MALDEN ISLAND, KIRIBATI – FEASIBILITY OF CAT ERADICATION FOR THE RECOVERY OF SEABIRDS

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Frontispiece - Grey backed Terns at a colony in *Sesuvium* and *Portulaca* near the main Malden lagoon.

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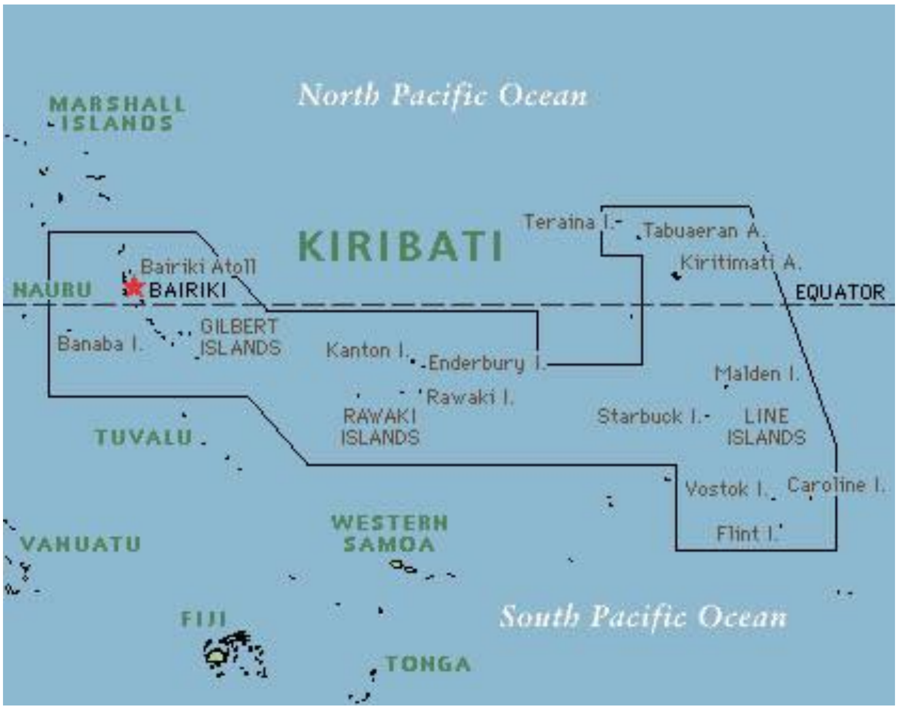
EXECUTIVE SUMMARY

This study describes the biodiversity values of Malden Island, Kiribati, and assesses the potential benefits, feasibility and costs of removing key invasive species. Malden is relatively pest-free, but two significant invasive species are present - feral house cats and house mice. We believe that the most cost-effective and beneficial conservation action in the short term for Kiribati is to undertake a cat eradication programme. This would take pressure off nearly all of the 11 species of seabirds which currently breed at Malden, and allow for the natural and/or enhanced recovery of a further 5-6 species, including the Phoenix Petrel (EN). This petrel and other sensitive species occur as foraging species in the seas around Malden and occasionally visit the island, where they are currently susceptible to cat predation. By removing the cats, this population "sink" effect on a number of species could be almost completely removed and the island would ultimately provide a secure breeding site for 15+ seabird species. Malden's remote location and difficult landing conditions are natural defence barriers against potential invasive species incursions, but there will still need to be strengthened procedures put in place by Kiribati and visiting parties to prevent the invasion of invasive rodents, ants and other invasive species.

In the longer term, if funding permits, Kiribati could consider removing mice from the island. Our recommendation is to defer mouse eradication for the foreseeable future, and concentrate in the short term on the potentially far greater conservation gains possible through eradication of cats alone. The preferred approach for cat eradication is by spotlighting and shooting, supplemented with trapping and potentially dogging, but methods will have some necessary constraints due to environmental conditions and non-target species considerations. There will also be considerable logistics required to get people and equipment on-site to this remote uninhabited island, almost certainly through international borders.



Map of Kiribati showing location of Malden Island within Line Is

ACRONYMS AND KEY DEFINITIONS

Biodiversity	The diversity of plants and animals of a site, e.g. Malden
EN and VU	Endangered and Vulnerable threat rankings of IUCN
ENSO	El Nino Southern Oscillations, fluctuating weather patterns that bring warmer waters during El Nino events to the eastern Pacific including Malden and cooler waters during La Nina
IAS/Invasive	Invasive alien species – introduced animal or plant species that become damaging to biota
Incursion	First detection of invasive species on an island
GPS	Global Positioning System
Guano	Bird excrement that has accumulated on islands like Malden over thousands of years and which has been exploited by humans for agricultural fertiliser
Monitoring	Ongoing structured surveys of indigenous biota, c.f. surveillance for IAS – see below
Pelagic	Oceanic, in this case referring to seabirds that feed on the ocean's surface often far from land
PII	Pacific Invasives Initiative, based at the University of Auckland, NZ
PIPA	Phoenix Islands Protected Area of Kiribati, a World Heritage Site
Procellarids	Tube-nosed seabirds, in this case petrels, shearwaters and storm-petrels
Pulli	Chicks that are older than downy chicks and acquiring flight feathers, but not yet flying
SPC	Secretariat for the Pacific Community based at Suva, Fiji
SPREP	Secretariat for the Pacific Regional Environment Programme based in Samoa
Surveillance	Ongoing structured searches for invasive species on an island, vessel, etc.
YCA	The yellow crazy ant (*Anoplolepis gracilipes*), an invasive species

Fig 1.2 – Map of Malden showing location of key features and habitat zones

1.0 INTRODUCTION

Malden Island (3850 ha) is a remote, uninhabited atoll located at 4^{o} S latitude and about 700 km SE of Kiritimati (Christmas Island) in the Line Islands of Kiribati. It is seldom visited by humans today, but has experienced a long history of Polynesian and British occupation, the latter including a sustained period of settlement during guano extraction in c.1870-1930, followed by military occupation during nuclear testing of 1957-62. These British periods of occupation saw significant habitat destruction in the form of guano excavations and infrastructure works (including a perimeter railw-ay line) and other constructions. These activities, along with the introduction of several animals, including feral pigs, goats, feral house cats and house mice, contributed to a decimation of the flora and fauna of Malden over the one hundred year period. Although only cats and mice persist today, the previous legacy has resulted in tree-land and shrub-land now being severely depleted.

This study was undertaken with the Government of Kiribati to examine the biodiversity benefits, feasibility and costs of removing key predators from Malden Island. If Malden could be made predator-free it could potentially provide an important seabird island and back-up to Kiritimati (Christmas Island) which is the global stronghold for Phoenix petrels (*Pterodroma alba*) and White-throated storm-petrels (*Nesofregetta fuliginosa*), and supports other important seabird and landbird populations. Malden could also provide a strategic link between Kiritimati in the north and the growing network of restored islands in the South Pacific including Phoenix Islands (GOK 2015), Suwarrow (Cook Islands) (Evans and Cranwell 2011) and several islands in the Tuamotu (SOP Manu 2015).

We undertook surveys of vegetation, birds and invasive species on Malden Island during 13-17 September 2015. We also surveyed pelagic birds en route to and from Malden to gauge the use of local feeding areas by key seabird species.

2.0 GENERAL DESCRIPTION OF MALDEN

2.1 Geology and landforms

Malden Island is a large, pentagonal-shaped closed atoll with a shallow hypersaline lagoon at its centre. The large internal lagoon is estimated to range between 1122 and 1637 ha (29-42% of the total land area of Malden of 3850 ha) depending on rainfall and associated water levels. Therefore, dependent on the water levels, approximately 515 ha is either sparsely- or non-vegetated mudflat or ephemeral shallow water bodies.

The entire outer perimeter of the island is composed of an elevated (up to c.10 m asl.) rim of coral debris with the fringing beach also comprised predominantly of coral debris. These non-vegetated coral rubble areas total c.313 ha. The total vegetated area of Malden is about 1900 ha.

The prevailing ocean current and wind direction is from the E quarter and only in the lee side of the island at the NW beach is there a continuous sandy beach. The principal landing site for the island is on this NW beach and even this is a "wet landing" and can be hazardous with a relatively steep beach profile and 'dumping' waves. Landing is possible in calmer conditions elsewhere on the island but cannot be relied upon. This sandy beach extends along c.2 km of the island from NW Point to the cemetery and is visible as a white band in Fig 1.2. Inland from this perimeter rim, the topography slopes gently downward and flattens out to a broad plain which gives way to the large central lagoon. Scattered throughout are many mainly artificially excavated pools of brackish water. There is no evidence of any direct ocean connectivity to the lagoon, but there is some subterranean movement of water between the ocean and the lagoon (Dixon 1877).

