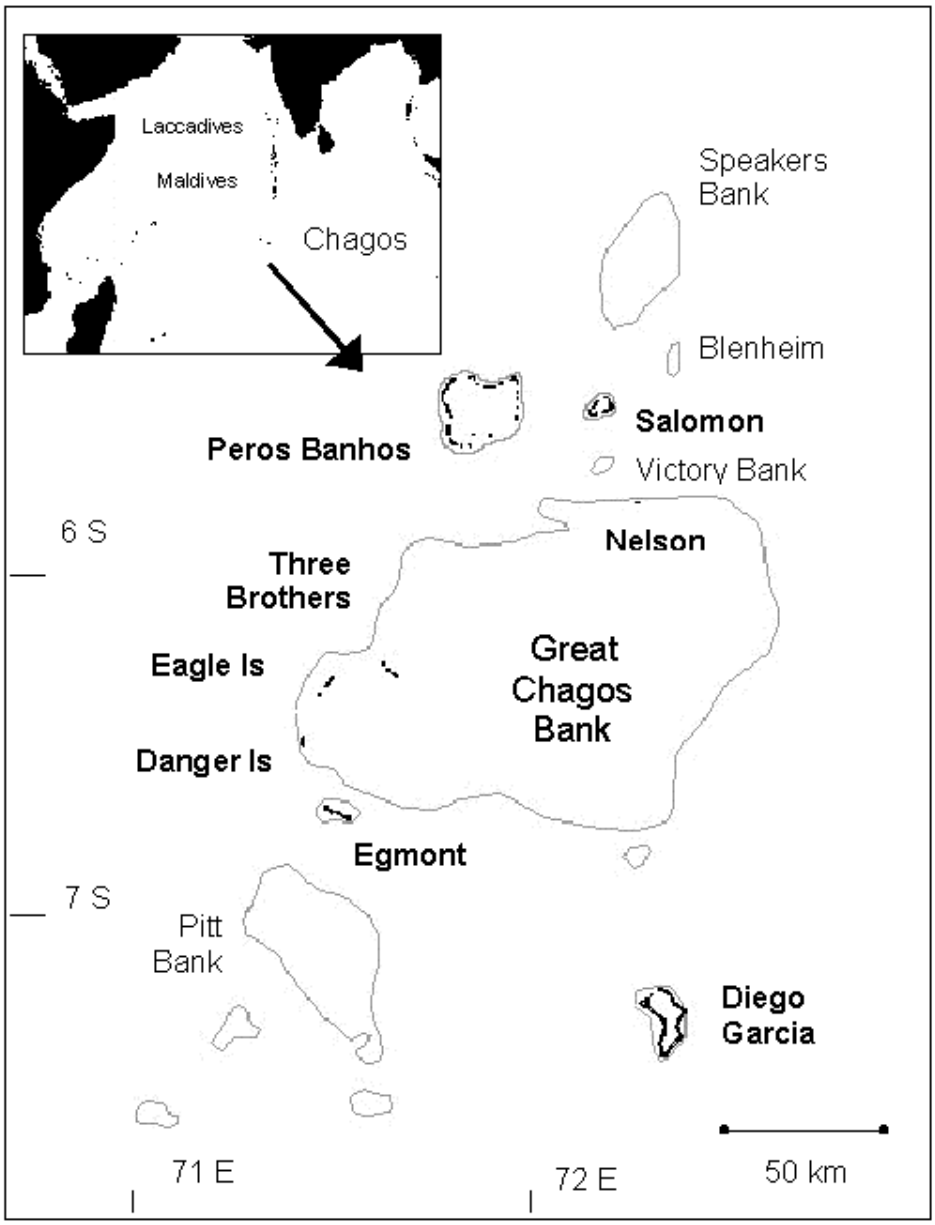
STUDY AREA

The Chagos Archipelago (or British Indian Ocean Territory) is positioned in the central Indian Ocean at the southern end of the Laccadive-Chagos ridge. Its Exclusive Economic Zone (EEZ) lays within 04°-08°S and 70°-74°E and covers an area of approximately 640,000km^2. Of this about 50km^2 (≈0.008%) is *terra firma*. Some 29km^2 (≈58%) of this land is the single inhabited, rat-infested island of Diego Garcia. The remainder of the archipelago holds four further islanded atolls and several other atolls

and banks which are awash or completely submerged. (Sheppard *et al*, 2013). In total there are thought to be 55 land masses in the archipelago capable of supporting breeding seabirds.

