Apolima Island rodent eradication feasibility assessment

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Date: August 2023

Version History

Version	Reason for change	Date
1	Draft for internal review	1st May 2023
2	Draft for IEAG and stakeholder review	19th May 2023
3	Peer reviewed final	14th August 2023

1. Executive Summary

This report assesses the feasibility of eradicating rats from Apolima – a 115ha island inhabited by approximately 80 people, located in the Apolima Straight between the two main islands of Samoa. The Department of Conservation led the assessment, in collaboration with Samoa's Ministry of Natural Resources and Environment, the South Pacific Regional Environment Programme, and the Apolima Island community. The work is funded by the New Zealand Ministry of Foreign Affairs and Trade through the Managing Invasive Species for Climate Change Adaptation in the Pacific project.

Rats have been eradicated from similar sized tropical islands with equally challenging terrain, but the steep slopes and cliffs on Apolima require poison bait to be applied from the air to succeed. This method of broadcast baiting is the logical method for the rest of the island in combination with more careful placement of bait around the village area. To achieve this requires significant preparation which in turn requires the inhabitants to have a full understanding of how the project affects them and be able to give informed consent. Until this happens the project is not feasible because social acceptance remains unresolved.

Apolima is the crater and rim of an old volcano, approximately 1.5 km diameter surrounded by cliffs of up to 140 m high. The only access to the interior is through a small harbour with a sandy beach and is the site of the only settlement on the island. The island is highly modified with most of the accessible interior modified by crops and livestock to support the community's self-sufficiency. The island has high cultural value with inhabitants living a largely traditional and semi self-sufficient lifestyle.

There are few remaining native species and only one, the endemic Samoan flycatcher, with special conservation status. Several species of seabird nest in the coastal cliffs. Kiore (*Rattus exulans*) are present, but the status of other rodent species is unknown. Rats have a significant impact on the livelihoods and wellbeing of the community, and likely the flycatcher and seabirds although the pigs, cats, dogs, and weeds also contribute to the environmental degradation.

Rat eradication in isolation to other restoration work may not provide worthwhile outcomes. More work is required to understand the biological complexities and the desires of the community and other stakeholders before meaningful consultation can take place with stakeholders.

The island and community are well placed to implement the biosecurity measures required to sustain a rodent free island with limited incursion pathways and a proven culture of vigilance and following protocols.

The key dependencies must be satisfied to progress to operational planning:

- All key stakeholders agree and can clearly describe a long-term vision for Apolima, the reasons for, objectives of, and desired outcomes of a rat eradication.
- Key institutions involved understand and agree on their respective roles and are willing to commit the necessary resources to the project.

- The Apolima community understand and agree to implement the management actions required to protect livestock, pets, and people from accidental poisoning, to reduce the operational risk posed by interference from non-target species (pigs, chickens, etc.) and to eliminate/reduce alternate food sources available to rodents. They understand and accept risks to other non-targets.
- The community and MNRE understand and accept the negligible impacts of toxin residue in the ocean, soil, and water.
- Support from the community to proceed with the project is given (via the mayor) once consultation is complete and all required management actions have been agreed.
- Key stakeholders understand the applicable pest management options for Apolima and make an informed decision to proceed with a rat eradication.

The recommended next steps to expand on this feasibility assessment are:

1. Feedback to the community and seek their input.
2. Fund a role based in Samoa to lead the ongoing engagement and next steps.
3. Undertake further work with all key stakeholders to clarify:
    a) the reasons for undertaking eradication project,
    b) objectives and intended outcomes of the project, and
    c) a long-term vision for the island.
4. Further engagement with the Apolima community to identify all management plans required to ensure the technical and social feasibility of an eradication. This includes identifying management options, discussing these with the community to ensure the requirement and associated impacts are understood and agreeing to an action(s). This is required for the following areas:
    a) Exclusion zones and areas of special baiting sites
    b) Availability of alternate food sources to rats
    c) Impacts of non-target species (to prevent them compromising eradication)
    d) Risk and mitigation to non-targets (cats, dogs, chickens, pigs, and humans)
    e) Long-term management of livestock, cats, and dogs compatible with the outcomes identified in 3 above.
5. Interim Biodiversity surveys and baseline data collection.

2. Introduction

The purpose of this document is to assess the feasibility of eradicating rats from Apolima Island, Samoa.

The New Zealand Department of Conservation (DOC) undertook this study at the request of the Secretariat of the Pacific Regional Environment Programme (SPREP) as part of the Managing Invasive Species for Climate Change Adaptation in the Pacific (MISCCAP) project, funded by the New Zealand Ministry of Foreign Affairs and Trade (MFAT).

The goal of the project is to enhance community and ecosystem resilience to climate change through the eradication of rats from Apolima Island which will lead to more secure food production and storage, reduced public health risk and some benefits to biodiversity.

Apolima is a small, inhabited island located between the two main islands of Samoa. Invasive species including rodents (*Rattus* spp.), myna birds (*Acridotheres* spp.), feral pigs (*Sus scrofa*) and a range of invasive flora are impacting the local community's ability to grow and store food, their health and wellbeing, and the island's biodiversity.

An initial consultation between SPREP and MNRE identified management of invasive species on Apolima Island as one of the Samoan government's priority activities given the site's status as a Key Biodiversity Area. This is supported by the Samoa National Invasive Species Strategy and Action Plan (NISSAP) being the key national instrument outlining invasive species priorities for Samoa (SPREP 2021).

SPREP approached DOC in March 2021, the project was approved but the effects of the Covid-19 pandemic delayed significant progress until late 2022 when two separate site visits were conducted.

DOC's role was to lead the feasibility assessment working together with SPREP, MNRE and the local community. MNRE provided in-country knowledge and advice, logistical support, and liaison with the local community. Samoa's National Invasive Task Team (SNITT) were kept informed of the projects progress and interim findings.

This assessment is intended for stakeholders in Samoa to understand the complexity and feasibility of the project and what potential next steps are.

Table 1 Scope of this feasibility study

In scope	**Out of scope**
Feasibility Study	Operational planning or implementation
All rodents	Other invasives including common myna, flora, invertebrates, feral pigs, cats, dogs, domestic pigs, chickens

3. Site and target pest description

3.1 Location and physical environment

Apolima Island lies between the two main islands of Samoa; it is 9 km to the east of Upolu (113 322 ha) and 7 km to the west of Savai'i (171 283 ha). The neighbouring Island of Manono (305 ha) is just 3 km southeast of Apolima. There is a small rock stack (0.18ha) 400m to the north.

Apolima is shaped like an upturned bowl, the crater and rim of an old volcano, approximately 1.5 km diameter and a total area of ~115 ha. Steep cliffs of up to 140 m high encircle the island with small rock platforms and caves around the base. One small opening in the cliffs at the north of the island provides the only access to the interior. This opens to a small harbour with a sandy beach and is the site of the only settlement on the island.

Access is via small boat only, a 40 min journey from Apolima Uta on Upolu via Apolima Strait in often rough conditions. The entrance to the harbour is a narrow zig zag channel (approx. 6 m wide) through the rocky reef and only possible in good weather and with the skill of local *alia* (boat navigators).

The island is highly modified with most of the accessible interior modified by crops and livestock to support the community's self-sufficiency. Very few native plant species remain and are mostly confined to the steep outer slopes. The flat interior is generally damp and boggy, the tracks are very muddy and there is significant pig rooting throughout. The plantations contain primarily coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*) and bananas (*Musa spp*). The interior slopes are steep with a mix of native and invasive species including *Planchonella grayana* (flowering tree), *Diospyros spp*., and *Dysoxylum spp*.

The steep outer cliffs are papa slab rock patchily vegetated with *Pisonia grandis* (grand devil's-claws), a species of flowering tree in the Bougainvillea family as well as littoral scrub species (Freifeld 2001). A full list of flora species observed in November 2022 can be found in Appendix 2: List of Flora.

Interior and exterior cliffs are vertical in many places and the crater ridge is significantly drier than lower slopes.

Figure 1 Map of Samoa showing the location of Apolima island.

Figure 2 top: Apolima as seen from the sea; bottom left: Apolima from above; bottom right: Apolima Tai village**.**

3.2 Climate

No specific weather data exists for Apolima and there is no weather station on the island. The closest station is Faleolo Inut on Upolu, so records for Apia will be used as an approximation.

Common to most tropical islands, Samoa experiences two distinct seasons; "Hot and Wet" from November through to April and "Cool and Dry" from May to October. Temperatures are relatively constant year-round. Mean annual temperature range for Apia is 26 to 31 degrees Celsius. The relative humidity is high, often 80% or above. Samoa's annual mean rainfall ranges from 3000 to 6000 millimetres. About 70% of the annual mean rainfall is observed during the Hot and Wet season with the El Niño Southern Oscillation being the main driver of Samoa's rainfall (generally less rain in El Niño conditions and more with La Niña) (Samoa Meteorological Services 2021).

Southeast trade winds dominate throughout the country year-round and bring more rain to the windward side than the north and northwest. Warm westerly winds are associated with bad weather conditions (Samoa Meteorological Services 2021).

Heavy rain showers are common and were experienced daily during the November 2022 site visit.

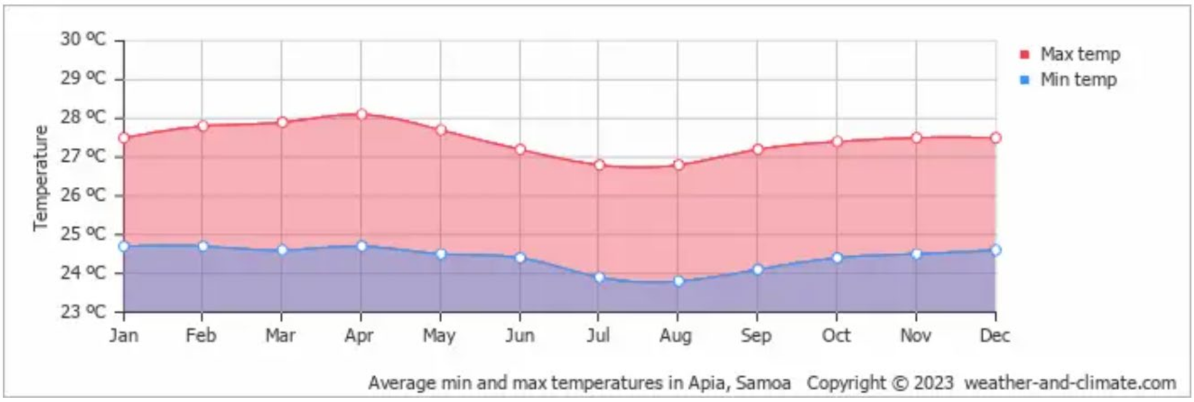

Figure 3 Average minimum and maximum temperatures in Apia, Samoa (Weather & Climate, 2023)

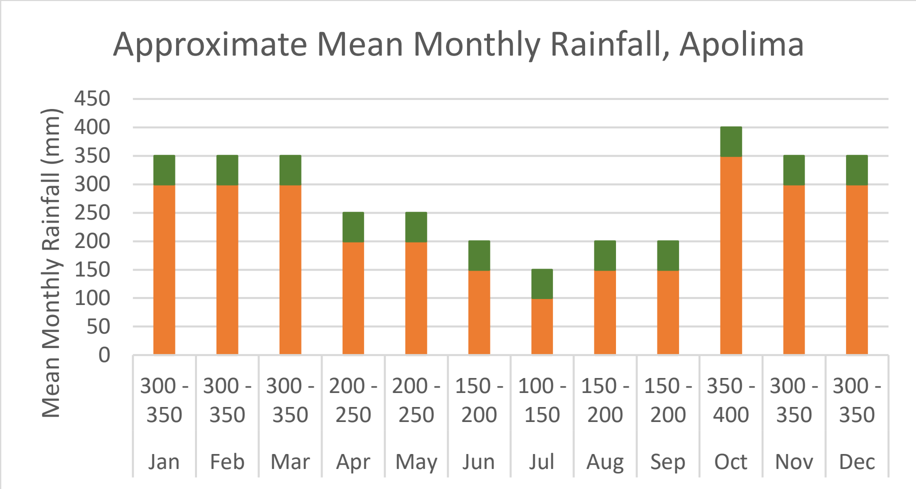

Figure 4 Approximate mean monthly rainfall, Apolima (data from Samoa Meteorological Services 2021)

PLANNING ISSUE 1:
More information about local weather patterns is required, particularly rainfall and wind patterns due to their effect on bait availability and suitable operating conditions for aircraft respectively.