2.2 Climate and weather

Located at 4 ^{o}S, Malden Island is in the trade wind belt with SE to NE winds predominating 91 % of the time throughout the year. Weather details were recorded during the early British occupation of 1890-1919 and these are summarized in Table 2.2.

Table 2.2 – Average weather at Malden during 1890-1919 (approximate figures converted from inches and Farenheit)

	Mean	Minimum	Maximum
Annual rainfall (mm)	727	100	2375+
Annual temperature (^{o}C)	29.3	23.9	37.2

Rainfall was extremely variable in 1890-1919 and was greatest in January to May. This general pattern is likely to be similar pattern today but vary between ENSO events. North of the equator, Kiritmati is experiencing increasingly wet and warm years particularly during El Nino years (Australian Government 2011). Rainfall events appear to have given rise to the many brackish pools around the island.

Temperatures during 1890-1919 had reasonably narrow extremes (Table 2.2). During our visit the daytime temperatures were moderately high with temperatures estimated to be reaching the low 30s ^{o}C, but cooler in the evening and at night. Direct sunlight and the almost complete lack of shade made for uncomfortably hot work in the period 1000-1630 h, except on cloudy days during which working conditions were relatively pleasant. Refracted sunlight and latent heat of the coral rubble in sparsely- or non-vegetated areas clearly exacerbate the effects of sun and temperature and working conditions could become almost intolerably hot, especially if the usual trade breezes were absent.

2.3 Human use

Polynesian buildings and graves dating back several hundred years (Dixon 1877) are present on the northern parts of Malden. They indicate that the island was an important resource replenishment and staging area for Polynesians traveling along the Line Islands between Tahiti and Hawaii. The island possibly also provided a more permanent home for hundreds of people.

During the 1860 to 1927 the island was used for guano extraction, the largest source in the Line and Phoenix Islands, and intended for use as fertilizer in gardens throughout the British Empire. During this time many buildings were built for supervisors and workers in NW Bay and water wells, water distillation plants and a wharf was also built there, but the wharf has since disappeared and the landing is potentially dangerous. A railway line was constructed in phases completely around Malden and wind sails on carriages utilized the prevailing winds to transport guano to the loading area at NW Bay (Dixon 1877, Beck 1955).

The elevated railway lines are a conspicuous feature and a convenient access route around the island today. In places the wooden railway sleepers and especially iron rails are clearly visible. A graveyard near NW Bay provides testimony to the many mainly Niuean guano workers and supervisors and family members who lived and died on Malden. The lack of terrestrial food resources meant that diet would have been limited to farmed pork, goats and poultry and perhaps reef fish and lobsters which are common today, but all heavily supplemented by imported foods (Dixon 1877). It was during this period that feral cats and probably also house mice were introduced to Malden.

Malden was little visited during the 1940s and 1950s, but the Cold War saw the British return to use Malden as a preliminary site for nuclear weapon experimentation ("Operation Grapple") in 1957-62, before moving north to continue these activities at Kiritimati. The northern and especially NW margins of Malden are littered with relics of this nuclear period and include rusting vehicles, containers, buildings, and dump sites containing hundreds of rusting fuel drums. Time has done little to heal the c.55 year old vehicle tracks made along the upper shore in this period (Appendix 5 photos).

Recent visitations have been limited mainly to marine surveys and maritime accidents, including a yacht grounding here in early 2015.

2.4 Vegetation and flora

Malden is depauperate in trees and shrubs, being dominated by grasses and low scrub. Undoubtedly it would have supported more luxuriant vegetation historically and would have supported stands of Te Puka (*Pisonia grandis*) which thrived in the nutrient rich soils (Dixon 1877), and other trees and shrubs e.g. Te Ren (*Heliotropum foertherianum*), Te Koura (*Sida fallax*) and possibly Te Mao (*Scaevola taccada*). Combinations of guano excavation, fire (one as recently as 1977) and damage over many decades by pigs and goats would have greatly impacted these stands. The lagoon edge has extensive areas of filamentous green algae, which turn shades of brown and red when decaying.

Currently there are four main vegetation zones present, dominated by *Sesuvium* (refer map p.4):

- a broad zone of *S. portulacustrum* on the low-lying seasonally flooded flats surrounding the lagoon (Fig 2.1, 2.2)

- many scattered areas of Te Boi (*Portulaca)*, Te Koura and grasses on elevated ridges extending through the *Sesuvium* zone (Fig 2.3)

- a variable-width band of grasses and *Tribulus*-dominant forming a moderately broad band around the perimeter of the island (Fig 2.4)

- localized stands of trees mainly along NW Bay which are dominated by Te Ren and a few Te Puka (Fig 2.5).

Fig 2.1 - *Sesuvium* flats in western sector of island with overgrown railway; also coral structures in middle ground and linear mounds in distance.

Fig 2.2 – *Sesuvium* fringes on the NE edge of lagoon

Fig 2.3 above – *Portulaca*-dominant ridge in area of primarily *Sesuvium* flats, west central area.

Fig 2.4 - Grass-dominant area in arid NW area of Malden, lagoon in background

Fig 2.5 – The largest stand of Te Ren in NW Bay, September 2015

Coconut palms have been planted in the past and while established have not thrived, with only two live trees in poor health and three seedlings observed. Several other coconut trees have recently died, indicating that at least periodically the island may become too dry for them.

Nineteen plant species were recorded during our 2015 survey (Appendix 1). Further intensive survey is likely to reveal additional species, especially weeds.

3.0 FAUNA OF MALDEN

3.1 Breeding Seabirds

A total of 19 species of birds was recorded in 13-17 September 2015. These included 11 species of breeding seabirds, three visiting seabirds, further seabird species offshore, and four migratory waders (Appendix 2). Key components of the avifauna are described below:

Lesser frigatebird (Te Etei)

A very large lesser frigatebird colony of 15,000+ pairs was successfully nesting in the central western area. The colony was remarkably synchronized with c.14,000 pulli (mid to late stage chicks) nearly most of which were close to fledging (Fig 3.1). This is a remarkably productive colony especially given an El Nino phase is developing this year (2015). This colony exceeds previous Malden estimates of 7000 individuals (Perry 1980, Birdlife 2015) and is approximately the same size as the impressive colonies on Jarvis (Rauzon et al 2011) and Rawaki Island in the PIPA (Pierce et al 2013). Clearly Kiribati supports two of the globally most important breeding colonies for this species.

Fig 3.1 – Part of a crèche of lesser frigatebirds (left) and a nesting masked booby shading its egg (right)

Great Frigatebird

Many diffuse colonies of varying size were scattered across the Sesuvium zone in the vicinity of the Lesser Frigatebird colony. They were less synchronized than the Lesser Frigatebirds. The total count was an estimated 3000 pairs, and represents a significant population for this species comparable to the total colony sizes for PIPA and Kiritimati.

Masked Booby

A large population of Masked Boobies spread throughout the island particularly in the *Sesuvium*-dominant areas. Most were establishing territory and courting. Daytime counts suggested c.6000 pairs, but late afternoon counts, evening fly-on counts and sizes of roosts all suggested that this figure may be more accurate at c.10000 pairs and is likely to be at about that breeding level in November-December 2015. This is the second largest breeding population of this species in the Line Islands and Kiribati, second only to Kiritimati and exceeds counts for all of the PIPA atolls combined (Pierce 2013, Rauzon et al 2011).

Brown Booby

A colony of at least 200 breeding pairs was in the early stages of nesting (many nests of 1-2 eggs being incubated) in Sesuvium on the eastern lagoon edge (Fig 3.2). A very few birds were seen at other sites on the island but only roosting (in Te Ni trees) or flying around. This figure is much less than by Perry (1980), but the current figure may be slightly higher than our 2015 estimates. At 200+ pairs this is currently Kiribati’s highest breeding concentration exceeding the 100 pairs present on Enderbury Island and may exceed the total for all the PIPA atolls combined.


Fig 3.2 - Brown boobies nesting on elevated rail way and adjacent *Sesuvium* flats (left) and a red-footed booby selecting a ground nest site on *Sesuvium* flats (right)

Red-footed Booby

At least 1000 breeding pairs were present on Malden and many more juveniles and other non-breeders at night. Colonies were mainly restricted to Te Ren and Te Puka trees nearly all of which were heavily utilized by this species and the Te Ren trees often suffering chronically because of this. Many small colonies were also found on small motu and areas of broken coral or extensive Sesuvium on mainland sites (Fig 3.2).