There are presently three categories of sites of global importance in the Chagos Archipelago: a single IUCN Category 1 No-Take Marine Protected Area that encompasses all of the EEZ; a Ramsar site based upon the eastern arm of Diego Garcia and seas out to three miles (from Carr *et al*, 2013) and ten IUCN Important Bird Areas (IBAs) (Carr, 2006) and two proposed IBAs (McGowan, Broderick & Godley, 2008). All of the IBAs are categorised as Strict Nature Reserves with the exception of the site on Diego Garcia, which is a Conservation (Restricted) Area. This affords them a degree of protection, both through BIOT Law and effective enforcement of the Law (Carr *et al*, 2013)

Map One. The Chagos Archipelago (from Sheppard *et al*, 1999).



METHODS

Through October 2008 to October 2010 one author (PC) visited every island in the Chagos Archipelago. During this period a concerted effort was made to review the distribution of invasive mammalian predators throughout the archipelago. This resulted in several islands being repeatedly visited and many camped on overnight. In addition, through 2010 to 2015, PC as a participant on seven scientific research expeditions further investigated invasive mammalian predators. Some of this data was used in a review of the Important Bird Areas of the Territory and also for a Masters by research. In 2014 GH visited the Chagos Archipelago twice, the second visit in August with PC. These trips were specifically focussed upon *Rattus rattus* research and eradication.

Table 1. Criteria used for presence of rats.

CRITERIA	PRESENT
Rats trapped	✓
Rats sighted	✓
Rats detected by but not limited to:	
Obvious rat trails (see Plate 1)	✓
Rat chew marks on fallen fruits and nuts (see Plate 2)	✓
Evidence of predation on nesting birds especially terrestrial nesting terns	✓
Rat droppings	✓

b

Plate 1. Rat trail with path highlighted.

Plate 2. Rat gnawed coconut *Cocus nucifera*

RESULTS

Table 2. Distribution of *Rattus rattus* in the Chagos Archipelago.

Legend. P = Rats present. A = Rats absent. U = Status uncertain. E = rats eradication has taken place, awaiting outcome of the operation. Comments in **bold** are for where there are differences from the results of Symens (1999) and references therein, i.e. rats are not present, or is new data.

No.	ATOLL	ISLAND	SIZE km^2	STATUS	COMMENT
1	DIEGO GARCIA	DIEGO GARCIA	29.98	P	Harper & Carr. 2014. Possibly the greatest density of rats on any island in the world.
2		WEST ISLAND	0.02	A	Symens, 1999. Post 1996 there have been a minimum of 15 visual inspections conducted between 2008 and 2015 and this island remains rat-free (Carr, unpubl.).
3		MIDDLE ISLAND	0.04	A	Symens, 1999. Post 1996 there have been a minimum of ten visual inspections conducted between 2008 and 2015 and this island remains rat-free (Carr, unpubl.).
4		EAST ISLAND	0.14	A	Symens, 1999. . Post 1996 there have been a minimum of ten visual inspections conducted between 2008 and 2015 and this island remains rat-free (Carr, unpubl.).
5	**EGMONT ISLANDS**	**ILE SUDEST**	**1.95**	**P**	**These islands have not previously been surveyed for invasive mammalian predators. They have merged and are now a single entity. Seven rats trapped in ten snap traps overnight on 19 February 2009 (Carr, unpubl.).**
6		**ILE TATTAMUCCA**	**0.01**	**P**	
7		**ILE CARRE PATE**	**0.06**	**P**	
8		**ILE LUBINE**	**1.2**	**P**	**These islands have not previously been surveyed for invasive mammalian predators. They have merged and are now a single entity. Two rats trapped in ten snap traps overnight on 19 February 2009 (Carr, unpubl.).**
9		**ILE SIPAILLE**	**0.58**	**P**	
10		**ILE DES RATS**	**0.01**	**P**	
11	GREAT CHAGOS BANK	DANGER ISLAND	0.66	A	Symens, 1999. Post 1996 these have been a minimum of fifteen visual inspections conducted between 2009 and 2015 and this island remains rat-free (Carr, unpubl.).
12		SEA COW	0.2	A	Baldwin, 1975. Post 1975 there have been a minimum of twenty visual inspections conducted between 2009 and 2015, including three overnight inspections and this island remains rat-free (Carr, unpubl.).
13		EAGLE ISLAND	2.52	P	Daltry, Hillman & Meier, 2007. Post the 2006 failed rat eradication attempt there have been a minimum of 10 further visual inspections and this island remains rat-infested (Carr, unpubl.).
14		SOUTH BROTHER	0.23	A	Symens, 1999. Post 1996 these have been a minimum of fifteen visual inspections conducted between 2009 and 2015 including one overnight inspection and this island remains rat-free (Carr, unpubl.).
15		RESURGENT	0.007	A	Symens, 1999. Post 1996 these have been a minimum of five visual inspections conducted