3.3 Biodiversity values

Apolima is within the Polynesia-Micronesia Biodiversity Hotspot, one of 34 regions in world where extraordinary levels of biodiversity and endemism are coupled with extremely high levels of threat (Mittermeier et al. 2004). But the community's semi subsistent way of life including plantation crops and the impacts of livestock, limit the ability for many native species to thrive.

At least two reports have noted the paucity of baseline biodiversity data from Apolima Island and placed importance on gathering data (SPREP 2011; Government of Samoa 2013). The only published survey is from 1999 (Freifeld 2001).

There is only one known terrestrial species of special conservation status, the endemic Samoan flycatcher (*Myiagra albiventris*) listed as Near Threatened. The endangered Humphead Wrasse (*Cheilinus undulates*) and the vulnerable Bumphead Parrot fish (*Bolbometopan muricatum*) are found in the surrounding Marine Key Biodiversity Area (2 129 ha) and under pressure from fishing (MNRE & SPREP 2010).

The vulnerable Coconut crab (*Birgus latro*) is reported as only a very rare visitor and are much prized as a delicacy. It is likely that pigs, dogs, and rats are partly responsible for the scarcity.

Table 2 The first published survey of the smaller islands of Samoa (Freifeld 2001) recorded 6 species of land bird in 2.5 person hours of search effort on Apolima in April 1999, an additional 3 species were observed by the DOC field team in 2022 over 3 days.

Species	Number counted in 1999 survey	Field observations 2022	Diet	Feeding stratum	Notes
Gallus gallus (chicken)	Observed but not counted	~50 – 100 Only seen in village area	Fed daily with rice and coconut	Ground	Not feral At risk from eating baits

Gallirallus philippensis (Banded rail)	4	Not seen but locals say is still present	Insects, snails, crustaceans, fruit	Ground	At risk from eating baits or scavenging poisoned rats
Ptilinopus porphyraceus (Crimson-crowned/purple capped fruit dove)	1	1 sighting	Frugivorous	Sub-canopy	likely to nest on Apolima
Lalage maculosa (Polynesian triller)	8	Numerous sightings and hearings throughout plantation area and higher areas	Insects, caterpillars, fruit	Ground	At risk from eating baits or scavenging poisoned rats
Aplonis atrifusca (Samoan starling)	30	Numerous sightings	Fruit, insects	Sub-canopy	Endemic At risk from eating baits or scavenging poisoned rats
Myzomela cardinalis (Cardinal honeyeater)	1	Numerous sightings	Nectivorous	Sub-canopy	
Foulehaio carunculate (Polynesian wattled honeyeater)	36	Very common around village	Nectivorous, fruit, insects, lizards	Sub-canopy	
Porphyrio? (Swamp hen)	Not observed	None sighted but mentioned by community		Ground	At risk from eating baits or scavenging poisoned rats
Myiagra albiventris (Samoan Broadbill/fly catcher)	Not observed	2 seen in plantation	Insectivore	Sub-canopy	Endemic, Near Threatened
Acridotheres tristis (Common Myna)	Not observed	Common around village, not in plantations			Only non-native species

Table 3 Seabird observations by the DOC/MNRE field team in November 2022.

Scientific name	Samoan name	English name	Sighting Frequency	Location	Known to community
Fregata minor	Atafa	Great Frigate bird	Common	Soaring high in the air	Y
Sula dactylatra	Manupapa / Fua'o	Masked booby	A few individuals	Flying below lighthouse	N
Sula sula	Fua'o	Red footed booby	Common sighting from top of crater	Nesting in trees and on rock slabs, outer edges and on top of crater rim	Y
Anous stolidus	Gogo	Brown noddy	Yes, few individuals	Flying below lighthouse	N
Gygis alba	Manusina / Gogosina	White tern	Isolated individuals	In the straight during ferry crossing, 1 on outer cliffs	Y
Procellariiformes.	Ta'I'o	Tropical shearwater or Petrel	1 sighting	Outer cliffs, seen from boat	N

Table 4 Terrestrial fauna present on Apolima or reported by locals, November 2022

Scientific name	Samoan name	English name	Location and numbers	Notes

Discoplax rotunda	Kupa	Land crab	Burrows on lawn, caught in traps at beach and houses. ~ 30 burrows across lawn (70x30m) Obvious habitat in rock walls around houses	
unknown		Snail	Lawn, individual sightings only, were attracted to peanut butter in traps	
unknown		Slug	Not seen	Known to destroy cabbages
Oryctes rhinoceros		Coconut/ Rhinoceros beetle	Not seen	Damages coconut trees
Hemidactylus frenatus		House Gecko	Inside fale and houses (assumed to be introduced)	May out compete and replace other species 
unknown		Skinks	Not seen	
unknown		Millipedes/ centipedes	Observed in houses	
Candoia bibroni		Pacific Boa	Very rare as people kill them, can be eaten by pigs	
Ramphotyphlops braminus		Blind snake	Not seen	Small, worm like
Anoplolepis gracilipes		Yellow crazy ants	Not seen	damage stored food/produce
unknown		Little ants	Common, attracted to peanut butter in traps	

PLANNING ISSUE 2:

Comprehensive flora and fauna surveys should be undertaken to better understand the biodiversity values and potential of Apolima as well as to provide a baseline from which to measure future changes.

3.4 Land use and tenure

The island is divided geographically into three main land uses: the village area, the flat interior, and the slopes (interior and exterior). The village area is flat, well kept (maintained by the women and children), with a mown lawn, ornamental gardens, and small vegetable gardens. The flat interior is made up of plantations, tended daily by the men. The surrounding slopes and crater rim are steep and generally not accessed by locals.

The island is governed by the *pulenu'u* (mayor) and *matai* (family head) for each family. This chiefly system is designed to ensure benefits to the whole community. Each family has its own *fale*, cookhouse, and plantations. Full permission is required from the landowner to go onto someone else's plantation. The mayor exercises strong leadership and permission for visits to plantations are arranged through him.

Figure 5 View of the village with plantations behind and surrounded by crater ridge.

3.5 Human history and cultural values

Samoa was first settled by Polynesians ~1000BC. It is unknown when Apolima was first settled. It was used as a fortress in the 18th and 19th centuries when required by powerful neighbouring Manono.

A census in 1867 indicated a population of at least 40 (Bargatzky 1998) which had risen to 204 in 1945 (Census 1945). The most recent census in 2021 reports a population of 81 (50 male, 31 female) (Samoan Bureau of Statistics 2021). Observations in November 2022 found almost half of the population were children. The community consists of 10 families, each with a *matai* (family head).

Apolima, together with neighbouring Manono and Nuulopa islands, is listed on the UNESCO tentative list of sites of outstanding universal value for their cultural values *"The landscape of Manono, Apolima and Nuulopa resembles the unique historical traditions and cultural values of the past and present settlement of people of Samoa."* (UNESCO 2006).

The community lead a very traditional, semi subsistence lifestyle known as fa'a Samoa. They are conservative, attend church and include many Christian traditions in their daily life such as nightly hymns and prayers (saa) and taking Sundays as a day of rest where men are not allowed to tend to their plantations. English is not widely spoken on the island, limited to the pastor, his wife and young adults who have studied abroad and returned.

There are very few visitors to Apolima, usually Samoan working people (Tuipoloa-Utuva 2017). Palagi visitor (tourist) requests go through Manono or the Samoan Tourism Authority and usually consist of an overnight stay hosted by one of the families. Children travel to the main island each day to attend school leaving around 6:30 am and returning mid-afternoon.

Figure 6 The Apolima Tai community, August 2022

3.6 Existing infrastructure

The village consists of approximately 15 houses and 1 church. Most of the houses are open *fale* style, with timber framing, concrete floors, and corrugated iron or thatched roofs. A few are *palangi* style with gibbed ceilings and walls. Most have an associated cookhouse and a storage shed for coconuts, husks, and shells. These are open timber framed structures with a corrugated iron or thatched roof with bare earth floors (Figure 7).

There is a solar power system supplemented by a generator, as required.

Taps and toilets are plumbed and fed from rainwater tanks. Grey water management is very basic; most kitchen sinks just drain into the ground to seep away. There are septic tanks for the toilets.

The only source of drinking water on the island is a natural spring which has been concreted to help preserve it and has strict protocols around its use to avoid contamination. It is much valued by the community.

Most cooking is done on open fire, using coconut husks, shells, and timber. Each cookhouse has a 2-ring gas cooker which is used when catering for visitors or on special occasions.

There are no roads or vehicles other than 3 *alia* (boats). Access tracks to the spring and plantation are unformed and muddy. There is a concrete wharf in disrepair and unusable and an old concrete slipway at the beach.

Waste management consists of storing plastics, tin and nappies which are returned to the main island every two weeks via a special boat. Rubbish was observed stored in hanging feed bags and sealed plastic buckets. Significant amounts of mixed waste were also observed thrown into the bush surrounding the village and in concentrated areas within the village. Food scraps are fed to pigs or thrown into the forest to decompose.

There is a lighthouse at the north-western end of the island which is accessed via steep concrete steps which are in poor condition.

There are wire and corrugated iron fences throughout the interior which attempt to protect various crops from rooting pigs.

There is phone and internet coverage, which can be affected by heavy rain.

Figure 7 (clockwise from top left) Concrete channel near the source of the natural spring; rainwater tank in village; kitchen greywater system; typical coconut storage; solar power station.

3.7 Target species ecology and impacts

Distribution

Kiore also known as Pacific rat (*Rattus exulans)* are present (confirmed by one specimen caught and identified by the DOC/MNRE field expedition in November 2022). The presence of ship rats (*Rattus rattus*) is indicated by community responses to identification sheets and reports of distinctive holes in coconut shells but requires further research to confirm. The presence of Norway rats (*Rattus norvegicus*) is deemed unlikely based on absence of anecdotal evidence from the community. The presence of mice is unknown.