Red-tailed Tropicbird

An estimated fewer than 50 pairs were breeding in four concentrations around the island. The nest sites were invariably under coral overhangs.


Fig 3.3 – A Red-tailed Tropicbird (left) uses an undercut coral ledge for nesting while this motu (right) provides a safe breeding site for noddy species

Blue-grey, Brown and Black Noddies

None of these species was very common and their breeding areas were largely confined to lagoon motu and adjacent parts of the mainland on the western edge and especially the NW corner of the lagoon. Some additional blue-grey noddies were territorial on the outer beach area of the NW Point.

Grey-backed tern

An estimated total of 7-8000 pairs were breeding in two colonies and a third colony had recently been abandoned. The extant colonies were at the incubation stage. Only three juveniles were seen of over two thousand birds examined for plumage details. In addition adults and eggs were suffering high levels of cat predation (Section 4). This possibly the largest breeding population in Kiribati, being roughly similar to total numbers present in the PIPA in 2011 (estimated at 5000+ pairs but increasing, Pierce 2013) and possibly also exceeding that of Kiritimati (Pierce et al. 2012).

Fig 3.4 – Grey backed tern (left) and a crèche of young sooty terns (right)

Sooty Tern

A colony occupying 18 ha had recently fledged many young and many juveniles were seen at sea. Given that nesting was over it was difficult to estimate total numbers but a conservative estimate of c.1 nest per square metre would give a total of nearly 200,000 pairs, making it a significant colony and at least the third most important in Kiribati.

3.2 Visiting seabirds

Evidence of island visits by Phoenix petrels, Wedge-tailed Shearwaters and Great Crested Terns was obtained (Appendix 1). These two procellarid species (plus Tropical Shearwaters and White-throated Storm-petrels) were also seen near Malden during pelagic transects (Appendix 4).

3.3 Shorebirds

Malden is an important staging and/or "wintering" area for four Arctic waders (Appendix 1) including the Te Kiwi or Bristle-thighed Curlew. Our transect counts suggested that at least 200 individuals were present at the time of our visit and given this was early in the non-breeding season, it is possible that hundreds of individual curlew utilize this island, clearly the most important for this Vulnerable species in Kiribati. They frequented virtually all available habitats including rocky and sandy seashores, lagoon edge, isolated pools and open grassland and *Sesuvium* flats. Although hermit crabs were a conspicuous prey in all these habitats, they also took smaller prey, possibly including spiders and grasshoppers which were common.

Fig 3.5 – A bristle-thighed Curlew (left) flicks a piece of hermit crab on to a coral anvil while a Wandering Tattler still in breeding plumage (right) stalks invertebrates at the lagoon edge.

3.4 Other indigenous fauna

At least two lizard species occur on the island. Snake-eyed skinks (*Cryptoblepharus poecilopleurus*) were very commonly seen foraging during the day throughout the vegetated parts of the island and on structures, while mourning gecko (*Lepidodactylus lugubris*) appeared to be confined to structures, coral outcrops and trees.

Fig 3.6 – Mourning gecko (left) and snake-eyed skink (right)

Fig 3.7 - Hermit crabs (left) and unidentified crab (right) were widespread on Malden but uncommon.

Other invertebrate fauna included three species of crabs one of which was common around brackish water and occasionally seen in relatively dry areas with coral outcrops, grasshoppers (Odonata), iridescent green-coloured ladybirds, brown-red coloured dragonflies, moths, dipteran flies and midges.   Also spiders, cockroaches, beetle sp.

Green turtles (*Chelonia mydas*) were seen in small numbers in the waters along the northern coast by the authors and also reported by the crew of the Kwai, and a small number of relatively fresh tracks and nest sites (c.7) were seen on shore on the sandy NW coast. Nests appeared to be restricted to this c.2 km stretch of sandy beach in NW Bay.

Close offshore, bottlenose and spinner dolphins were seen, along with manta rays.

4 INVASIVE SPECIES AND THEIR IMPACTS

4.1 Past invasive species

Several mammals were introduced deliberately or accidentally to Malden, including feral cats and mice. Goats died out but the final pigs were not eradicated until 1964 after about 100 years of impact (Garnett 1983). Several plant species were introduced probably mainly accidentally, including *Tribulus cistoides*. It is possible that a species of rat was once present on Malden but which has subsequently been wiped out by the introduction and rapid expansion of cats. Dixon (1877) reported that during his stay on the island from 1865-69 there was "a small species of rat, which was more than sufficiently numerous", but no evidence of rats was detected on our visit or on any previous scientific visits in the past few decades. It is feasible, but considered unlikely that Dixon mistook mice for small rats, and rather that the rat, probably the kimoa (*Rattus exulans*), subsequently disappeared. Complete extirpation of rat species following the later introduction of predators or competitor rodent species is unusual but not unheard of (several examples have occurred on New Zealand islands and in the Pacific e.g. Rauzon et al 2011), and the Malden Island environment with a noted severe lack of protective cover for rats would have made them very vulnerable to a population irruption of feral cats. It is remotely possible that rats still exist in extremely low numbers on Malden. On occasion, the presence of a rodent species on an island has been hidden or 'masked' by the presence of other rodents, e.g. *R. exulans* on Rangitoto-Motutapu were not detected due to higher densities of the ship rat *R. rattus;* while mice on Great Mercury Island were not confirmed present due to the masking effect of *R. rattus* and *R. exulans*. However, in all documented cases the dominant species masks the presence of the smaller species, which is not the scenario on Malden. If rats still occurred we believe they would have been dominant over mice and would have been more conspicuous.

4.2 House mice

Mice were the only rodent detected during our visit. There is no clear evidence of when they were introduced but most probably during the guano-collecting era. Their presence may have been masked by the reported former presence of rats, or the mice may have established subsequent to this. They were uncommon with only seven being trapped during three nights (36 trap-nights) in the most favourable habitat in and around the stone structures (Table 4.1). Encounters of mice on night walks in the more abundant but seemingly less favourable habitat types were infrequent (Table 4.2). They are, however, probably limiting the regeneration of many plant species including Te Ren and Te Puka.

The mouse population density on Malden is currently very low, perhaps restricted to some extent by cat predation. The highest densities of mice were found in and around the stone structures, where they could presumably find secure retreat sites from cats and perhaps also curlews which would probably prey upon them being an ideal-sized prey, although there is no evidence of this in the literature. Elsewhere on the island the low, open vegetation generally affords little protective cover from predators and therefore on Malden the effect of predators may have a greater than usual effect upon the mouse population and distribution over the island. Mice were rarely seen in nocturnal surveys and clearly exist in low densities, but this may also reflect the simplicity of the main habitat types with so few plant species and possibly the cyclical abundance of key food items such as seeds or invertebrate hatchings, etc.

Table 4.1 – Mouse captures at Malden, September 2015 (DB)

No.	Date	Weight	HBL	Tail	R Ear	Sex	Maturity
1	15	17	80	82	12	M	A
2	15	16	91	87	11	F?	A
3	15	12	69	69	12	F	J
4	15	15	72	73	12	M	A
5	15	10	65	71	12	F	J
6	16	14	77	79	11	M	A
7	16	17	82	79	11	M	A

Table 4.2 - Rodent and crab counts at night along 1 m x 50 m transects at Malden Island

Date in September 2015	14	16	16
Start point	Railway "sidings"	NW Bay	Railway "sidings"
Finish point	NW Bay	NW Bay	NW Bay
Route	Railway	Random	Railway
Dominant plants	Sesuvium	Grass	Sesuvium

Time start	1830	1855	1905
Time finish	1930	1935	2130
No. of 50 m transects	50	12	N/A
Total length	2500 m	600 m	2500m
Total mice	2	5	0
Total hermit crab	21	17	32
Total other crab	7	3	11
Observer	RP	RP	DB

4.3 Feral house cat

House cats were introduced (presumably for rodent control) in the 1860's or earlier, and by 1866 had "run wild and increased with extraordinary rapidity" and had reportedly caused a substantial (c.80%) reduction in tern numbers at one colony within two years (Dixon 1877).

They appeared to be uncommon during our four-day visit, with only nine sightings, five during the day (in most cases considered likely to have been disturbed from daytime retreats rather than being actively hunting during the day) and four at night (Table 4.2). These sightings were confined to about one third of the island's area from the Te Ren grove at NW point, extending south-west to the frigatebird colony near the linear mounds of earth (Fig 4.1). Cat sign was present but notably rare elsewhere on the island, perhaps reflecting the more hostile habitats on the windward shores of the island and the relative lack of colonial seabird prey (especially tern species) in such areas at the time of our visit. A cat skull and carcass remains were found in an old shipping container on the northern coast, and occasional footprints were seen in softer substrates on beaches and lagoon edges, but it was apparent that cat densities were heavily concentrated in the area described above.