					between 2009 and 2015 and this rocky outcrop remains rat-free (Carr, unpubl.).
16		MIDDLE BROTHER	0.07	A	Symens, 1999. Post 1996 these have been a minimum of fifteen visual inspections conducted between 2009 and 2015 including one overnight inspection and this island remains rat-free (Carr, unpubl.).
17		NORTH BROTHER	0.08	A	Symens, 1999. Post 1996 these have been a minimum of ten visual inspections conducted between 2009 and 2015 and this raised limestone island remains rat-free (Carr, unpubl.).
18		NELSON'S ISLAND	0.81	A	Symens, 1999. Post 1996 these have been a minimum of fifteen visual inspections conducted between 2008 and 2015 and this island remains rat-free (Carr, unpubl.).
19	PEROS BANHOS	ILE DE COIN	1.26	P	Symens, 1999. Visual confirmation of rat presence on 23 February 2010 when two rats were sighted (Carr, unpubl.).
20		ILE ANGLAIS	0.13	P	Symens, 1999. Signs of rat presence detected on 23 February 2010 (Carr, unpubl.).
21		ILE MONTPATRE	0.008	P	Symens, 1999. These two islands have now merged and are a single entity. They have been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
22		ILE GABRIELLE	0.02	P	
23		ILE POULE	0.92	P	Symens, 1999. This island has been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
24		ILE PETIT SOEUR	0.47	P	Symens, 1999. This island has been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
25		ILE GRAND SOEUR	0.54	P	Symens, 1999. This island has been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
26		**ILE FINON**	**0.01**	**U**	**This island has not previously been surveyed for invasive mammalian predators. Visually checked 27 March 2015, no obvious signs of rat presence (Carr, unpubl.).**
27		**ILE VERTE**	**0.03**	**U**	**This island has not previously been surveyed for invasive mammalian predators. Visually checked 27 March 2015, no obvious signs of rat presence (Carr, unpubl.).**
28		**UNNAMED ISLAND**	**0.02**	**U**	**This island has not previously been surveyed for invasive mammalian predators. Visually checked 27 March 2015, no obvious signs of rat presence (Carr, unpubl.).**
29		**ILE MANON**	**0.02**	**U**	**This island has not previously been surveyed for invasive mammalian predators. Visually checked 27 March 2015, no obvious signs of rat presence (Carr, unpubl.).**
30		ILE PIERRE	1.23	P	Symens, 1999. Visual confirmation of rat presence on 25 January 2009 when two rats were sighted. Eight-eight snap-traps deployed on 13 July 2009 with zero rats trapped (Carr, unpubl.).
31		PETITE ILE MAPOU	0.01	P	Symens, 1999. This island has been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).