The Global Invasive Species Database records established populations of Kiore, Ship and Norway rats on the main island of Upolu to the east. Kiore are also found on the large island of Savai'i to the west, and on both islands in the Aleipata group to the east (Nu'utele since 1991 and Nu'ulua, since 2003) (Global Invasive Species Database 2021). A partially successful eradication operation of Kiore and Yellow Crazy Ants (*Anoplolepis gracilipes*) was undertaken on the Aleipata group in 2009. Rats were successfully removed from Nu'ulua but not Nu'utele (Butler 2011).

Origins

Community elders report rats as always having been present in their lifetime with no knowledge of when they first appeared on the island. All three rat species were caught in Apia in 1924-25 (Boxton & Hopkins 1927) and Polynesian rats were common across the main islands of Samoa in the 1950s (Marples 1955) but likely present from much earlier.

Breeding, home range, preferred habitat

Rat numbers, densities, and reproductive cycles on Apolima are unknown. However, experience from other tropical islands suggests that a proportion of the rat population is likely to be breeding at any time of the year and peaks in breeding activity are likely to coincide with periods of increased rainfall (Butler et al 2011). During the Aleipata operation, rats were confirmed to breed year-round on Nu'utele and Nu'ulua giving weight to this assumption (Butler 2005).

The smallest home range size reported in literature is 0.015 ha in area for kiore which have smaller home ranges compared to ship rats (Wirtz 1972; King and Forsyth 2021). The size of the home range of breeding adults is not affected by density fluctuations or reproductive activity (Wirtz 1972), but it is likely that some individuals will not be actively foraging at any point in time e.g. pups and breeding females. Weaning times reported for kiore (Wirtz 1972; Tobin, 2005) and ship rat (Cowan, 1981) range from 21 to 28 days.

There is some evidence to indicate that kiore can be dominant over ship rats on some islands in the Pacific, which at odds with the situation in temperate environments such as New Zealand (DOC 2023; J Reardon per comms).

Impacts

The effects of rats on the livelihood and wellbeing of the Apolima Tai community are obvious. All food and stores must be kept in sealed containers, otherwise they are prone to being consumed or contaminated by rats. Agricultural yields are diminished as rats consume crops such as kumara, yams, cocoa, and taro. Rats feed, chew holes, urinate, and defecate and often ruin household items, such as pillows and clothing. There is a potential increased risk of diseases such as leptospirosis and salmonellosis owing to the presence of rats in commensal areas and rats may act as hosts for mosquitos. As such, the eradication of rats would lead to increased food security, reduce the risk of illness, reduce stress, and free up time for other activities.

The impacts of introduced rats on biodiversity and island ecosystems is well documented. Introduced rats have a significant impact on island ecosystems and have been one of the leading causes for species extinctions of mammals, birds, invertebrates, and reptiles (Atkinson 1985; Towns et al. 2006; Hutton et al. 2007; Duncan and Blackburn 2007). Rodents have significant impacts on seabirds, preying upon eggs, chicks, and adult birds thereby causing population declines, with the most severe impacts on burrow-nesting seabirds (Atkinson 1985; Jones et al. 2008; Towns et al. 2006). In addition to the predation of fauna, rats feed opportunistically on plants and alter the floral communities of island ecosystems (Campbell and Atkinson 2002); in some cases degrading the quality of habitat for fauna that depend on the vegetation (Wegmann 2009; Young et al. 2010).

On Apolima there is a noticeable absence of seabirds. Both kiore and ship rats are likely to have a negative impact on bird species that breed on these islands, especially the smaller ground-nesting species, due to direct predation of eggs, chicks, and nest disturbance.

PLANNING ISSUE 3:

Monitoring should be undertaken to ascertain the absence/presence of other rodent species (ship rats, Norway rats and mice) and distribution of target species. Monitoring activity should include:

- *Trapping.*
- *Static monitoring devices such as tracking tunnels, chew cards, trail cameras.*
- *Bait availability study to help inform population estimate. (see also Planning Issue 11 – Bait availability study)*

3.8 Historical pest control

A few years ago, the mayor of Apolima introduced cats to control rats. The community have since formed strong views that cats are effective at controlling rats as rat sightings around the village have reduced significantly since their introduction. The cats are now breeding and are considered as household pets.

The community has never used poison to control rats (and do not use pesticides or manufactured fertilisers) but have undertaken some limited and sporadic trapping in the past.

Historical pest control for species other than rats is unknown.

PLANNING ISSUE 4:

Potential impacts of and risks to cats (during and after a rodent eradication) need to be discussed with the community and an appropriate plan agreed.

Cats will be at risk of secondary poisoning during and immediately after the operation via scavenging of poisoned carcasses (see section 7.5). After a successful operation and elimination of rats as a food source, cats may require more feeding and may prey increasingly on other species such as birds, insects, skinks, and geckos (see section 4.4).

3.9 Other pests

Invasive pests present include the Rhinoceros/Coconut beetle, Yellow crazy ants, Common myna, and Crown of Thorns starfish in the surrounding marine environment.

The presence and management of domestic and feral livestock is a key part of any rodent eradication. The island is home to many pigs (domestic and feral), domestic free-range chickens, cats, and dogs. All these species will require management plans to ensure a successful operation.

Domestic pigs

There is a large and healthy pig population (estimated >200, many sows seen with large litters) which are kept for economic purposes and as a food source. Pigs are semi-free range. They are fed up to three times a day with coconut, breadfruit, and food scraps in the village area. They are nominally penned at night but often escape. Extensive pig rooting was observed throughout the island and pig damage to crops was often reported as a significant issue by the community members during interviews. Pigs are also likely suppressing local invertebrate and ground nesting bird populations.

Figure 8 Left: Pigs in the village, Right: a typical sight – sow with many piglets

Feral pigs

There is a small feral pig population. Evidence of breeding was seen in November 2022 when a nest with four piglets was found along the crater ridge. Individuals were sighted numerous times along the ridge indicating they range across the entire island. This population is not hunted by the locals but if they find piglets, they will take them back to the village to domesticate.

Chickens

Chickens are kept as an occasional food source, for special occasions and visitors. Any chicken eggs are collected and incubated not eaten. The chickens are fed daily with rice and coconut and are free to roam. Their range seems to be limited to the village area as none were seen on the ridge nor in the plantations. Population estimate is 50 – 100 chickens. It is likely they play a role in suppressing local invertebrate and herpetofauna populations and the community complained of the damage caused by their digging.

Cats

As described in the previous section, cats are kept as pets and to control rat numbers. They are fed daily and range freely.

Dogs

Dogs are generally considered as “roaming” but some households keep them as pets. The community reported issues with the dogs, such as: “digging anywhere”, noise, faeces and scavenging in rubbish.

PLANNING ISSUE 5:

Accurate population estimates of all livestock and pets along with their ownership is required to help inform management options.

Figure 9 left: pig rooting in the plantation; right: pigs roaming freely on path to plantation

4. Why do it?

4.1 What is the goal?

The goal of the project is to enhance community and ecosystem resilience to climate change through the eradication of rats from Apolima island.

4.2 What are the objectives, outputs, and desired outcomes?

Table 1. Eradication project objectives, outputs, and desired outcomes

Area	***Objective***	***Output***	***Outcome***
Community / Biodiversity	Rats are eradicated from Apolima island	Implementation of the eradication project and subsequent report	Apolima is rat free and remains so
			An increase resilience of the community through more secure food production and storage and reduced public health risk
			An increase in seabirds nesting in areas inaccessible to pigs and cats
Biosecurity	Apolima island remains free of rats	Implementation of biosecurity and ongoing reporting	Apolima is rat free and remains so
			Capacity development for community, control, ownership
Partnerships	Work collaboratively to achieve conservation outcomes	The success of partnerships is reported on	Cost and effort are reduced, and positive relationships are built
Community	Community is supportive of eradication and ongoing biosecurity	Community attitudes are measured and reported	The local community benefits from the eradication: reduced damage to crops and belongings, reduced risk of disease and reduced daily effort to protect food from rats
Knowledge	Capacity and knowledge are increased and shared	Project documented	Future projects benefit from knowledge gained in this one.
			Increased national capacity via partner organisations e.g. MNRE, SPREP, local community

PLANNING ISSUE 6:

Consultation and engagement need to occur with all key stakeholders to understand and agree on project objectives and intended outcomes. What do you want this island to look like in 50 years time?

To date it is clear that improved resilience via increased food security and reduced health concerns are shared desired outcomes. Uncertainty remains regarding environmental or biodiversity outcomes.

DEPENDENCY 1:

Key stakeholders can clearly describe and agree on the objectives and desired outcomes of the project.

4.3 What are the ecological benefits of eradication?

The benefits brought about to avifauna, herpetofauna, and invertebrate populations on Apolima are likely to be limited due the ongoing presence of pigs, chickens, cats, and dogs. There may be some recovery of species in areas with limited or no accessibility to cats, pigs, and chickens such as steep slopes and the crater rim. Removal of feral populations should be included as a goal to maximise the ecological benefits and benefits to livelihoods. Ecological benefits have not been identified as a key driver or outcome for this project.

Potential ecological benefits include:

- Increased nesting and breeding of seabirds in areas inaccessible to pigs and cats, leading to longer term improvement to reef health from increased input of micronutrients from their guano.
- More protected habitat for the near threatened Samoan Broadbill/fly catcher.
- Recovery of plant and tree species whose seeds and seedling are eaten by rats.
- Improved pollination rates.
- Improved resilience over time to introduced weed species as the forest recovers.
- Improved land crab recruitment.

4.4 What are the potential unintended ecological consequences of eradication?

Negative ecological consequences could include short-term impacts to non-target species due to direct or indirect poisoning from the use of rodenticides. It is likely that individual mortality within the island populations of avifauna may occur. See Table 2 for relative risk for different species based on their diet and feeding stratum.

There may also be short-term fluctuations in the abundance of resident species, for example the removal of rats could lead to an increase in invertebrate species that could in turn lead to short term impacts to plant life.

There is also potential for an increase in invasive plants that may have been suppressed by rats consuming seeds.

If cats remain on the island after rodents as a food source are removed, they may have a short-term increased impact on other species such as birds, insects, skinks, and geckos. The number of feral cats would decline in the longer term with the reduced availability of rats as a food source. Dogs, pigs, and chickens will continue to have the same impact as present.

4.5 What are the potential positive and negative social consequences of eradication?

Positive social consequences anticipated from the eradication of rats from Apolima include:

- Increase local food security in the long-term from the likely increase in agricultural crop yields from locally grown produce such as kumara, yam, cocoa, taro, banana, coconut, tomatoes, and cabbage.
- Increase local food security from eliminating rat consumption and spoiling of stored dry goods and food products.

- Improve hygiene and sanitation in living and cooking areas due to the absence of rats as well as eliminating the contamination of water sources.
- Improvement in mental and physical health from the absence of rats by not having to clean the mess of rats daily, and the time spent protecting food stores from rats.
- Increase biosecurity awareness and practical biosecurity processes instigated by the community, which may help prevent new invasive species arriving on the island and negatively impacting the community.
- Upskilling of local community members in rat ecology, monitoring, and biosecurity.
- Upskilling collaborating partner organisations (SPREP, MNRE) in the planning and implementation of an eradication.
- Strengthening DOC's relationships with MNRE and other key stakeholders in Samoa.
- Community seen as national leaders in eradicating rodents and, as a result, other projects in Samoa may follow the example.