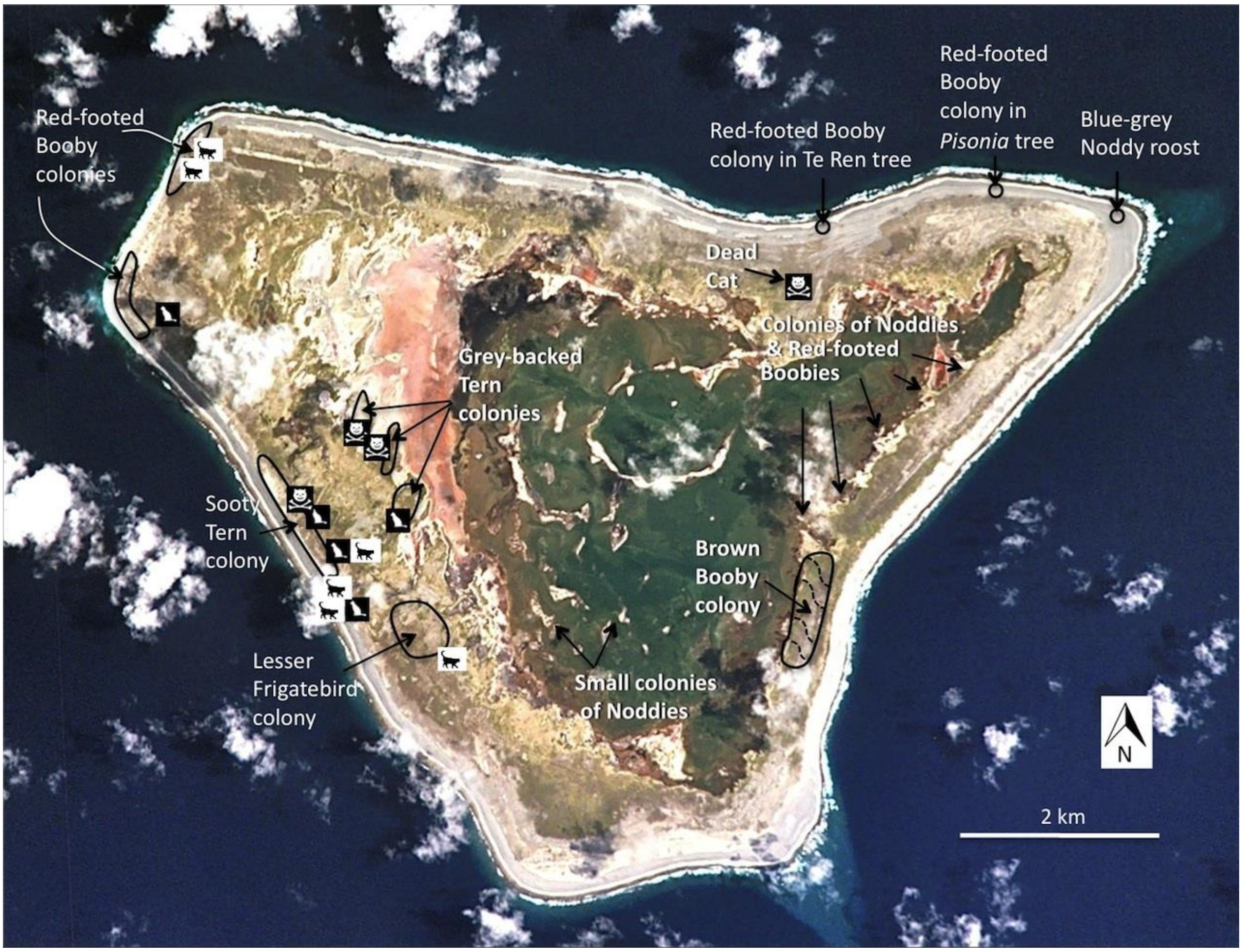


Fig 4.1 – Locations of key seabird colonies and sightings of cats; [cat icon] = daytime, [night icon] = night and cat sign [cat sign icon]

Table 4.3 – Cat sightings at Malden Island in September 2015 (Refer map in Fig 4.1)

Date	Time	Location	Habitat, notes and observers
13	2010	NW Bay, near village	Broken coral and long grass; spotlighted from c.40 m; KK, RP
14	0915	West-central; 200 m N of railway structure	*Sesuvium*, grass, open area. Flushed and ran 200+ m to NW; Moderate sized grey tabby with bold dark grey markings; KK, RP
14	1545	West-central; 100 m E of frigatebird colony	Leaped out of coral overhang (Fig xx) in well vegetated area of *Sesuvium*. Nesting RTTBs present. Moderate sized and had darker markings than the animal seen at 0915; RP
15	0930-45	NW Bay, Te Ren trees	Flushed from beneath Te Ren trees that were being heavily used by nesting Red-footed Boobies. Walked quickly away from us but seen 15 minutes later a short distance away in same Te Ren area; Moderate sized dark tabby; AI, KK, RP
16	0930	West-central, Railway structure	Flushed, possibly from shade of coral structure (which smelt of cat urine); ran to west through sparse grassy area at S end of Sooty Tern colony; Similar looking individual to the one seen on 14th at 0915; RP
16	1730	Western coast	Flushed from coral slab shelter (good shady spot); ran steadily away south toward sooty tern colony, lost from sight in taller grasses. Moderate sized low contrast brown tabby; DB
16	1910	West-central, near grey-backed tern colony	Eye-shine glimpsed for a few seconds at a distance, appeared to be in close proximity to tern colony; DB
16	1955	West-central, near rail line	Detected by eye-shine at relatively close range (c.50m) – was sitting and not moving, but checked site later - no evidence of any prey or den. Observed for a minute or two, slowly walking off into thicker vegetation. Similar colouration to cat spotted at 1730; DB
16	2020	West-central, near rail	Eye-shine detected then cat observed for 10+ minutes, got as close as 25m to it.

		line	Relatively unhurried but wary movements to the north (away from observer) on and to either side of rail line, moved closely past a number of roosting sooty terns and masked boobies with no obvious interest. Grey tabby; DB

Our observations indicated that cats were clearly impacting directly on the seabirds currently nesting at Malden, most notably terns in the same geographic area as our sightings (Table 4.4). Grey-backed terns were being heavily preyed upon at the time of our visit with some caches of multiple birds in and adjacent to one of the colonies (Fig 4.2).

Table 4.4 - Summary of predation sign seen on birds at Malden Island in September 2015

Date	Location	Prey	Number	Notes
13-16	Scattered west side of island	Lesser frigatebird	<5	Single cat-gnawed carcasses; birds have been weakened by injury/starvation first; KK/RP
14	N side of island	Masked booby	c.10	Remains of dead adults possibly cat-killed but could have been scavenged; AI
14	N side of island	Red-footed Booby	c.10	Dead adults; AI
15	Sooty Tern colony	Sooty tern and eggs	20++	At least 20 partially eaten pulli, a few adults and several in-folded eggs found in c.5% of the total colony area; RP.
15	Grey-backed tern colony 2	Grey-backed tern	100+	Over 100 partially eaten adult terns and some pulli; carcasses often clustered in loose piles (Fig xx); RP

Fig 4.2 – Cat-killed caches of dead Grey-backed Terns on the edge of one of the tern colonies.

Terns typically breed in two extended pulses per year in the tropics and so at Malden they represent readily available prey for most months of the year. During the non-breeding periods of terns their nocturnal roosting flocks, would still provide some night-hunting opportunities for cats, but it could be that cats are forced to roam more widely during this period of relative food scarcity.

Malden appears to be a relatively hostile environment for cats with very little shade and few protected den sites, periodic relative scarcity of seabird prey and perhaps occasional periods with very limited fresh water. This is likely to be accentuated during El Nino periods when oceanic warming and food scarcity may cause several bird species (including the terns) to abandon nesting. Consequently at times they could go through population bottlenecks, but at other times the food resources (especially nesting terns) would appear almost unlimited. The cat population is considered very small (<20 individuals) but clearly has sustained itself over many decades.

In addition to the observed impact, cats are clearly preventing other bird species from recolonizing Malden. Before cat introduction, Dixon (1877) noted at least three procellarid species to be present (probably wedge-tailed shearwater, Phoenix petrel and one or two others). These have not been recorded breeding on Malden since then, but during our visit Phoenix petrel and Wedge-tailed Shearwater were observed visiting the island, while Tropical Shearwaters and White-throated Storm-petrels were seen at sea nearby (Appendix 4). Prospecting individuals of these species would be very susceptible to cat predation.