32		GRANDE ILE MAPOU	0.2	P	Symens, 1999. This island has been visually inspected at least seven times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
33		ILE DIAMANT	0.9	P	Symens, 1999. Visual confirmation of rat presence with sightings of singletons on 14 July 2009 and 23 January 2010 (Carr, unpubl.).
34		ILE DE LA PASSE	0.2	P	Symens, 1999. Visual confirmation of rat presence with two rats sighted on 21 February 2010 (Carr, unpubl.).
35		ILE MORESBY	0.31	P	Symens, 1999. Visual confirmation of rat presence with three rats sighted on 21 February 2010 (Carr, unpubl.).
36		**ILE SAINT BRANDON**	**0.002**	**A**	**This emerging cay has not previously been surveyed for invasive mammalian predators. Visually checked 28 March 2015, no rats present (Carr, unpubl.).**
37		**ILE PARASOL**	**0.08**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including deploying 50 snap-traps overnight on 30 May 2009 and 22 January 2010. Rats are not present (Carr, unpubl.).**
38		**ILE LONGUE**	**0.22**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including deploying 50 snap-traps overnight on 22 February 2009, 16 July 2009 and 22 January 2010. Rats are not present (Carr, unpubl.).**
39		**PETITE ILE BOIS MANGUE**	**0.09**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including deploying 100 snap-traps overnight on 06 October 2009 and 23 January 2010. Dr. Grant Harper confirmed island as rat-free on 07 August 2014 (Carr & Harper, unpubl.).**
40		**GRAND ILE BOIS MANGUE**	**0.13**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including one overnight inspection and deploying 50 snap-traps overnight on 23 May 2009 and 23 January 2010. Rats are not present (Carr, unpubl.).**
41		ILE MANOEL	0.3	P	Symens, 1999. Signs of rat presence detected 23 February 2009, 23 January 2010 (overnight inspection) and 21 February 2010. Twenty snap-traps were deployed overnight on 23 January 2010 with zero rats captured (Carr, unpubl.).
42		**UNNAMED ISLAND (MARLIN'S ISLAND)**	**0.001**	**A**	**This miniscule emerging cay has not previously been surveyed for invasive mammalian predators. Visually checked 29 March 2015, no rats present (Carr, unpubl.).**
43		ILE YEYE	0.61	P	Symens, 1999. Visual confirmation of rat presence with four rats sighted on 23 February 2009 (Carr, un
44		**ILE PETITE COQUILLAGE**	**0.19**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including two overnight inspections and deploying 100 snap-traps overnight on 05 October 2009 and 20 February2010. No rats are present (Carr, unpubl.).**

45		**ILE GRAND COQUILLAGE**	**0.21**	**A**	**Symens, 1999. This island has been visually inspected a minimum of twenty times between 2009 and 2015 including one overnight inspection and deploying 100 snap-traps overnight on 22 February 2009 and 20 February 2010. No rats are present (Carr, unpubl.).**
46		COIN DE MIRE	0.01	A	Symens, 1999. This rocky outcrop has been visually inspected at least five times between 2009 and 2015 and remains rat-free (Carr, unpubl.).
47		**ILE VACHE MARINE**	**0.11**	**E**	**Symens, 1999. This island had a rat eradication operation undertaken on it in August 2014. No rats were detected throughout a two day inspection 25/26 March 2015. The island is to be inspected again in August 2016 when the outcome of the operation can be claimed.**
48		ILE FOUQUET	0.02	P	Symens, 1999. This island has been visually inspected at least five times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
49		MAPOU DE L'ILE DU COIN	0.07	P	Symens, 1999. This island has been visually inspected at least five times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
50	SALAMON ISLANDS	ILE BODDAM	1.12	P	Symens, 1999. This island has been visually inspected at least twenty times between 2008 and 2015 and remains rat-infested (Carr, unpubl.).
51		**ILE DIABLE**	**0.002**	**U**	**Symens, 1999. This tiny islet laying some 100m of rat-infested Boddam should by rights have rats too. Five inspections between 2009 and 2015 failed to reveal any sign of their presence. This could be due to the very strong tidal currents that flow past the island four times a day.**
52		ILE ANGLAISE	0.73	P	Symens, 1999. This island has been visually inspected at least ten times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
53		**ILE DE LA PASSE**	**0.29**	**U**	**Symens, 1999. This island has been repeatedly surveyed for rats between 2008 and 2015. This includes one overnight inspection and deployment of fifty snap-traps overnight on 15 July and 04 October 2009 and 17 February 2010. No signs of chewing have ever been witnessed on fallen fruit. Against this case for a rat-free declaration is that this island is in a small, generally rat-infested atoll and this island holds obvious signs of previous inhabitation, even if it was purely temporary. It should have rats (Carr, unpubl.).**
54		**ILE MAPOU**	**0.04**	**A**	**Symens, 1999. The island that has the most rat inspections of all in the Chagos Archipelago. In addition to over fifteen daytime inspections there have been two overnight inspections and deployment of up to 50 snap-traps overnight on seven occasions. No rats have ever been detected. Rat-free status was confirmed by Dr. Grant Harper in August 2014.**
55		ILE TAKAMAKA	0.49	P	Symens, 1999. This island has been visually inspected at least ten times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
56		ILE FOUQUET	0.45	P	Symens, 1999. This island has been visually inspected at least ten times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).