Possible negative social consequences of eradicating rats from Apolima could include:

Short term

- The time and resources spent leading up to and during the operation to ensure the eradication has the best chance of succeeding. This includes changing lifestyles, prioritising waste management, clearing agricultural crops that may act as an alternative food source to rats during the eradication period, and other actions that may be inconvenient to ensure alternative food sources and habitat for the rats are reduced as much as possible during the operational phase of the eradication.
- Livestock either culled or temporarily moved until withholding period has ceased.

Long term

- Not achieving the expected benefits to the community's livelihood due to the ongoing impact of livestock, especially pigs.
- All eradication operations carry the risk of failure. If this were to occur, a loss of support from the community for future efforts and projects could result.
- Extra vigilance and ultimately time spent on biosecurity and transport of goods to the island to avoid a rat population re-establishing would need to be put in place. Not only by the community, but by families, businesses, etc. who ship goods to the island.

4.6 What outcome monitoring is recommended?

Agricultural yield

1. Currently losing 50% of cocoa crop to rodents
2. Currently 100% loss of kumara crops

Vegetation

- Seedling counts
- Establish photo points for monitoring changes in vegetation
- Capture baseline photos before eradication

Invertebrates

- Baseline surveys using pitfall traps (away from village area due to the effect of chickens and cats)
- Repeated surveys at appropriate intervals after eradication
- Visual crab counts (baseline survey and repeated at appropriate intervals after eradication)

Seabird numbers

- Establish a baseline and monitor yearly via boat surveys, acoustic monitoring, transects, burrow monitoring

Public Health

- Establish baseline data on time/effort currently spent on rodent related hygiene practises and incidence of disease or illness

PLANNING ISSUE 7:

Specific, measurable, achievable, relevant, and time bound (SMART) measures need to be defined for outcome monitoring.

Baseline values need to be captured before the eradication operation is undertaken.

5. Is it achievable?

5.1 Is eradication the most appropriate pest management tactic?

Taking no action (maintaining the status quo) should always be considered and compared to the cost and benefits of an eradication. Advantages of taking no action include no project expenditure of money or resources, no impact or effort required of the community and no requirement of the community to change their current practises. A form of sustained rodent control is already in place via the introduction of cats. The obvious disadvantage of taking no action is the ongoing crop losses, health and lifestyle issues caused by rats.

Further control actions could be implemented such as trapping and bait stations. These would require ongoing inputs of resources (money and effort) for only marginal improvements on the intended outcomes. Eradication is the only way to fully realise the benefits.

Similar to the Aleipata eradication feasibility study which found that the eradication of rats was of reduced value if nothing was done about the Yellow Crazy Ants (Butler 2005), on Apolima the value of eradicating rats is limited whilst current pig (and to a lesser extent chicken and cat) management practices remain.

DEPENDENCY 2:

Key stakeholders understand the applicable pest management options for Apolima and make an informed decision to proceed with a rodent eradication.

5.2 What tools will be used?

Trapping is not considered an option for eradication of rodents on islands larger than 5ha due to the intensive effort required and risk of human error to set and check traps at 20m intervals across the entire island (>2500 traps in this case) as well as the tendency for a small percentage of rodents escaping or becoming wary of traps making them increasingly harder to catch. Therefore, this method does not achieve the eradication principle of exposing every individual.

The most suitable method of eradication for this site is the use of 2nd generation anticoagulants combined with a highly palatable cereal bait, distributed across every rat territory in a methodical and comprehensive manner.

Of the second-generation anticoagulants available, brodifacoum is the most commonly used anticoagulant in rodent eradications (Howald et al. 2007, Parkes et al. 2011).

This method has been developed and refined over many years and in many different eradication projects, in a range of different ecozones, including on tropical islands. Anticoagulants cause death in rats by preventing blood clotting, causing internal haemorrhaging. The effects of the anticoagulants are not felt by the rats until a few days after consumption, meaning bait avoidance or shyness is unlikely before receiving a lethal dose. 2nd generation anticoagulants are more potent and more persistent than 1st generation anticoagulants, but do not require multiple feeds and a lethal dose can be attained through a single feed of bait. This is a characteristic suited to tropical rodent eradications where competition for bait from non-target consumers (such as crabs and invertebrates) is usually high, and natural food availability is high year-round.

Hand broadcasting bait is not feasible due to the size of the island and the terrain. Like trapping, to ensure bait reaches every individual rat, it would need to be sown by hand on a 20m grid covering the entire island. The steep slopes, dense vegetation, vertical cliffs and near inaccessible caves would make accurate human access to the entire island impossible.

Similarly, widespread use of bait stations is not feasible for the same reasons as above. Additionally, bait stations are a less reliable method than aerial broadcast as there is greater chance of an individual rat not coming in contact with bait. Also, if there are multiple target species (kiore and ship rats) one may dominate the station preventing access by the other. All three of these techniques hold potential for human error, leaving gaps in coverage.

Due to the difficulty in easily accessing the entire island on foot (steep slopes, vertical cliffs), and the imperative that bait reaches the home range of every rat (which can be as small as 150 sq m which is roughly an area 12m by 12m), broadcast aerial application is required to ensure the required distribution. The village area, (approx. 3ha, 250mx150m), would be excluded from aerial bait application and instead treated by hand baiting, bait stations and bait trays as would other special areas such as buildings, structures, and caves.

Application of bait by helicopter is well proven, low risk and each application could be completed in a single day. However, as there are no helicopters based in Samoa, a helicopter would need to be imported at significant cost (>$100,000 in addition to operational costs of >$150,000) along with an appropriate bucket, experienced pilot and supporting engineer.

Use of Unmanned Aerial Vehicles (UAV) or drones to broadcast the bait is another option. It is likely that each application could be completed in 2 days and the cost would be lower than the overheads associated with a helicopter but still ~$100,000. However, this is an emerging technology, and a recent review of UAV aerial baiting operations has identified reliability issues (Appendix 3 / DOC-7058623). For operational deployment of drones, the principal requirement is line-of-sight control, such that a drone can always receive a signal from the operator, this may require installation of a repeater(s) on the ridgeline.

Table 5 Comparison of helicopter and UAV options

	Helicopter	UAV
Cost	~$280,000 which includes ~$100,000 shipping costs, opportunities to cost share if other helicopter work could be aligned with project timelines	~$100,000, drones are much easier to transport (although batteries can be difficult to ship by air), generally charge on a daily rate
Reliability	Well proven, ready for immediate deployment	Emerging technology, building a successful track record on flat sites but more development is required to achieve reliability required for eradication operations on steep terrain
Duration	Each application could be completed in a single day, meaning smaller windows of suitable weather conditions could be used	A single application may take more than one day (could be minimised by using multiple UAVs) meaning a longer weather window would be required

Bait storage and load site	Could be stored and loaded on Upolu (saving additional shipping and logistics costs)	Bait would need to be shipped and stored on the island or a barge (with associated costs)
Supporting logistics	Could use Faleolo airport. Contract would include pilot, engineer, ground crew, bait bucket, bucket calibration, fuel (~17 drums)	Requires line-of-sight control so installation of a repeater on the ridgeline may be required. Contract would include pilot(s), ground crew, calibration, and fuel.

PLANNING ISSUE 8:

An options analysis needs to be completed to compare the relative cost, availability, performance, and logistical support required of using a helicopter versus an UAV (drone) for aerial baiting.

An options analysis will allow budget and timelines to be planned more accurately.

PLANNING ISSUE 9:

An options analysis needs to be completed to compare the relative cost, availability, performance, and associated shipping logistics of the two bait options.

There are two baits available PestOff20R produced by Orillion in Whanganui, New Zealand and Bell Laboratory's "Island" bait produced in the USA. Both are proven in the field, and both contain the same 2nd generation anticoagulant brodifacoum.

An options analysis will allow budget and timelines to be planned more accurately.

5.3 What is the proposed eradication design?

Timing of bait application would be in the driest time of year, June – August. Lower rainfall means bait will be present and palatable for longer as it will not lose form and breakdown as fast as when rainfall is present.

There are significant preparatory actions that will need to be taken on island before the operation can proceed to ensure all rats have access to and take the bait (see Section 5.4). This is achieved by removing alternate food sources and removing places that could harbour rats away from the bait eg piles of coconuts, open rubbish pits. These management actions may involve changes to infrastructure such as installing more septic tanks, or how coconut resources are stored, changes to waste management practises ie cleaning, sorting, collecting and carefully storing all household rubbish in sealed buckets (includes food waste), storage of all human food in rat proof containers. These preparations may take weeks or months and are vital to the success of the operation.

Two aerial broadcast applications of bait (~5t total, application density not yet known) along parallel flight lines guided by GPS across entire island except the village area, spaced at least 10 days apart. Each application would also include perimeter baiting. Two applications of bait help counteract unforeseen bait losses (e.g., from weather); allows young rats emerging from nests after the first application to be exposed to fresh bait; and a second application may help target a sub-dominant species if two rat species are present.

Bait availability monitoring will occur during the first and second application over the first four nights. If bait availability is high after the fourth night of the first application, a reduction in bait application rates for the second application may be considered; however enough bait will be on hand to apply the same amount of bait in the 2nd application.

A 20 metre by 20 metre grid of approximately 80 bait stations within the village and spring areas and bait trays inside every buildings and structure with 20 pellets per tray will be placed on the same day broadcast application is occurring. Each bait tray will be monitored daily and replenished, with a record of bait take kept. Bait trays will be checked daily until 3 consecutive days of no bait take has occurred, then will be checked weekly for a fortnight.

Other areas that have been identified as requiring special baiting include caves, the spring, areas of rubbish/material that might act as three-dimensional habitat for rats, coconut stores in cookhouses and domestic vegetable gardens.

PLANNING ISSUE 10:

Once the means of aerial distribution is known (helicopter or UAV) then a specific flight plan needs to be developed which will inform the total amount of bait required along with aerial logistics such as how many loads, total flying time, which in turn affect final cost.

PLANNING ISSUE 11:

A bait availability study should be undertaken to help inform the most appropriate bait application rate and understand rodent and non-target take. This in turn informs the total amount of bait required for the project and the aerial logistics i.e., how many loads, total flying time, etc.

This study should be undertaken at the same time of year as the proposed eradication.

PLANNING ISSUE 12:

All sites that have special baiting requirements (e.g., buildings, storage areas, areas of rubbish, caves) need to be identified along with an appropriate method of baiting and management plans where appropriate to remove or mitigate these sites.

These management activities may involve tasks like clearing rubbish piles, sealing access, etc.

5.4 Can all individuals be placed at risk?

The proposed eradication design (timing, spatial distribution, and intensity) should reasonably put all individuals at risk as it follows best practice provided non target consumers can be managed to avoid interference. Contingency bait will be available to use, based on monitoring of bait take.