Similarly, Dixon reported presence of white terns (a “pure white” ‘prian’) during his stay on the island, but this species is notably absent now, and this can reasonably be attributed to cat predation.

From these observations and the known impacts of cats elsewhere in the Line and Phoenix Islands (Rauzon 2011, Pierce et al 2012), a general assessment of cat impacts can be inferred at Malden (Table 4.5).

Table 4.5 - Estimated level of cat impact on bird and other vertebrate populations at Malden

Low	Medium	High
Great Frigate bird Lesser Frigatebird Masked Booby	Red-footed booby Geckos and skinks? House mice? Shorebirds? Green turtle?	Phoenix Petrel Wedge-tailed Shearwater Tropical shearwater White-throated Storm-petrel Red-tailed Tropicbird Brown booby Sooty Tern Grey-backed Tern Brown Noddy Black Noddy Blue-grey Noddy White tern Bristle-thighed Curlew

5.0 ERADICATION BENEFITS, RISKS, COSTS AND FEASIBILITY

5.1 Benefits of cat eradication

At a population level the following locally breeding birds are certain to benefit from cat eradication – Red-tailed Tropicbird, Brown Booby, Red-footed Booby, Sooty Tern, Grey-backed Tern, Brown Noddy, Black Noddy and Blue-grey Noddy. Based on population responses elsewhere (e.g. Kiritimati, Jarvis, Howland, Baker) the following additional species are likely to recolonize after cat removal without further intervention – Phoenix Petrel, Wedge-tailed Shearwater, Tropical Shearwater, and probably Christmas Shearwater, White-throated Storm-petrel and White Tern. Audial lures and/or translocations of pulli could possibly assist this process for procellarid species.

Additional fauna to benefit from reduced predation levels would be Bristle-thighed Curlew (VU), skinks, geckos and probably mice and green turtles (VU). Curlews could benefit from both a reduction in predation rates from cats, and perhaps also from potential increases in mice, given that small rodents are common prey of the curlews on Pacific islands (L Tibbitts, USGS, pers. comm.). Cats are also a known predator of turtle eggs and hatchlings (Seabrook 1989), including green turtles (Himler et al 2010). During our visit cat tracks were common on the sandy beaches where the turtle nests were located and their removal may enhance turtle productivity at Malden to some degree.

Strategically, cat removal at Malden would provide significant gains in the Line Islands by providing a large secure island for endangered seabirds notably Phoenix Petrel and White-throated Storm-petrel (both EN) and other sensitive species, including shearwater species and blue-grey noddies. This would reinstate a geographic link with the large populations of most of the seabird species on Kiritimati to the north and the island groups to the south including the northern Cook Islands and Tuamotu. The importance of this gain is highlighted by the increased pressure on Kiritimati populations stemming from increased development and the recent arrival there of *Rattus rattus* adding to the existing pressure from feral cats, *Rattus exulans*, mice and human predation (Pierce et al 2012).

5.2 – Benefits of mouse eradication

The current effect of mice on Malden's biodiversity especially its seabird community is considered to be far less significant than that of cats. However, they may be having subtle but significant effects in vegetation recovery, for example by consuming any seeds produced by the tree species on the island, thereby reducing or eliminating the ability of trees to re-establish and spread on the island.

Mice are likely to cause ecosystem-wide changes in nutrient cycling through predation of invertebrates and plants (Marris 2000, Phiri *et al.* 2009). A New Zealand study (Williams et al. 2000) showed that mice destroy all seed they eat, and do not act as seed dispersers. This may have multi-level effects within an island ecosystem – for example, competing with natural seed-dispersing agents such as birds, limiting the natural seeding of favoured plants, and consequential alteration in relative abundance of plant species and therefore even habitat types within certain ecosystems.

Removal of mice will probably mean a gradual restoration toward the original (pre-invasive species) vegetation communities, as well as increased populations of a variety of invertebrate species, the two lizard species and perhaps some of the smaller bird species.

Much longer term, the recovery of tree species and shrubland may facilitate the ability to use Malden as a potential translocation site for Bokikokiko, the Line Island reed-warbler (EN).

Removal of mice (along with cats) would mean the last mammalian invasive species would be removed, a significant step in restoring Malden's natural ecosystems. However, removal of mice alone would probably not result in major conservation gains (especially for fauna) unless cats were also removed.

5.3 – Eradication Feasibility

<u>Feral Cats</u>

Feral cats have been eradicated from at least 83 islands worldwide, and of these 11 have been sizeable islands of over 2,000 ha (Parkes et al 2014). The largest island for which cats have been successfully eradicated is subantarctic Marion Island (29,000ha) while the largest tropical/arid islands have been Ascension Island (10,000ha) in the Atlantic Ocean and Hermite Island, Australia (12,394ha) (DIISE 2015), both considerably larger and more geographically challenging than Malden.

The fairly large size of Malden and the sometimes challenging temperatures in which hunters or trappers would need to operate are potentially negative factors for successful cat eradication. However, cat eradications have successfully occurred on many tropical and/or arid islands, including other islands in the Line Island group or nearby islands (e.g. Howland (233 ha), Baker (191 ha), Jarvis (440 ha), and Wake 752 ha)); multiple islands in Mexico up to the size to Santa Catalina (4300 ha); and in several other locations (e.g. 2770 ha Baltra Island in the Galapagos, 6147 ha San Nicolas in California, and 1,136 ha Alegranza in El Salvador (DIISE 2015)).

The cat population on Malden is small, but the nature of the island with extensive visibility, and relative lack of cover and retreat sites on the island means that individual cats are considered to have a relatively high level of detectability. They are therefore highly vulnerable to several control options. At the time of our visit, and presumably at many other times, they appear to concentrate heavily and are drawn in towards the most favoured prey species, which largely nest in concentrated and discrete colonies. Thus, it is expected that most cats will be found in a relatively small geographic area, in close proximity to the most abundant and preferred food source at any given time of year.

Footprint evidence leads us to infer that at times when the terns are not breeding, the cats on Malden may well have very large home ranges, and could easily travel a large proportion of the island in a single night. Home ranges may also be greater during mating periods.

Both scenarios lend themselves toward successful eradication – if abundant prey is available, the cats will concentrate around the colonies (and roosts outside breeding times), making them more easily detected and targeted. If the seabirds are not breeding however, the cats may be far more mobile and hungry particularly during periods of bright moonlight (when they may be more readily spotted by roosting birds), and therefore potentially more susceptible to attractive baits and lures.

The constant high temperatures and frequent drying winds, and the presence of several scavenging non-target species (especially crabs and ants) means that the effectiveness of some cat control options such as use of fresh fish or soft (degradable) baits would be severely constrained in the Malden environment.

In contrast, spotlighting and shooting, and the possible option of hunting dogs, would be highly suited for such a flat, open environment with a dearth of escape cover for cats. Cats were visible over considerable distances and skilled shooters could effectively hunt a wide area of the island each night. High-powered rifles (e.g. .223 calibre) suitable for longer distances may be required, though lower-powered rifles such as .22's or .177's may be suitable in most conceivable situations. Spotlights capable of detecting cat eye-shine over long distances would also be required equipment. Shotguns may also be of value for when cats are flushed from daytime dens. Importing firearms across international borders can be problematic, but has been achieved before, e.g. for the Rawaki Island rabbit eradication (Brown 2011).

Dogs would be a likely eradication method. Either ‘detection’ dogs as used by the New Zealand Department of Conservation, or trained ‘hunting’ dogs could be used. ‘Detection’ dogs could be used to locate daytime dens and the dog handlers could shoot the cats either within the den or as they flush, or if unable to flush the cat out of deeper dens to set traps across the den entrance. Alternatively, ‘hunting’ dogs could be used to actively hunt and run down the cats. However, while this option is of considerable potential value, both the finding of suitable dog teams and handlers experienced in extended work in extremely hot conditions, and the authorisations and conditions for movement of dogs across international borders could be problematic.

Use of traps would require solid covers to prevent accidental capture of non-target species such as seabirds and curlews. Any uncovered traps would be generally considered to be of too great a risk with so many ground-dwelling birds present. Leg-hold traps (e.g. Victor 1 ½ softcatch traps) or kill traps (e.g. Conibears) could be used in conjunction with wooden ‘chimney’ type covers as used in New Zealand.