57		ILE SEPULTURE	0.02	P	Symens, 1999. This islet has been visually inspected at least five times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).
58		**ILE JACOBIN**	**0.02**	**E**	**Symens, 1999. This islet had a rat eradication operation undertaken on it in August 2014. The island is to be inspected again in August 2016 when the outcome of the operation can be claimed.**
59		**ILE DU SEL**	**0.02**	**E**	**Symens, 1999. This islet had a rat eradication operation undertaken on it in August 2014. The island is to be inspected again in August 2016 when the outcome of the operation can be claimed.**
60		ILE POULE	0.002	P	Symens, 1999. This islet has been visually inspected at least five times between 2009 and 2015 and remains rat-infested (Carr, unpubl.).

Map 2. Rat distribution in the Chagos Archipelago in 2016.

See attached.

All 55 islands of the Chagos Archipelago were inspected for invasive mammalian predators between October 2008 and April 2015 (see Tables 1 & 2). Non-native, invasive *Rattus rattus* remains the only rodent detected in the archipelago. Taking in to consideration the conjoining of islands, rats are now confirmed as present on 26 islands, absent on 20, eradicated awaiting confirmation of the outcome on three and of uncertain status on six. Seven additional islands have been surveyed since the first comprehensive survey in 1996 (Symens, 1999). Six islands assessed as holding rats in 1996 have subsequently proven to be rat-free.

In terms of the 50.07km^2 of landmass available for breeding seabirds, there are rats present (P) on 46.23km^2 (92.33%); absent (A) from 3.32km^2 (6.6%); eradicated awaiting final confirmation of results (E) from 0.15km^2 (0.3%) and islands of uncertain rat status (U) on 0.37km^2.(0.7%). If the rats absent, awaiting confirmation of eradication operations and uncertain status landmasses are combined the figure for potential rat-free land is 3.75km^2 or 7.5% of the total landmass. If the area of the inhabited anomaly of the island of Diego Garcia is removed the figure for P drops to 16.34km^2 and the remainder percentages are amended to A = 20.3%, E = 0.9% and U = 2.26% (total of 23.5% of landmass).

In terms of the numbers of islands available for breeding seabirds, 47.3% are rat-infested, 36.4% are rat-free, rising to a total of 52.7% if the U and E categories prove to be rat-free.

DISCUSSION

From a global and historic perspective, the Chagos Archipelago is not the worst impacted area by invasive mammalian predators. Unlike for example Hawaii or New Zealand, there have been no known extinctions of irreplaceable endemics. The Chagos Archipelago does not have any terrestrial endemic mammals, birds, reptiles or amphibians and has to date on land only recorded one endemic species and two endemic subspecies of Lepidoptera (Carr *et al*, 2013).

Of non-native, invasive mammals, it holds three, *Rattus rattus* and Feral Cats *Felis catus* that impact throughout and donkeys. Donkeys *Equus asinus* are found on Diego Garcia and one beast is present on Ile de Coin, Peros Banhos (Carr, 2011b). The population on Diego Garcia appears to be stable at *c.* 40-60 beasts (Vogt, 2015) and are not deemed to impact breeding seabirds (Carr, unpubl.). This population is negatively impacting the island's vegetation especially in areas that reforestation is being attempted (Carr, 2011c; Vogt, 2015).

The distribution of *Felis catus* is debatable. There is a tiny population of >30 adults still present on Diego Garcia despite attempts to eradicate them over the past two decades (Vogt, Guzman & Necessario, 2014). Throughout the remainder of the archipelago, Barnett & Emms (1998) recorded *Felis catus* on the former largest settlements on the atolls of Peros Banhos (Ile de Coin) and the Salomon Islands (Ile Boddam). These findings are perfectly logical in that when these atolls had the human populations removed in the early 1970s (Edis, 2004), there would have been cats on them and there is every likelihood they would have been left on the islands at resettlement. In the same vein, *Felis catus* should be present on Eagle Island and Ile Sudest in the Egmont Islands. However,

despite intense eradication activities on Eagle Island in 2006, no other invasive mammals were recorded except rats (Daltry, Hillman & Meier, 2006). Similarly, despite repeated surveys of all four of the former plantation headquarters in the northern atolls, Ile de Coin, Peros Banhos; Ile Boddam, Salomons; Ile Sudest, Egmonts and Eagle Island (Carr, unpubl.), and literally hundreds of incidental visits to Ile de Coin and Ile Boddam by British Forces personnel and visiting yachts, there has never been a single further report of *Felis catus* from any of these islands.