Non target consumers (chickens, pigs, dogs) will need to be managed to ensure bait is available to the target species as well as to avoid contamination of the human food chain (the latter discussed in Section 7.5). This could include containment of some sort e.g. penning, or temporary or permanent removal from the island and would apply to domestic, free ranging and feral populations. This is a key factor that adds length and complexity to the eradication e.g. the effort to find and capture or kill all feral pigs.

The 20x20m grid proposed in the village area is more intensive that the minimum requirements (25x25m) suggested for best practice for eradication of kiore, providing confidence and a larger margin for error for bait coverage to ensure every individual has access to bait.

No eradication attempt would proceed without full landowner permission. The island community have indicated full support if a decision to proceed was made by the mayor.

One of the significant risks associated with the eradication is the presence of alternate food sources which may decrease the likelihood of rats consuming the bait. Some potential alternate food sources that would need to be managed have been identified (Table 6).

Table 6 Potential alternate food sources that would need to be managed**.**

Source	Issue/description	Management required
Wastewater (grey water)	Most (all?) kitchen sinks currently drain straight into the ground rather than closed tanks. Rats could potentially survive on fat and food scraps from sink waste.	• underground septic tanks? • Use sink plug sieves to catch food waste which can be emptied into sealable food waste buckets.
Household rubbish	Household rubbish, particularly food packaging, can be a food source to rats. Household rubbish is often not cleaned well and while some is stored in sealed containers for return to the main island, some is stored in hanging bags and some is just thrown direct into the forest.	A waste management system needs to be in place prior and during the operational period, where household rubbish is cleaned, sorted into plastics, glass, compostable and general waste, and placed in sealed buckets. These buckets will need to be collected and replaced daily and stored centrally and disposed of at an appropriate time and place.
Food waste	Discarded food from meal preparations, to discarded coconuts, are a food source to rats. Current practice is to feed to livestock or discard in the bush.	• Household food waste will be part of the household rubbish system described above. • Pictorial educational materials will be used to remind people to dispose of food scraps appropriately.
Livestock and domestic animals	Livestock (chickens and pigs) as well as domestic animals (cats, dogs) and feral pigs provide a source of food from food and scraps fed, animal excrement, chicken eggs and chicks.	• Appropriate management of livestock and domestic animals immediately before, during and after the eradication needs to be discussed and agreed with the community. • Options include culling all livestock prior to operation and replacing afterwards, securely penning a number of animals….
Human food	Human food stores can be a source of food for rats.	Community to store all food in rat proof materials. Storing fresh fruit and vegetables in rodent proof containers is challenging in such humid and hot environments, so a temporary ban immediately prior, during, and the weeks after the baiting phase – using dry goods, frozen goods, and canned goods only – may be required.
Rubbish areas	Areas where rubbish is discarded, i.e. in bush, around village can often house rubbish that can act as food and habitat for rats.	Several weeks prior to the baiting, all areas of rubbish will need to be collected and transported from the island. From this point on, all household rubbish will need to be collected and managed as agreed in project planning. During the baiting phase, bait will be specifically broadcast in rubbish holes to ensure rat access to bait.
Fish cleanings?	Remnant cleanings/entrails from fish processing can act as a food source for rats.	Extreme vigilance is required in the clean-up of fish gutting/cleaning. Processing areas should be on a hard, wipeable surface, so that scraps can be easily recovered and stored in sealable containers, if not disposed of at sea.

		If disposing at sea, should be far enough away from the island so there is no risk of remnants washing to shore.
Agricultural produce	A range of crops are grown and some may fruit/ripen during the operational period.	Potential to harvest before operation and/or avoid a crop for the operational period.
Domestic garden produce	Domestic gardens produce tomatoes, capsicum, cucumbers, greens, and other food sources for rats.	An agreed method to manage this needs to be in place, one option may be to harvest these gardens a week before bait application.
Coconuts	Coconut husk piles are common (used for cooking), and husks can sometimes contain remnant coconut meat that can act as a food source to rats.	Making available gas cooking stoves and gas bottles for use prior, during and post-eradication to avoid the need for coconut husks and shells as a fuel source.

PLANNING ISSUE 13:

Management plans are required for the non-target species which would compromise the eradication (domestic and feral pigs, chickens, and dogs). Management options for each need to be identified and discussed with the community and a preferred option identified and committed to. The required management actions are likely to have a significant impact on the community's daily life in the lead up to, during and after the eradication so it is essential that the affected parties fully understand the need for these actions, what is involved and the importance of completing them to the required standard.

Potential options include culling/removing all livestock before the eradication and replacing them afterwards, securely penning all or some livestock for the duration of the operation.

PLANNING ISSUE 14:

A definitive list is required of all alternate food sources available to rodents. E.g. human food, human waste, crops in plantations or in storage, livestock food, etc. Management options for each need to be identified and discussed with the community and a preferred option identified and committed to. The required management actions are likely to have a significant impact on the community's daily life in the lead up to, during and immediately after the eradication so it is essential that the affected parties fully understand the need for these actions, what is involved and the importance of completing them to the required standard.

A part of this issue is to undertake research to better understand the timing and availability of each crop on the island as an alternate food source to the target species. Species that are usually fruiting or available to rodents at the time of year of the proposed eradication may require specific management actions to reduce the risk e.g., early or total harvesting, planning ahead and avoiding a specific crop for the year of the eradication.

DEPENDENCY 3:

The Apolima community agree to all required management activities to reduce the risk posed by non-targets and to eliminate/reduce alternate food sources available to rodents.

5.5 Can the target pest be detected at low abundance?

There are a range of tools available for the detection of rats, and combined with intensity and time, there is a high level of confidence in the ability to detect both kiore and ship rats in low abundance based on significant operational experience on both temperate and tropical islands. Suggested tools include Victor snap traps baited with high oleic content peanut butter and icing sugar, peanut butter infused waxtags and motolures dispensing peanut butter one hour after sunset and one hour before sunrise paired with motion activated trail cameras. Toasted coconut has also been proven as an effective lure in the Pacific.

It is suggested that motolures paired with trail cameras; and transect trapping with Victor traps are employed post-eradication especially in the village area as this area may pose the highest risk of failure. A suggested time frame of at least 6 months after the 2nd bait application is suggested as the fecundity of surviving rats in this environment would be expected to have a reasonable distribution and therefore reasonable detection probability by this stage.

5.6 Can pests be killed faster than they breed?

Kiore are able to exceed population densities of over 200 rats per ha on tropical islands, and ship rats 119 per ha (Harper and Bunbury 2015). Mean litter size for kiore in tropical islands is 3.5 and 4.5 for ship rats (Harper and Bunbury 2015). Young can breed towards the end of their first season of birth – with ship rats more likely to reach sexual maturity earlier. Even given the maximums of breeding capacity, enough bait will be applied to kill all individuals in a population faster than they can breed. The expected latent period between bait ingestion and death is likely to be approximately 5 days (DOC 2022).

6. Is it sustainable?

6.1 Can immigration of the target pest be managed?

Both species of rat are present on Savai'I, Manono and Upolu. While all these islands are well beyond the swimming range of the target species, risk does exist via the daily boat trips to Upolu. The alia (boats) are small and generally overnight on Apolima but there is the potential that rats could stowaway on the boats or within cargo being transported.

Biosecurity protocols for sending and receiving goods, cargo and passenger transfer will need to be developed and adhered to by the community.

A monitoring network including permanently baited bait stations and traps should be installed around the landing area on Apolima and Apolima Uta.

An incursion response plan should be developed, and appropriate training provided to the local community and agency.

The community have good biosecurity awareness and several precedents exist providing a solid foundation on which to further strengthen biosecurity for the island. The island experienced an incursion of the giant African Snail which the community believe came with plants. They responded quickly and effectively, using salt to kill the snails, because they knew of the impacts the snails were causing in Apolima Uta. The people we interviewed told us that since the incursion, they have banned the bringing of plants, including taro seedlings, from the mainland. Cattle have also been banned from the island due to the destructive impact on soil.

The islands response to the Covid pandemic is another example of the community's willingness and ability to comply with protocols for the benefit of the whole community.

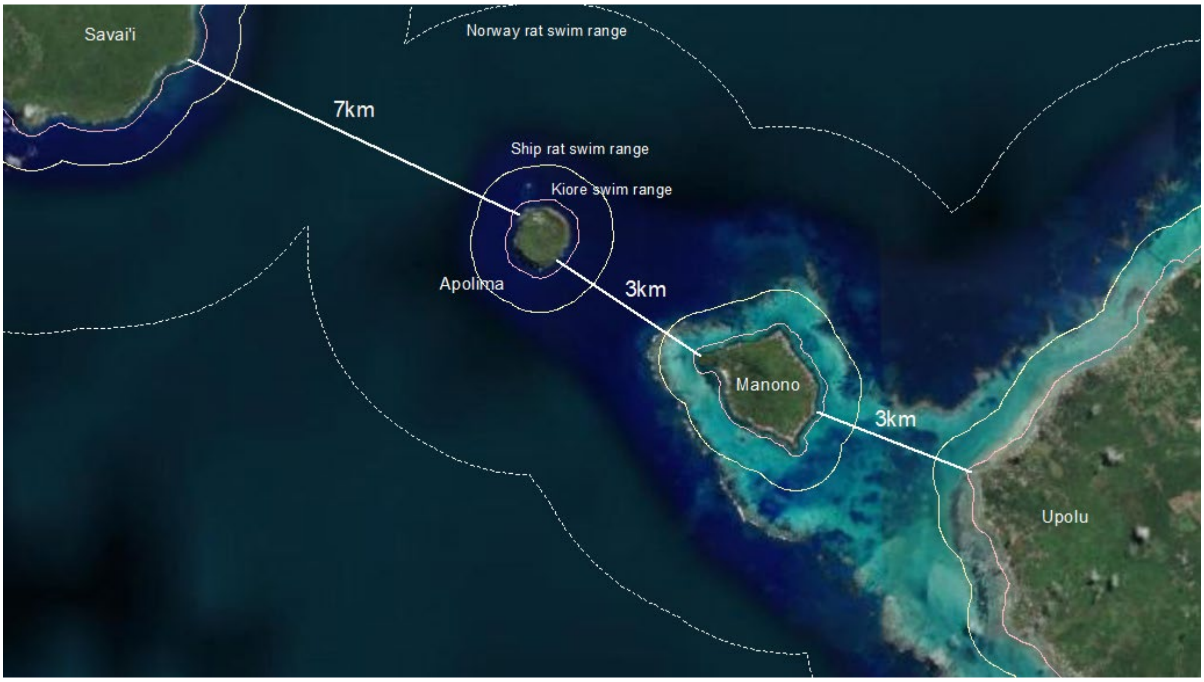

Figure 10 Map of Apolima showing proximity to other islands**.**

PLANNING ISSUE 15:

Engagement with boat operators, regular passengers and cargo providers is required to ensure future biosecurity protocols will be feasible to implement and sustain.

6.2 Can dispersal be managed?

Containment of the operational areas naturally occurs given the site is an island.

7. Is it acceptable?

7.1 Do local island families support eradication?

The families of Apolima Tai were supportive of the eradication project at the initial two consultations in August and November 2022 with the proviso that risk to children, fresh water and livestock could be managed safely. However, they are not yet aware of the full requirements and impacts the project would bring to their daily lives before, during and after the eradication.