Baits would either need to be long-lasting (e.g. a fishmeal/polymer pellet), or replaced daily (e.g. fresh fish), and would need to be placed above ground (e.g. on wire pegs) to limit loss of bait to scavenging crabs and ants. Given the seasonal abundance of seabird prey, the attractiveness of baits may be lower than in most cat eradication scenarios. Alternative options such as cat-specific lures (catnip oil or materials incorporating cat scent, e.g. sawdust impregnated with cat urine) may be as useful if they can be sourced.

Toxic bait such as PAPP has been relatively recently developed and used in Australia for feral cat control, and the baits developed there for use in arid environments could be applied here. However, their use requires a trained operator (in New Zealand a ‘Controlled Substances Handler’), while sourcing the baits and potentially transporting them across several international boundaries may create major logistical issues.

Additional detection/monitoring methods likely to be used in an eradication project are natural tracking in sand and silt substrates on the island, and use of motion-detecting cameras at key sites.

Cat eradication could potentially be done in conjunction with mouse eradication, i.e. baiting for mice occurs first, which could reduce cat numbers through them eating bait or poisoned mice, and cat eradication follows immediately on from this. However, the usual high mortality of cats expected through secondary poisoning in joint rodent-cat eradications might not manifest here due to the low density and patchy distribution of mice, which we suspect are not the cats’ primary prey. Regardless of the percentage of cats killed by secondary poisoning, follow-up work would still be required to target surviving cats so the savings to a cat eradication project would not be great. Potentially delaying the removal of cats until the far more costly and logistically challenging mouse eradication is developed and funded may not be the best management option.

We believe any pre-planned combination of shooting, traps, toxic baits and dogs would be effective enough to create a very high chance of successful eradication of cats. On this basis, if the project is adequately resourced and the project personnel are suitably skilled, the eradication of cats on Malden appears to be highly feasible, and clearly warranted as soon as practical.

<u>Mice</u>

Mice have been one of the trickier mammalian invasive species to eradicate from islands, with a relatively high failure rate compared to rat species or cats, though success rates have improved markedly in recent times.

Attempts at mouse eradication prior to 2007 had considerably lower success rates (62%) than operations for the various rat species (>90%, MacKay et al. 2007). However, from 2007 to 2011, the success rate in mouse eradications worldwide increased to 91% (McKay 2011). It appears that where operations have occurred using experienced personnel and following now-established rodent eradication 'best practice', the success rates are very high. Griffiths and Towns (2008) showed that 10 out of 10 mouse eradication operations (e.g. Pomona and Rona, Adele, Tonga and Fisherman's Islands in New Zealand) undertaken by the New Zealand Department of Conservation using IEAG advice and following best practice guidelines had been successful.

The largest islands on which mouse eradication has been achieved include the 12,785 ha Macquarie Island in the Australian subantarctic, and 3,842 ha Rangitoto-Motutapu project in New Zealand.

The current number of successful mouse eradications on large, tropical/arid islands is comparatively rather low, and Malden would be considerably larger than the biggest islands to date (Bugio (c.468 ha) in the Deserta Grande group and Salvagem Grande 290 ha off Portugal, DIISE 2015). As such, an eradication attempt on Malden would be 'pushing the envelope' in terms of achievements to date, and there is a consequent but unspecifiable extra risk of failure.

The authors' impressions are that mice may not be limited by food resources on Malden, rather their numbers are dictated somewhat by relative lack of escape cover from predatory cats (and possibly other species such as curlew). Likely mouse prey, such as lizards and larger invertebrates (especially a grasshopper species) seemed quite abundant during our visit, indicating predation by mice was not severe. In such a situation, the attractiveness of toxic baits (the standard technique for eradication of mice) may not be as high as on islands where natural food resources are in short supply.

Eradication of mice would require the broadcasting of highly-palatable pelleted bait containing an anticoagulant toxin, as this is the only currently proven method. On an island the size of Malden the use of bait stations or the hand-broadcasting method is likely to be extremely difficult, costly and logistically challenging despite its flat open nature. It is more than 6X larger than any island successfully treated by these methods for mice. These techniques would require very large labour inputs for a number of weeks, and would require the landing of tonnes of bait through the surf on the island, a process not without risk of damage to bait and human safety issues. Neither would be impossible, but would be extremely challenging. Therefore, the most efficient and recommended 'best practice' option would be the use of a GPS-guided helicopter and bait-sowing bucket probably operating from the deck of ship as used in recent rodent eradications such as on Birnie Island in the Phoenix group or alternatively from the land as on Palmyra in the northern Line Islands. Such helicopter-dependent operations can be extremely costly, and this would definitely be the case for Malden Island, due to its remoteness – not only would a suitable helicopter need to be chartered, so would a ship large enough to carry and launch the helicopter as well as carry many tonnes of bait and related equipment and supplies. As a standalone project, eradication of mice from Malden may be well down the priority list in terms of conservation gain compared against the cost. However, it may become more financially feasible if linked with other possible invasive species eradication projects in the central Pacific area (e.g. possible future mouse eradication projects on Jarvis and Baker Atolls, and a rat-cat eradication on Swain's Island, A. Wegmann pers. comm.) and done concurrently using the same ship and helicopter. Such an option while possible is probably a number of years away, while a cat eradication on Malden could commence as soon as funding is available.

Currently the effect of mice on Malden's biodiversity seems to be very limited compared to that of cats. Conversely, the expected cost of an eradication attempt on mice would be far greater than that for cats. Therefore, we consider the eradication of mice from Malden to be feasible, but with appreciably greater risk, lower conservation return and at a significantly higher financial cost than that for cats. Our recommendation would be to defer mouse eradication for the foreseeable future, and concentrate in the short term on the potentially far greater conservation gains possible through eradication of cats alone. Curlews are likely to be having a greater impact than cats on the mouse population (through greater numbers and wider distribution of curlew than cats), but it is advisable to monitor mouse populations opportunistically in the future.

5.4 – Risks

There are some inherent risks associated with use of firearms, toxic baits and traps commonly used for cat or mouse eradication. Some individuals of non-target species may be at risk, either being attracted to bait and caught in traps (e.g. hermit crabs) or potentially killed by deliberate ingestion of toxic bait (e.g. curlews, ruddy turnstones and plovers) or accidentally being caught in traps (most ground-nesting seabirds and curlews, etc.). Malden is clearly an important island for bristle-thighed curlew and is likely to have a significant non-breeding population present in "winter". Avoiding significant mortality of this species is difficult and expensive to achieve and not guaranteed as revealed by baiting in the Phoenix Islands and Palmyra Island (Pierce and Brown 2011, A Wegmann pers. comm.)

Shooting presents a lesser risk but individual birds may be at risk through flying through firing zones, ricochets, etc. Any dogs used as a cat eradication method would need to be fully trained to avoid seabirds and be under firm control of their handlers at all times. However, whilst there has been 'collateral damage' to non-target species in many previous eradication operations this has generally not been significant at a population level. Almost all effects of eradication projects on non-target species have been short-term, while successful eradication of invasive predator species often result in long-term increases in populations of many native species that far outweigh any short-term negative effects.

If cat eradication proceeds (and succeeds) as a standalone project, it is possible - and perhaps probable - that mouse numbers will increase significantly when the predatory effect of cats is removed. This is unlikely to have any effect on most of the larger seabird species, but could result in increased predation levels on lizards, invertebrates and perhaps some smaller bird species, but this is unlikely to be significant at a population level. A more subtle but potentially significant effect could be on seed germination, with increased mouse populations reducing seed germination rates for some plant species, particularly those with larger seeds (e.g. the current tree species on the island).

Health and safety of staff involved in such a project would need to be a strong focus of planning. Work in such a hot and remote location and use of firearms and toxins all create risks. Evacuation of sick or injured staff could threaten project success but with careful staff selection, adequate planning and safety protocols then risks to the project from this source could be minimized.

Given sufficient resources, skilled staff and managerial commitment, the prospects for success of a cat eradication are very high. A mouse eradication has appreciably higher financial risks associated with it, but still has a high chance of success if undertaken in accordance with established best practice protocols.

5.5 Estimated Costs

It is not possible for accurate costs for eradication of mice or cats to be developed at this stage. However, broadly indicative figures can be presented on the basis of past experience. Please note these are not accurate budgets, but are 'ball-park' estimates which would need to be refined at a later date in the possible development of operational plans.