Hilton & Cuthbert (2010) assessed *Rattus rattus* to be present on 95.3% and *Felis catus* on 62%. The rat figures are based upon Symens (1999) surveys in 1996, who assessed 45 islands for birds and mammals in under 42 days. The revised figures are 92.33% and 73.7% respectively using data from Barnett & Emms (1998) and assumptions of *Felis catus* presence on all of the islands that held substantial human populations. The extent of the landmass under consideration, some 50km^2, means these differences in percentages as far as conservation is concerned are near inconsequential. The important figure to consider is the **number** of islands that are rat-free. Symens (1999) recorded 36 islands of 47 as being rat-infested. The revised figure is 26 islands out of 55, with 20 islands being definitely rat-free. This figure could increase by nine following further surveys of islands of uncertain status post-eradication efforts or lack of visits to confirm status to date.

The second consideration of importance is the location of rat-infested islands. Map 2 shows rat-infested Eagle Island, the second largest landmass in the Territory, as being nestled on the western rim of the Great Chagos Bank in the vicinity of five rat-free IBAs. The ecological significance of this was first noted by the visionary Hirons, Bellamy and Sheppard (1976) in 1975. Map 2 further shows rat-infested Iles Manoel and Yeye in north-eastern Peros Banhos as laying between a cluster of six IBAs. It also shows that eastern Peros Banhos has Strict Nature Reserve (SNR) status, effectively preventing interference of the islands by anyone other than those permitted by the BIOT authorities to visit. The boundary of the SNR at present runs from the eastern point of Moresby to the western tip of Fouquet. Representations have been made to the BIOT authorities to shift this boundary to the eastern tip of Passe to the eastern tip of Fouquet. If this boundary change were to happen there would be two deep water, wide channels either end of a chain of islands and the discreet packages of rat-infested islands of Passe and Moresby and, Manoel and Yeye – Vache Marine already having had its' rats eradicated (awaiting final confirmation). This provides ideal conditions for localised rat eradication programmes. Without helicopter support Manoel and Yeye would likely be undertaken as individual operations. *Contra* to the recommendation in RSPB (2014) who state Passe in Peros Banhos as the highest priority for ecological intervention in the Territory, any eradication operation on Passe would have to be undertaken at the same time as neighbouring Moresby due to their being a very narrow channel separating them that is easily fordable by rats.

It has been recommended by Harper (2014) that the Chagos Archipelago offers the opportunity to have its' rats eradicated in a single, all-encompassing ship and helicopter operation. If attempted this would be a ground-breaking endeavour in tropical island eradication operations and a leading-light for others to follow. Technically this goal is achievable. If the political will or financial backing is lacking then the island-by-island approach can be continued. This update on rat distribution throughout the archipelago must be used to inform the prioritisation of which islands are to receive ecological intervention in the form of rat eradications.

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REFERENCES

Atkinson, I.A.E. 1985. The spread of commensal species of Rattus to oceanic islands and their effects on island avifauna. In; Moor, P.J. (Ed.). 1985. Conservation of Island Birds. ICBP Technical Publication 3, Cambridge, UK.

Barnett, L.K. & Emms, C. 1998. An annotated checklist of the Chagos Archipelago terrestrial fauna (omitting birds) recorded during the 1996 'Friends of Chagos' expedition. Phelsuma 6: 41-52.

Bellamy, D. 1979. Half of Paradise. Cassel, London.

Carr, P. 2006. British Indian Ocean Territory. In: Sanders S.M (Ed). Important Bird Areas in the United Kingdom Overseas Territories. Sandy, UK, RSPB.

Carr, P. 2011a. Important Bird Areas. The British Indian Ocean Territory. British Birds 104: 642-659.

Carr, P. 2011b. A guide to the birds of the British Indian Ocean Territory. Pisces Publications for the RSPB, Sandy, UK.

Carr, P. 2011c. Barton Point native hardwood restoration project – 2011 up date. Chagos News 38. The periodical newsletter of the Chagos Conservation Trust and Chagos Conservation Trust USA.