Significant further consultation is required to ensure the community fully understand what is required for a successful eradication and actions such as trialling penning pigs could be part of this consultation.

The associated community of Apolima Uta, on the island of Upolu, are not required to be consulted on this project as they do not have a say in what the island decides.

DEPENDENCY 4:

Support from the community to proceed with the project is given (via the mayor) once consultation is complete and all required management actions have been agreed.

7.2 Do key stakeholders support eradication?

SPREP are supportive of an eradication of rats from Apolima and originally raised the request to MISCCAP. Resources to directly support the project appear to be limited due to a large and diverse existing work programme.

MNRE are supportive providing the local community is. The project is an opportunity for capacity development. Similar resourcing issues exist.

The community is well practised at working under the leadership of the mayor. It is clear that whatever decision or commitment he makes, the community will support. Most individuals who were interviewed in November 2022 were at first wary but then supportive of the use of toxin once assurance was provided that the risks to children, water and animals could be managed. There were a couple of individuals who were flatly against the use of any toxin but who reiterated that even though they disagreed they would support the consensus and decision of the mayor.

Further consultation is required with all key stakeholders to ensure they understand what the project would require of them.

PLANNING ISSUE 16:

Further engagement with key stakeholders is required to define a long-term vision for Apolima. Currently there is no agreed and defined vision for the island post eradication and uncertainty as to the reasons for undertaking it.

PLANNING ISSUE 17:

Engagement with stakeholders is required to ensure they fully understand the implications, impacts and tasks required of them. E.g. resource commitment, prioritisation, in country logistical support, etc

DEPENDENCY 5:

Key stakeholders agree on and commit to a long-term vision for Apolima.

7.3 Does the project have institutional support?

There are six key institutions involved in this project, listed below (Table 7). Likely roles have been described but further work is required to define and agree roles.

Table 7 Key institutions involved in the project.

Institution	Type	Key contact	Role (yet to be confirmed)
NZ Department of Conservation (DOC)	NZ government	Souad Boudjelas (MISCCAP project manager) Veronika Frank (Project Lead)	• Liaison with partners • DOC's inputs coordination • Operational planning • Provide field staff • Technical input and capability building • Part of Project Working Group

Ministry of Natural Resources and Environment (MNRE)	Samoan government	Czarina Stowers	• Governance • Liaison with island community • Lead community engagement • Part of Project Working Group • Advice around local legislation and regulations • Provide field staff
South Pacific Regional Environment Programme (SPREP)	INGO	Dave Moverley	• Lead on awareness-raising • Part of Project Working Group • Support with in-country logistics
Apolima Mayor	Local government	Leala Afe Solo	• Support community engagement • Part of Project Working Group • Support with in-country logistics
Predator Free Pacific technical leads IC and BLI	NGOs	Richard Griffiths Steve Cranwell	• Technical input • Part of the Working Group
NZ Ministry of Foreign Affairs and Trade (MFAT)	NZ government	Bex Ansell	• Funding

PLANNING ISSUE 18:
Project roles and agreed resource commitments need to be defined and agreed upon with key institutions involved in the project.

DEPENDENCY 6:

The key institutions involved (MFAT, MNRE, SPREP, DOC) understand and agree on their respective roles and are willing to commit resources to the project.

7.4 Is there political opposition or support?

Apolima island is largely self-governing and in a strong position to make decisions on matters that affect the island and its community. Government agencies respect this autonomy. No wider political influence of relevance to this project has been identified.

7.5 What non-target and environmental impacts are likely?

Anticoagulants, such as brodifacoum, added to cereal baits have been used to successfully remove rodents from numerous islands around the world. As with any vertebrate toxin, there are risks to using it to human health and to non-target species. However, risks are very low in a well-planned and controlled operation (SPREP 2016).

Non-target species

There are several species on Apolima where poisoning of individuals could occur through eating bait directly (primary poisoning) or secondary poisoning (consuming something, including a carcass, that has eaten bait) (Table 8). Bait is dyed green to deter birds to minimise this risk. None of the locally recorded bird species are high risk so there is no requirement to capture and hold any birds. None of the bird species are harvested for consumption by the local community. Cats and dogs are also susceptible to secondary poisoning and may ingest enough residual toxin via scavenging rat carcasses to cause death.

Chickens and pigs are export products as well as food sources for the local community. If they are present on the island during or immediately after the baiting operation there is the risk of secondary poisoning to humans via residual toxin in these animals. This risk needs to be managed.

The mechanism of brodifacoum action in humans is the same as that in other mammals. Anticoagulants are a class of toxin that work to prevent coagulation of the blood. They do this by interfering with the synthesis of vitamin K-dependent clotting factors, which increase's the blood's clotting time. Vitamin K1 is recognised as a very effective antidote (Eason & Wickstrom 2001). Concentrations used in rodenticide products registered in New Zealand mean accidental ingestion of a lethal dose is highly unlikely – a 90kg adult would have to eat over 300 pellets to cause mortality. Small children can be susceptible because of their size and potential for eating baits. These risks are addressed via the use of bait stations and bait trays within the village area, and by extensive community education however the use of these adds risk and complexity to the operation.

Table 8 Non-target species potentially at risk, none are migratory

Species	Common name	Risk pathway	Risk rating
Gallus Gallus	Chickens	Primary consumer, and secondary (invertebrates)	High
Sus scrofa	Pigs	Primary consumer, and secondary (carcasses)	Medium
Felis catus	Cats	Secondary consumer (carcasses)	High
Canis lupus familiaris	Dogs	Secondary consumer (carcasses)	Medium
Gallirallus philippensis	Banded rail	Primary consumer, and secondary (invertebrates and carcasses)	Low
Ptilinopus porphyraceus	Crimson-crowned/ purple capped fruit dove	Primary consumer, and secondary (invertebrates)	Low
Aplonis atrifusca	Sāmoan starling	Primary consumer, and secondary (invertebrates)	Low
Porphyrio?	Swamp hen	Primary consumer, and secondary (invertebrates and carcasses)	Low
Acridotheres tristis	Common myna	Primary consumer, and secondary (invertebrates)	Low
Gygis alba	White tern	Secondary consumer (crustaceans)	Very Low
Lacertilia & Scincidae	Geckos and skinks	Secondary poisoning (invertebrates)	Low

Other environmental impacts

Soil

It is expected that brodifacoum residues will be present in soil for a time after bait application but pose little risk to human health. Soil residues are rarely found in random sampling but have been detected from soil taken from near or under disintegrating baits. Operational monitoring from other projects reported to date suggests soil residues will fall below detectable levels after two to six months. Soil type, temperature, and the presence of soil micro-organisms capable of degrading brodifacoum all affect the degradation time of brodifacoum in soil.

At Palmyra Atoll, residue concentrations decreased with time and brodifacoum was not detected in most of the 28, 36, and 50-day soil samples; trace amounts (≤0.2 ppm) were detected in a few samples from these groupings (Alifano et al. 2012).

Freshwater

Residues are rarely detected in water as brodifacoum has a very low solubility (<10 mg/L at 20°C and pH 7) in water, about the same as chalk. For comparison, table salt has a solubility of 1,200,000 mg/L under similar conditions. Residues in fresh water are extremely rare. Only one ever recorded in New Zealand and three others worldwide despite at least 324 samples analysed over 11 operations. The highest residue recorded was 200 times less than the concentration of the baits used (DOC 2021). On Apolima, bait will not be sown over the site of the natural spring and being sourced from underground means the water should remain safe for human consumption. Bait will not be sown on the roof of buildings to avoid any potential contamination of collected rainwater.

Ocean

It is highly unlikely that there would be any effect on marine life, as very little bait will be distributed into, or towards, the sea by the application method. While some bait is likely to enter the ocean (via rolling down steep perimeter cliffs) at such a low bait density, brodifacoum will be virtually undetectable (Primus et al. 2005; Masuda et al. 2014). A total of 41 seawater samples have been analysed following four operations with none showing detectable brodifacoum (DOC 2021).

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Management plans are required for chickens and pigs to avoid the risk of secondary poisoning to humans and for cats and dogs to avoid the risk of mortality. These plans need to be developed in conjunction with the management plans to manage the interfere to the operation of these species and require full community support. Options may include a withholding period, testing of animals or preventing the exposure of the animals to baits or poisoned carcasses.

DEPENDENCY 7:

The Apolima community understands the management actions required to protect livestock, pets and humans from accidental poisoning are agreed to implementing them. They understand and accept risks to other non-targets.

DEPENDENCY 8:

The community and MNRE understand and accept the negligible impacts of toxin residue in the ocean, soil and water.

7.6 Is the proposed eradication consistent with other planning documents?

Table 9 Alignment between national priorities and the proposed eradication

Document	Relevant Objectives	Agency
Samoa National Invasive Species Strategy and Action Plan (NISSAP) 2019 – 2024	1. To develop appropriate programs and procedures to minimize the impacts of established invasive species by eradicating them where practicable, or otherwise control them 2 To enhance the knowledge and understanding of the Samoan community to increase levels of compliance and support for preventing the introduction of invasive species that have not yet reached Samoa and managing those already here. 4 To foster regional and international cooperation on invasive species, to effectively address the threat of potential new invasions and manage established invasive species.	MNRE, DEC
National Invasive Species Action Plan, July 2008 – June 2011	Superseded by the above	MNRE, DEC
Priority Sites for Conservation in Samoa: Key Biodiversity Areas	Management of invasive species on Apolima Island is one of the government's priority activities given the site's status as a Key Biodiversity Area	MNRE, SPREP

(MNRE & DEC a; MNRE & DEC b; MNRE & SPREP, 2010).

8. What will it take?

8.1 What is needed to effectively manage the project?

A potential project organisation and governance structure are outlined in Figure 11 below and described in Table 10**.** The eradication project team will consist of collaborating agencies – DOC, MNRE, SPREP and the Apolima community as well as potentially other PRISMSS partners such as Island Conservation or Birdlife International. The operational planning and delivery would be managed by the project manager, who will coordinate the field team who will deliver the field component of the eradication. The field team will likely comprise of staff from all the collaborating agencies listed earlier.

Once feasibility is proven and a decision to proceed is made, an operational plan will be produced which will help guide the logistics and task specifications to the detail required to ensure the eradication has the best chance of success.

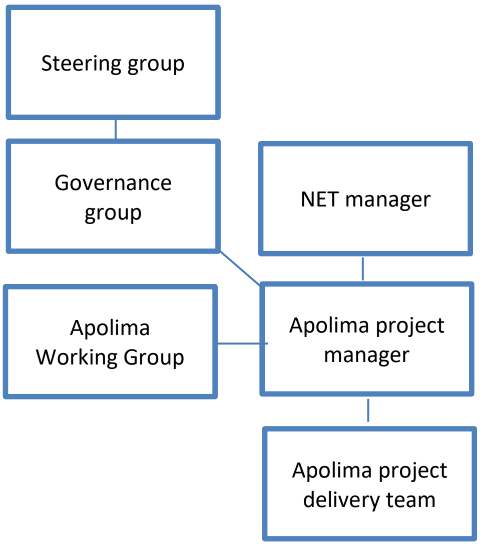

Figure 11 A potential project organisation and governance structure

Table 10 Description of roles of different organisational components. Note this is indicative only and needs to be reviewed and updated as appropriate when the project is ready to progress beyond the feasibility phase.