Mouse eradication

Mouse eradication if done in accordance with tropical best practice for rat eradication would require two applications of bait (at a minimum of 10 kg/ha) an absolute minimum of 10 days apart. All vegetated areas of the island (1,900 ha) would need to be covered, with adjacent bare sand/rubble/mudflat areas probably also receiving applications but possibly at lower rates. The precise total area would need to be assessed using GIS, and unpredictable variance in water levels within the lagoon (and therefore total land area) may require some extra contingency to be factored in. If an approximate land area of 2,500 ha was treated twice at 10 kg/ha, a quantity of 50 tonnes of bait would be required. Adding 10-20% contingency the quantity required would be 55-60 tonnes. This bait, which currently costs c.$3500-6000/tonne (depending on the manufacturer) would be required to be shipped from point of manufacture to the departure port, a costly process, and which would necessitate international customs clearances and importation permits. The application of this bait on the island would require a chartered ship, at least one helicopter (preferably two, for operational safety), suitably qualified staff and associated equipment for at least 25 days, depending on location of the departure port (probably Hawaii). Cost of bait would be at least $200,000, and road and shipping transport of this to and storage at the departure port a further $50,000+. Charter of a suitably-sized ship is estimated to be at least $10,000/day and helicopter charter (for one helicopter) and associated costs at least $5,000/day, both for at least 25 days, and possibly more if they have to be sourced from wider afield. A field team of at least 8 people would be required for c.250 person/days (pilot(s), helicopter engineer, GIS specialist, operations manager and general staff – bait loaders, field monitoring, etc.) at an estimated average of $400/person/day. Other costs, e.g. for planning time, field equipment and supplies, international airfares and accommodation etc. would add perhaps another $50,000.

It is therefore estimated that a mouse eradication on Malden would cost in the vicinity of *at least* Aus$800,000, and potentially $1 million+, not including post-operational monitoring.

Sharing a project ship and helicopter with other eradication projects on nearby islands may substantially reduce this cost by reducing overall length of ship and helicopter charters.

Cat Eradication

Parkes et al (2014) have reviewed previous cat eradications on large islands, and derived a figure of 543±341 days of effort per 1,000 ha was required to achieve cat eradications. We consider Malden would require considerably less effort per unit area, due to ability to draw upon these past learning experiences, and the island's easy topography, open vegetation and a small cat population. We believe the cats are almost exclusively found only within the 1,900ha vegetated area on Malden and rarely if ever utilise the large and barren coral rubble and bare mudflat areas, and this reduces the target area.

However, to achieve cat eradication it would still require at least two separate visits to the island by small field teams (c.4 people and possibly at least one dog team), ideally using local charter boat options (e.g. the SV Kwai), most likely from either Kiritimati or Hawaii, the closest ports and international airports. The primary visit would need to be at least 5-6 weeks in duration, and a follow-up trip within 3-6 months of a possible similar or shorter length, depending on results of the first trip. Total staff input is tentatively calculated at 400 person-days. It is possible that field teams could be placed on Malden by the SV Kwai on its Kiritimati-Cook Island run, a voyage which usually takes at least 5 weeks – this would mean a vessel would not need to be on charter (on standby off the island) for the entire duration of the trip, and each pick-up or drop off at the island would be a one-way charter not a return trip cost. Alternative vessels (e.g. ocean-going yachts) may be able to be chartered from Hawaii or Kiritimati, but would require return trip charters for each pick-up or drop off.

Equipment and field costs would be relatively low ($20,000 for firearms and ammunition; spotlights; generator and fuel and/or a solar system to recharge batteries and a small freezer/cooler; traps and baits/lures; motion-detecting cameras; GPS units; field equipment and supplies, and food for c.400 person/days which may need to be sourced from Hawaii as Kiritimati may not have reliable bulk supplies of field suitable food) so the major costs would be vessel charter and staff costs. The vessel would not need to be large, and a much smaller vessel could be chartered than that required for a mouse eradication. The SV Kwai would be very suitable. A boat charter cost could be expected to be c.$4,000/day, and from Kiritimati each trip would be at least 3-4 days. If alternative boats need to be used, at least 2 return trips (two drop-offs, two pick-ups) from Hawaii of 18 days duration would initially have to be budgeted for. If the Kwai or other local vessels are available ex-Kiritimati for all trips this would be ideal, and the overall cost could be much lower, with only c.6 days charter per trip required for a return trip from Kiritimati to Malden.

Two experienced international staff (skilled hunters, shooters and/or dog handlers) should be budgeted at an average of $350/person/day (for up to 200 person days = $70,000), plus international airfares and accommodation and any associated costs e.g. dog importation and quarantine costs (c.$.10,000). Some staff could fly to or be sourced from Kiritimati, reducing travelling time and wage costs for them. The charter vessel if sourced from elsewhere, e.g. Hawaii, could call at Kiritimati to collect all staff and equipment not already embarked at Hawaii.

Staff time for planning costs, equipment and staff sourcing and selection, and other preparatory work and post-operational reporting could require c.$15,000.

It is therefore estimated that a cat eradication on Malden using the Kwai on its regular runs as the charter vessel would cost in the vicinity of Aus$180,000, not including contingencies or post-operational monitoring. However, this scenario assumes some local (WCU) staff are employed in lieu of international staff (as their salaries are already covered), and that local (Kiritimati) charter vessels are available, and especially if work on Malden can be tied in with the Cook Island runs of the SV Kwai. Any departure from this would substantially increase overall project costs. The length of the second trip (and therefore associated staff costs) could also be reduced dependent on results of the initial trip.

Combining the mouse and cat eradications could create only relatively minor savings (at least one less small vessel charter) and some possible multi-tasking of personnel and equipment. An estimate of a combined mouse-cat eradication would be in the order of $950,000.

6. PRELIMINARY RECOMMENDATIONS

Malden has very high natural values particularly for seabirds which can be further enhanced through the removal of predators, particularly cats. We provide the following recommendations to progress planning for the restoration of Malden:

- Discuss and agree within MELAD on the priority for the restoration of Malden aiming for the initial removal of feral cats
- Discuss with potential sponsors the cost implications of cat eradication from Malden and possible timetables
- Discuss with other island managers in the region on the potential for collaboration between projects to reduce costs
- Develop an operational plan for cat removal
- Strengthen biosecurity generally in Kiribati via the K-NISSAP and raise awareness of precautions needed for Malden visits.

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Appendix 1 – Flora species recorded on Malden in September 2015.

Note: status* Ind = indigenous, Ex = exotic

Species	Family	Local names and status*	Distribution and abundance
Bidens pilosa/kiribatiensis	Asteraceae	Ex	Widespread but patchy
Boerhavia albiflora	Nyctaginaceae	Te Wao; Ind	Common throughout
Boerhavia tetrandra	Nyctaginaceae	Te Wao; Ind	Uncommon, western beach
Cenchrus echinatus	Poaceae	Ex	Common throughout
Chamaesyce prostrata	Euphorbiaceae	Ex	Common in disturbed areas
Cocos nucifera	Arecaceae	Te Ni; Ex	2 live adults and 2 seedlings, village
Digitaria stenotaphrodes	Poaceae	Ind	Locally common throughout
Eragrostis whitneyi/pauper	Poaceae	Ind	Common throughout
Fimbristylis cymosa / atollensis	Cyperaceae	Ind	Common
Heliotropium anomalum	Boraginaceae	Ind	Rare, NW beach
Heliotropium foertherianum	Boraginaceae	Te Ren; Ind	Rare, mainly western beaches
Ipomoea pes-caprae brasiliensis	Convolvulaceae	?	Localised upper beaches
Lepturus repens	Poaceae	Ind	Widespread
Pisonia grandis	Nyctaginaceae	Te Puka; Ind	Rare, 5 groups of trees/suckers
Portulaca lutea	Portulacaceae	Te Boi; Ind	Common throughout
Sida fallax	Malvaceae	Te Koura; Ind	Common throughout
Suriana maritima	Surianaceae	Pigweed; Ind	Common especially lagoon flats
Tribulus cistoides	Zygophyllacees	Te Maukinikini; Ex	Common especially along perimeter
Triumfetta procumbens	Malvaceae	Te Kiaou; Ind	Common supralittoral zone

Appendix 2 – Summary of bird status on Malden Island in 13-17 September 2015.