Carr, P. 2013. Factors influencing breeding island selection of Red-footed Booby *Sula sula* (Linn. 1766) in the Chagos Archipelago, central Indian Ocean, and the implications for future island management plans. A thesis submitted to the University of Warwick in fulfilment of the requirements for the degree of Masters of Science by research.

Carr, P., Hillman, J.C., Seaward, M.R.D., Vogt, S. & Sheppard, C.R.C. 2013. Coral Islands of the British Indian Ocean Territory (the Chagos Archipelago). In: Sheppard, C.R.C (Ed.). Coral Reefs of the United Kingdom Overseas Territories. Coral Reefs of the World 4, DOI 10.1007/978-94-007-5965-7_17. ©Springer Science+Business Media Dorcrecht.

Daltry, J., Hillman, J.C. & Meier, G. 2007. Chagos Ecological Restoration Project: Follow-up visit to Eagle Island, March 2007. Unpublished report to BIOT Administration, London: Flora & Fauna International.

Edis, R. 2004. Peak of Limuria. Revised, updated and published by the Chagos Conservation Trust, London.

Harper, G.A. & Schlayer, J. 2014. Report on a visit to Ile Vache Marine and other northern Chagos islands in regard to proposed eradication of black rats. Unpublished report to the Chagos Conservation Trust, London, UK.

Harper, G.A. & Carr, P. 2014. An initial trial to determine an effective rat bait application rate at Diego Garcia, British Indian Ocean Territory. Unpublished report to Environmental Department of Public Works Department of NAVFACFE Diego Garcia.

Harper, G.A. & Bunbury, N. 2015. Invasive rats on tropical islands: Their population biology and impacts on native species. Global Ecology and Conservation 3: 607-627.

Hilton, G.M. & Cuthbert, R.J. 2010. The catastrophic impact of introduced mammalian predators on birds of the United Kingdom Overseas Territories: a review and synthesis. Ibis 152: 443-458.

Hirons, M., Bellamy, D.J. & Sheppard, C.R.C. 1976. Birds on the Chagos Bank. Nature 260: 387.

McGowan, A., Broderick, A.C. & Godley, B.J. 2008. Seabird populations of the Chagos Archipelago: an evaluation of Important Bird Area sites. Oryx 42(3): 424-429.

RSPB. 2014. Eradication of invasive alien vertebrates in the UK Overseas Territories. A prioritised framework for island restoration to enable the UK Overseas Territories' Biodiversity Strategy. A report to the RSPB, sandy, UK.

Russel, J.C. & Holmes, N.D. 2015. Tropical island conservation: rat eradication for species recovery. Biological Conservation 185: 1-7.

Scott, R. 1961. The lesser dependencies of Mauritius. Oxford University Press, New York & Toronto.

Sheppard, C.R.C., Seaward, M.R.D., Klaus, R. & Topp, J.M.W. 1999. The Chagos Archipelago: an introduction. In: Sheppard, C.R.C. & Seaward, M.R.D (Eds.). 1999. Ecology of the Chagos Archipelago. Linneaen Society Occasional Publications 2.

Sheppard, C.R.C. & 19 others. 2013. British Indian Ocean Territory (the Chagos Archipelago): Setting, Connections and the Marine Protected Area. In: Sheppard, C.R.C (Ed.). Coral Reefs of the United Kingdom Overseas Territories. Coral Reefs of the World 4, DOI 10.1007/978-94-007-5965-7_17. ©Springer Science+Business Media Dorcrecht.

Symens, P. 1999. Breeding seabirds of the Chagos Archipelago. In: Sheppard, C.R.C. & Seaward, M.R.D (Eds.). 1999. Ecology of the Chagos Archipelago. Linneaen Society Occasional Publications 2.

Varnham, K. 2006. Non-native species in the UK Overseas Territories: a review. JNCC Report no. 372.

Vogt, S. 2015. Feral donkeys on Diego Garcia. Appendix G1 to Diego Garcia Integrated Natural Resources Management Plan. PWD NAVFACFE, Diego Garcia.

Vogt, S. Guzman, N. & Neccesario, E. 2014. Feral cat control on Diego Garcia: current population estimate, evaluation and recommendations. Appendix J1 to Diego Garcia Integrated Natural Resources Management Plan. PWD NAVFACFE, Diego Garcia.

Wenban-Smith, N. & Carter, M. In press. Chagos: A history; exploration, exploitation, expulsion. Chagos Conservation Trust, London.