	Role	Organisation/s involved
Steering group	• Provides strategic guidance	TBC - depends on where funding comes from
Governance Group	• Provides guidance and support to ensure business objectives are being adequately addressed • Ensures the project remains viable and aligned to strategic principles • Reports to Steering group	TBC - depends on where funding comes from
NET manager	• Manages staff who are delivering projects on behalf of DOC	DOC
Project manager	• Leads the operational planning and delivery of the project. • Reports to the NET manager & Governance Group • Consults with the Working Group • Manages the project delivery team	DOC
Working Group	• Guides and support the Apolima project manager in the planning of the feasibility study and the rat eradication	DOC, MNRE, SPREP, Apolima community, PRISMSS partners supporting the PFP PRISMSS programme
Project field team	• Carry out the planning, logistics, and operations as specified by the operational plan and the project manager • Report to project manager	DOC, MNRE, SPREP, Apolima community, PRISMSS partners supporting the PFP PRISMSS programme

8.2 What is the capacity and capability need?

Significant resource and effort in social engagement, including translators, will be required to further community awareness of the impacts of an eradication and the associated management measures required i.e. managing waste, pigs, alternate food sources etc before the project can progress from the feasibility phase. Individuals with field skills will be required to conduct baseline surveys, and a bait availability study.

As local agencies do not currently have the capacity to support this work to the extent required, a project funded role based in Samoa is likely required in order to progress.

Individuals with skills and experience in invasive species eradication will be required for the project. A broad pool of these are available through PRIMSS and MISCAPP partners e.g. Island Conservation, NZ DOC, Birdlife International. While prior experience is required for key roles, many other roles can be sourced locally with training provided as required. A complete list of personnel, their roles, and skills needed should be provided in the Operational Plan.

The project requires a full-time operational lead to oversee the planning and delivery of the operational phase of the project. This includes writing an operational plan and related task specifications, GIS work, seeking technical input where required, communicating with project partners, and fulfilling reporting required by internal and external agencies for the project. An assistant staff (DOC) is also anticipated to help scope and organise logistical arrangements for the operational phase of the project.

There will be extensive preparatory actions required on island which are likely to involve months of planning and execution eg rounding up all feral pigs, changes to waste management practises. As well as potential actions required post delivery for follow up monitoring and ongoing work on cats if required.

For the delivery of the baiting phase, a field team will be required to support aerial operations (i.e. loading site, bait loading and management), achieve the creation of a 20x20m baiting grid in the village area, undertake special baiting in structures, ensuring identified issues relating to alternative food are managed adequately, and bait availability monitoring. The delivery phase of the baiting operation is predicted to take 2 to 3 weeks, not including travel.

A debrief of the operation will occur and be included in a post-operational report that records the baiting phase of the project. Post-eradication monitoring to determine success of the eradication take place approximately 6 months after baiting operations have been completed.

For the baiting phase of the project, attention to detail is critical to allow the project to achieve the two most important underlying principles for achieving the eradication of rats (every rat has access to bait and every rat eats bait). The project field team will consist of several DOC staff with experience and working ethos of invasive animal eradication; along with members of the community and partner organisations for which this will likely be the first time they have taken part in animal control operations in general. This presents an element of risk in that any level of complacency or misunderstanding in regard to key tasks could lead to failure. To mitigate this, experienced DOC staff will lead and oversee critical components of the field delivery, supported by collaborating partners. This model ensures the best chance of success while building the capacity of partner organisations.

In addition to these roles, the Apolima community will have delegated the daily cleaning, collection, and consolidation of household waste during the eradication period.

Specialised equipment will also be required and likely not available in Samoa so procure from NZ or Fiji e.g. helicopter, drones, pilots.

8.3 Can all required permissions be secured?

Known permissions required for the operation are listed in Table 11.

An operation to eradicate Kiore from Nu'utele and Nu'ulua islands in the Aleipata group, Samoa was completed in 2019. This provides a local precedent and suggests a general acceptance of the use of poison bait. However, a project on a populated island is likely to come under more intense scrutiny and regulations.

The registration, control, and management of pesticides in Samoa are regulated by the Pesticides Regulations (2011) administered by the Pesticides Technical Committee within the Ministry of Agriculture and Fisheries. They will need to be consulted on the project details.

An Environmental Impact Assessment (EIA) will be required as per the Samoa Lands, Survey and Environment Regulations 1998. This is required to be completed by an independent entity.

Table 11 Regulatory permissions required for proposed eradication project.

Consent/Permit required	Granted by	Notes
Formal community approval for access to island and broadcasting bait	Mayor on behalf of Island community	
Approval of project plan	CEO of MNRE	
Import of bait into Samoa	Customs?	
Use of brodifacoum within Samoa	Ministry of Agriculture and Fisheries	
Environmental Impact Assessment	MNRE	Need for a preliminary assessment can be waived
Import of helicopter or drones	Samoa Airport Authority & Civil Aviation	
Use of wharf on Upolu for storage of bait, landing and loading helicopter	Samoa Ports Authority	
Use of helicopter or drone on Apolima		
Export of samples and specimens		Previous to the Aleipata eradication attempt, an agreement was made with Auckland Museum to hold specimens on behalf of Samoa

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Sufficient time needs to be allowed to obtain all required permits and permissions. Eradication projects are still novel in Samoa with only one previous operation undertaken. This may also be more complex if the project manager is not based in Samoa.

8.4 What are the infrastructure needs?

An eradication field team would likely be billeted to local families or accommodated in a vacant *fale*.

Storage of ~5 tonne of bait on the island may be needed if bait is broadcast by drones. This is likely to be possible utilising unused buildings or creating a temporary structure to supply the required conditions (sheltered from direct sun, plenty of airflow and protected from rain). Bait will be manufactured and stored in plastic pails so will not be prone to interference by rats or crabs.

If a helicopter is used it may be more efficient to store bait on Upolu, given the short ferry distances for a helicopter and the logistics, risk and cost involved in transporting bait to the island i.e. Apolima Uta (10km/3mins), Airport (16km/4.5mins) or main port in Apia (42km/11mins).

Three alia (boats) and skippers are available on Apolima for transport to/from the island and for supporting special baiting around the seaward perimeter.

Reasonable cell and internet coverage exists and could be supplemented by a Starlink satellite connection.

8.5 What are the logistical constraints?

Personnel can fly into Apia (on the island of Upolu), journey overland to the wharf at Apolima Uta then transfer by small boat to the island of Apolima. The boat journey is generally available "on demand" with negotiable fares around SAT$500 but is reliant on good weather and local navigators.

The importation of helicopters is likely to be the single biggest logistical constraint.

If significant quantities of bait are required to be transported to the island (in the case of using UAVs rather than helicopters, i.e. 500 buckets) then the sea conditions affecting small boat travel may constrain when and how quickly this could be completed.

Constraints on bait production are that if Pestoff20R is to be used with an operational timing forecast of July, an order must be in confirmed with the manufacturer Orillion, for April production. This timing also provides time to ship the bait from New Zealand to Samoa and for it to clear customs.

Figure 12 Left: Access to the island through the small channel in the reef, Right: local boat

8.6 What are the quarantine, surveillance, incursion response and advocacy requirements?

Preventing re-invasion of rats is a prerequisite of the eradication from Apolima. It is also equally important to prevent the introduction and establishment of other, high impact, invasive species such as the giant African snail and the African big-headed ant.

Access to Apolima is only by sea using small boats that usually overnight on Apolima. People and goods depart to Apolima from the wharf at Apolima Uta on Upolu. On arrival, people and goods are unloaded on the beach and taken to the village.

Apolima does not have a landfill (similarly, on the neighboring Manono island), therefore, inorganic waste is collected and transported by a private company contracted with MNRE twice a week by boat and to Tafaigata Landfill on Upolu.

Some invasive species such as myna birds, invasive plant seeds, and insects could arrive at Apolima by flying, but most will get there through human-assisted means. It is well established that risk organisms can move between locations by various means or pathways as stowaways on plants or animals, or goods such as heavy machinery. A suite of risk organisms can be associated with a single introduction pathway. For example, potted plants can carry mosquito eggs, ants, snails, nematodes, worms, fungi, invasive plant seeds, etc. For this reason, a pathway approach to prevention is recommended as it addresses a wider range of risk organisms rather than focusing on a limited number of specific invasive species.

There is a good level of biosecurity awareness amongst the community and precedents of actions taken to reduce risk of transport and establishment of invasive species (see details in 6.1). In addition, the community appears to be interested and willing to enhance biosecurity practices to protect their island. We propose that this is achieved through the development and implementation of a biosecurity plan for the island. This plan should be completed and implemented well ahead of the rat eradication to ensure that the right behaviours and practices are well embedded and result in better biodiversity.

DEPENDENCY 9:

Manageable and acceptable biosecurity actions.

8.7 What result monitoring data will be collected to track progress, validate eradication success and report?

Progress

Bait availability monitoring during the baiting phase will take place as described in section 5.3 to determine if application quantities are to be adjusted for the 2nd broadcast application.

Validation

Given the island is inhabited, observations by the community are the first and ongoing monitoring tool. If rats have not been observed in the first 12 months post eradication, a series of baited trial cameras will be established over a week period, and footage will be reviewed to determine if the eradication was successful. Standard practise in New Zealand is to wait two years (two breeding cycles) before validating success but as rats breed year-round on Samoan islands this timeframe can be shortened.

8.8 What are the planning issues?

Significant planning issues are summarised in Table 13 below.