Estimated no. of individual birds (i) or pairs (p), shading = breeding confirmed

Common name	Scientific name	Approximate numbers and status September 2015
Phoenix Petrel	*Pterodroma alba*	Common at sea; one circling near lagoon 1725 h, 14 Sep
Wedge-tailed Shearwater	*Puffinus pacificus*	Present at sea; one flew off island 0600 h 16 Sep
White-throated Storm-petrel	*Nesofregetta fuliginosa*	Present within x km offshore (Appendix 1; not seen ashore
Red-tailed Tropicbird	*Phaethon rubricauda*	<50 p; clustered in 4 areas, nesting undercut coral banks
Red-footed Booby	*Sula sula*	>1000 p; nesting in Te Ren, Puka, coral ledges and motu
Masked Booby	*Sula dactylatra*	c.10,000 p; nesting throughout mainly in *Sesuvium* areas
Brown Booby	*Sula leucoptera*	>200 p; nesting eastern lagoon edge in *Sesuvium*
Great Frigatebird	*Fregata minor*	c.3000 p; nesting mainly one edges of *F ariel* colony
Lesser Frigatebird	*Fregata ariel*	>15,000 p; nesting mainly in one large colony
Sooty Tern	*Sterna fuscata*	250,000+ p (approx.) in 18 ha colony; fledged young
Grey-backed Tern	*Sterna lunata*	7000+ p in two colonies, 5000+ nests of eggs, 3 juveniles
Great Crested Tern	*Sterna bergii*	One flying along western shore
Brown Noddy	*Anous stolidus*	<500 p; nesting on motu mostly in NE corner of lagoon
Black Noddy	*Anous minutus*	c.100 p; present on motu mostly in NE corner of lagoon
Blue–grey Noddy	*Procelsterna cerulea*	20+ p; nesting on lagoon motu and barren NE coral
Pacific Golden Plover	*Pluvialis fulva*	200+ i, lagoon, ocean edge and open areas
Wandering Tattler	*Heteroscelus incanus*	200+ i, lagoon, ocean edge and pools
Bristle-thighed Curlew	*Numenius tahitiensis*	300+ i, *Sesuvium*, grass, pools, ocean and lagoon edges
Ruddy Turnstone	*Arenaria interpres*	c.50 i, ocean and lagoon edges

Appendix 3 – Seabird fly-on counts at Malden Island in September 2015

Date Sept 2015	14	15	16
Location	Lagoon edge	200 m S of village	Village
Time	1700-1800	1700-1830	1700-1830
Wind, cloud	Light SE, 60% cloud	Light SE, 20% cloud	Light SE, 40% cloud
Phoenix Petrel	1 flew in wide circles		
Red-tailed Tropicbird			1
Masked Booby	24	1099	Hundreds
Brown Booby	1		2
Red-footed Booby	77	226	500+
Frigatebird species	500+	111	200+
Sooty Tern		1000+	500+
Grey-backed Tern		6	2
Brown Noddy	3		
Blue Noddy	1		

Appendix 4 - Pelagic seabirds observed between Kiritimati and Malden Island 10-20 September 2015, all observed from SV Kwai by RP with help from DB, AI and KK.

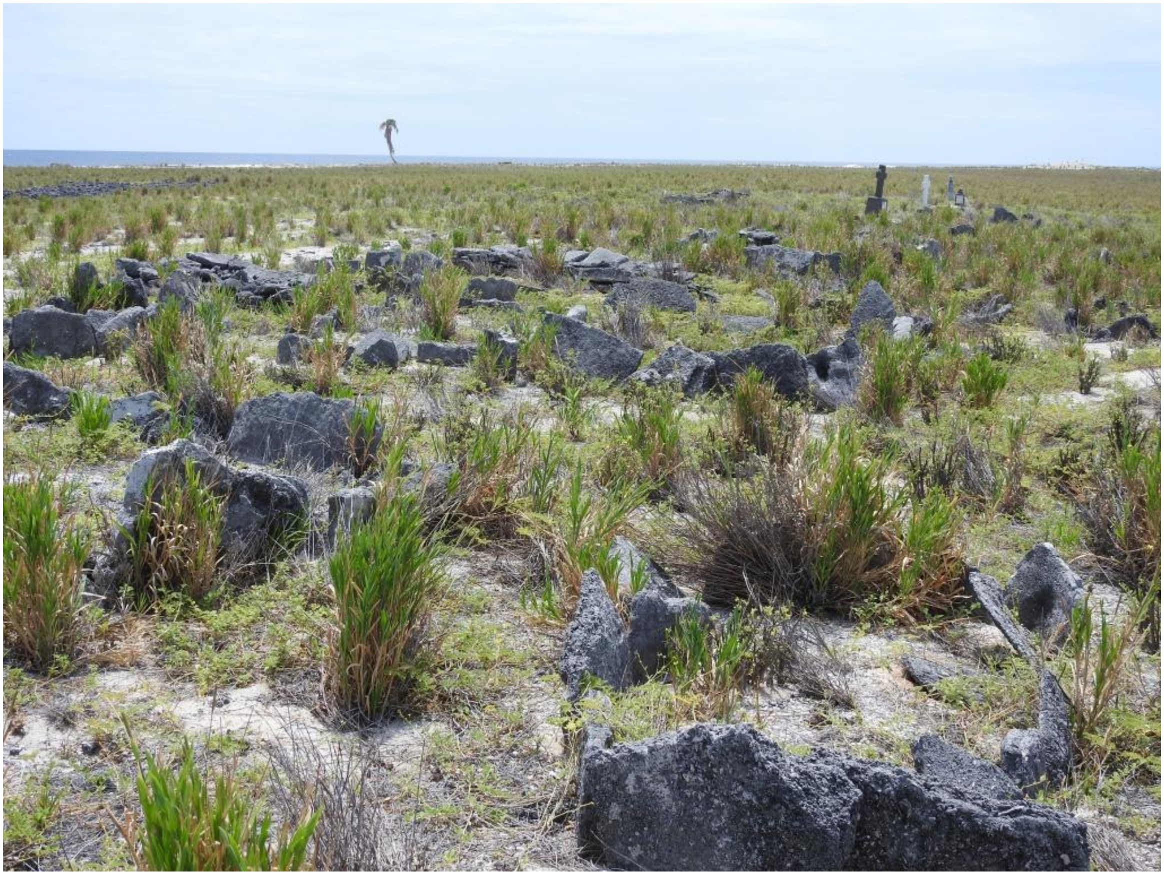
Date in September 2015		10	11	11	12	12	13	13	18	18	19	19
Total hours and am/pm		4pm	4am	4pm	4am	4pm	4am	4pm	4am	4pm	4am	4pm
Latitude start												
Latitude finish												
Pterodroma alba	Phoenix petrel	3	3	11		7	2	2	3	3	3	2
P. rostrata	Tahiti petrel									1		
P. neglecta	Kermadec petrel								1			
P. externa	Juan Fernandez petrel					1						
P. cookie	Cook's/Pycroft's petrel			1				1	4	1	2	2
Pterodroma sp.	Unidentified petrel					1			1			
Puffinus carneipes	Flesh-footed shearwater		2									
P. pacificus	Wedge-tailed shearwater		42			1	1				4	1
P. bulleri	Buller' shearwater				1							
P griseus	Sooty shearwater		3	2	1	8	3	1	13	7	5	3
P tenuirostris	Short-tailed shearwater		3	2	1	3		7				
P. nativitatis	Christmas shearwater	5										
P. lherminieri	Audubon's shearwater	8	2									
Puffinus sp.	Unidentified shearwater		1	5	1				2	2		
Nesofregetta fuliginosa	White-throated storm-petrel	2		2		1			3	2		
Oceanodroma tethys	Wedge-rumped Storm-petrel			2		2		1		5	4	1
O. castro	Band-rumped Storm-petrel					2				2		
Phaethon rubricauda	Red-tailed tropicbird	1					1				5	1
Sula dactylatra	Masked booby	24	5	2	3	1	48	19	1	5	4	11
S. sula	Red-footed booby	8				2	1	5				3
S. leucogaster	Brown booby	5										
Fregata minor	Great frigatebird	13			1		1					1
F. ariel	Lesser frigatebird	8			3	3	11	3			2	
Sterna bergii	Great crested tern	2										
S. lunata	Grey-backed tern	34	12					1				
Onychoprion fuscata	Sooty tern	300	125	30	216	41	30	34	50	118	140	68
Anous stolidus	Brown noddy	15										
A. minutus	Black noddy	111										
Procelsterna cerulean	Blue noddy	26		1								
Gygis alba	White tern	12		1	3	1					1	1
Pluvialis fulva	Pacific Golden Plover				1							

APPENDIX 5 – Some Malden Island images

KK scans the arid northern sector (above) with example of Polynesian structure (below)

AI on path to beach NE corner of island (above) and some of the last few coconuts (below)

Railway bank NE corner of lagoon (above) and cemetery (below)



Structures from guano collecting days (above and below)

Well (above) and tip carriage (below)

Relics of Operation Grapple NW Bay (above and below)

Relics of Operation Grapple (above and below)

Vehicle tracks from Operation Grapple (above) and biosecurity risk from poor navigation (below)