Table 12 Planning issues for the Apolima rodent eradication project

Planning issue #	Description	Section Reference	Priority
1	More information about local weather patterns is required, particularly rainfall and wind patterns due to their effect on bait availability and suitable operating conditions for aircraft, drone, and boats respectively.	3.2	
2	Comprehensive flora and fauna surveys should be undertaken to better understand the biodiversity values and potential of Apolima as well as to provide a baseline from which to measure future changes.	3.3	
3	Monitoring should be undertaken to ascertain the absence/presence of other rodent species (ship rats, Norway rats and mice) and distribution of target species	3.7	
4	Potential impacts of and risks to cats (during and after a rodent eradication) need to be discussed with the community and an appropriate plan agreed.	3.8	High
5	Accurate population estimates of all livestock and pets along with ownership is required to help inform management options.	3.9	
6	Consultation and engagement need to occur with all key stakeholders to understand and agree on project objectives and intended outcomes.	4.2	High
7	Specific, measurable, achievable, relevant, and time bound (SMART) measures need to be defined for outcome monitoring.	4.6	
8	An options analysis needs to be completed to compare the relative cost, availability, performance, and logistical support required of using a helicopter versus an UAV (drone) for aerial baiting.	5.2	
9	An options analysis needs to be completed to compare the relative cost, availability, performance, and associated shipping logistics of the two bait options.	5.2	
10	Once the means of aerial distribution is known (helicopter or UAV) then a specific flight plan needs to be developed which will inform the total amount of bait required along with aerial logistics such as how many loads, total flying time, which in turn affect final cost.	5.3	
11	A bait availability study should be undertaken to help inform the most appropriate bait application rate. This in turn informs the total amount of bait required for the project and the aerial logistics i.e., how many loads, total flying time, etc.	5.3	
12	All sites that have special baiting requirements (e.g., buildings, storage areas, areas of rubbish, caves) need to be identified along with an appropriate method of baiting and management plans where appropriate to remove or mitigate these sites.	5.3	High
13	Management plans are required for the non-target species which would compromise the eradication (domestic and feral pigs, chickens, and dogs).	5.4	High
14	A definitive list is required of all alternate food sources available to rodents. E.g. human food, human waste, crops in plantations or in storage, livestock food, etc. Management options for each need to be identified and discussed with the community and a preferred option identified and committed to.	5.4	High
15	Engagement with boat operators, regular passengers and cargo providers is required to ensure future biosecurity protocols will be feasible to implement and sustain.	6.1	
16	Further engagement with key stakeholders is required to define a long-term vision for Apolima and the reasons for undertaking a rodent eradication.	7.2	High
17	Engagement with stakeholders is required to ensure they fully understand the implications, impacts and tasks required of them	7.2	
18	Project roles and agreed resource commitments need to be defined and agreed upon with key institutions involved in the project.	7.3	

19	Management plans are required for chickens and pigs to avoid the risk of secondary poisoning to humans and for cats and dogs to avoid the risk of mortality.	7.5	High
20	Sufficient time needs to be allowed to obtain all required permits and permissions.	8.3	

8.9 What are the key dependencies?

Table 14 summarises the risks and dependencies identified with the Apolima rat eradication project. The management actions associated with these risks and dependencies need to be actioned/resolved otherwise the risk of failure is considered too high to proceed.

Table 13 Key risks and dependencies

Dependency #	Risk	Dependency	Section Reference
1	Lack of unified, clear direction for the project. Misaligned and/or incompatible objectives. Inability to measure project success.	Key stakeholders can clearly describe and agree on the objectives and desired outcomes of the project.	4.2
2	Key stakeholders may underestimate the cost and complexity of an eradication.	Key stakeholders understand the applicable pest management options for Apolima and make an informed decision to proceed with a rodent eradication.	5.1
3	Apolima community may underestimate the impact on their lives. Social support for the project may be lost.	The Apolima community agree to all required management activities to reduce the risk posed by non-targets (pigs, chickens, dogs?) and to eliminate/reduce alternate food sources available to rodents.	5.4
4	Delays to project activities which may incur additional costs or lead to project failure.	Support from the community to proceed with the project is given (via the mayor) once consultation is complete and all required management actions have been agreed.	7.1
5	Investment is not effective.	Key stakeholders agree on and commit to a long-term vision for Apolima.	7.2
6	Project failure due to factors such as under resourcing, lack of local knowledge, inefficient governance.	The key institutions involved (MFAT, MNRE, SPREP, DOC) understand and agree on their respective roles and are willing to commit resources to the project.	7.3
7	Secondary or tertiary poisoning of humans, pets and livestock. Loss of social support for the project.	The Apolima community understand the management actions required to protect livestock, pets and humans from accidental poisoning and agree to implementing them. They understand and accept risks to other non-targets.	7.5
8	Loss of social and organisational support for the project.	The community and MNRE understand and accept the negligible impacts of toxin residue in the ocean, soil and water.	7.5
9	Manageable and acceptable biosecurity actions		8.6

8.10 What are the estimated costs and timeline?

Table 14 Indicative key costs. These figures should be used as a guide only and need to be refined as requirements are better understood and planning progresses.

Phase	Item	Cost estimate (NZD$)	Notes
Feasibility	Community consultation	150,000	X4 trips + in country role. Technical and agency staff, international travel, island hosting costs
	Bait availability trials and baseline monitoring	20,000	Technical and agency staff, international travel, island hosting costs, bait, equipment
	Report and wider stakeholder engagement	10,000	Project Manager
Planning	Operational plan	50,000	Project Manager and support staff
	Community consultation	125,000	Island hosting costs and local support
Biosecurity	Biosecurity plan, materials, training	70,000	
Pre-Operation	Elimination of food waste and waste management	15,000	Estimate is +/- 100%
	Livestock and pet management	25,000	Estimate is +/- 100%
Eradication	Bait & shipping	50,000	5000 kg bait in 500 x 10kg pails (NZD$67.50/10kg pail) = $33,750 Freight: $10,961.32. Marine Insurance: $450 Silica container sticks x 8 = $216
	Helicopter/Drone	>100,000 (drone) 280,000 (heli)	Updated estimate will be required once method and quantities are known
	Field equipment incl bait stations, trays	20,000	
	Personnel incl travel and accommodation	50,000	
	Post operational reporting	5,000	Project Manager
Monitoring		15,000	
Contingency		$140 – $180k	20%
	Total	**$850 - $1065k**	Depending on heli / drone

9. Conclusion and recommended way forward

Eradications of rodents on inhabited islands are complex and Apolima is no exception. It is not currently feasible to progress to operational planning for eradication of rats from Apolima as there are too many identified risks and unknowns.

Whilst a successful eradication of rats would benefit the community's health and wellbeing, it is not clear to what extent it would benefit the residents through improved livelihood outcomes, given the extent of crop damage and interference caused by pigs.

Eradication of rats has the potential to provide some biodiversity outcomes, most likely to nesting seabirds on the island's slopes. Benefits to the forest are likely to be limited because of the damage caused by pigs. However, Apolima could provide Samoa with an island which could become a sanctuary for some Samoa's threatened species. This will require community support and engagement not only for the rat eradication but also for managing livestock, cats, and dogs and preserving habitat.

The island and community are well placed to implement the biosecurity measures that would be required to sustain a rodent free island with limited incursion pathways and a proven culture of vigilance and following protocols.

This assessment finds that there are significant operational risks which require further effort to eliminate or mitigate. Primarily the large pig population would need to be managed to ensure a reasonable chance of a successful and safe eradication operation. Further engagement with the community should be undertaken to resolve these risks.

Further engagement with all key stakeholders is required to be clear about the reasons for undertaking an eradication, the expected outcomes and the level of commitment required by all key parties. The implications of livestock management in the future, after an eradication needs to be discussed and understood to ensure it is compatible with the goals and outcomes of the eradication.

Feasibility, should be regularly re-assessed and this document updated accordingly as more information is gained.

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Appendix 1: Native species likely to benefit from eradication

Scientific name	Samoan	English	Conservation Status	Benefit
Myiagra albiventris		Samoan flycatcher	Near Threatened	Reduced predation
Gymnomyza samoensis	ma'oma'o	Mao (honeyeater)	Endangered	Potential translocation site

Appendix 2: List of Flora

Scientific name	Samoan	English	Notes	
Solanum torvum	Lapiki	turkey berry, devil's fig, pea eggplant, platebrush or susumber,	Spreads fast, hard to remove, spiky thorns	
Flemingia macrophylla			Native to Asia	
Mikania micrantha		Mile-a-minute vine		
Sphagnetica trilobata		Singapore Daisey	Thick carpets over open ground from beach up to edge of ornamental lawn and surrounds. Also in interior	
Febacae spp		Legumes/peas		
Spathodea campanulata		African Tulip Tree		

Convolvulcae spp		Morning glory		
Coccinia Grandis		Ivy gourd		
Clerodendrum Chinese Losa honalulu		Glory bower	In the bush and plantation areas.	
Leucaena leucocephala	Fuapepe		In the bush and plantation areas.	
Stachytarpheta urticifolia		Rats tail	commonly seen in around pathways and clearings on island	
Castilla elastica		Panama rubber tree		
Funtumia eleastica		WA Rubber tree		

Kylinga polyphylla		Navua sedge		
Clidemia Hirta		Kosters curse	Priority weed for Samoa In the bush and plantation areas.	
		mint weed		
		Mimosa	Strong sedative, very spiky and close-up when you touch them	
		Coconut	Staple diet	
		Taro	Staple diet	
	Taamu	Big taro	Staple diet	
		Breadfruit	Staple diet	
		Green Banana	Staple diet	
		Cocoa	Staple diet	
		Pandanus		
		Lemon	1 tree in village	
		Lime		
		Mango	1 tree in village	
		Pawpaw		
		Yam		
		Wild yam	In forest areas	
		Cassava?		
		Pineapple		
		Guava?		
	Kumara	Sweet potato	None currently present due to vulnerability to rats	
		Tumeric		
		Ginger		
		Egg plant	Individual house gardens	
		Tomato	Individual house gardens	
		Cabbage	Individual house gardens	
		Aloe vera	Individual house gardens	

Appendix 3: Review of UAV aerial baiting operations

Date: February 2023 , DOC ref doc-7058623

Subject: Summary of current Unmanned Aerial Vehicle (UAV) capability for aerial bait applications for pest eradication projects

Executive Summary

The availability of small-scale Unmanned Aerial Vehicle (UAV)[1] technology has grown in recent years. There are now several operators in New Zealand developing or using UAVs for aerial bait application. Current lift capacity of UAVs ranges between 12 and 50 kg. A model with a lift capacity of 200 kg is being developed by Envico Technologies Ltd[2] with funding from DOC's Tools to Market programme and is expected to be available in the next few years.

It is still early in the evolution of UAV technology for aerial baiting and relatively few operations have been delivered to date. Most operations have involved spreading cereal baits on small islands to eradicate rats as the use of UAVs is currently limited to small scale operations up to a few hundred hectares. The advantages of UAVs compared to helicopters are improved accuracy and consistency of bait spread and the ability to follow pre-programmed flight paths. UAVs also provide an option for bait distribution on small islands that are too large for hand-spreading of bait and too remote for helicopters to reach. Beyond this, the niche of UAVs for aerial bait spread is severely limited by payload and flight capability, including endurance when carrying a load. Battery-powered UAVs are constrained by their lithium power source. Many spare batteries are needed to keep UAVs operating continuously and charging batteries is time-consuming. Lithium batteries are also unable to be flown commercially and transport by land and sea is slow.

Bait application by UAVs is several times more expensive than by helicopter. Large support crews are required relative to the small-scale of delivery and operations are prolonged, so crews require accommodation. Despite being able to be transport UAVs by road, which is cheaper than positioning helicopters, there are currently few operators, so they typically must travel long distances to the operation sites. Reliability and contingency options (e.g., backup UAVs and parts) are needed to make UAVs a viable option.

Ultimately, UAVs need to compete with helicopters on cost to be a viable alternative for aerial broadcast of baits. UAV technology is expanding and developing quickly with a lot of investment. Performance measures (range, endurance, reliability, lift capacity, daylight restrictions) are expected to improve substantially in the coming years. The next generation of UAVs will include models with hybrid and combustion power units and increased lift capacity. The ongoing development of a New Zealand manufactured large lift capacity UAV will improve capability and availability for aerial bait spread.

UAVs are likely to develop a niche for small-scale operations due to their potential for night operations, safety considerations at exposed and remote sites and low volume precision baiting of specialist baits.

Context

In 2021 DOC's National Eradication Team (NET) engaged with DOC's Wānaka Operations Team to assess the viability of using a planned rat eradication on Mou Tapu Island, Lake Wanaka as a trial site for UAVs. The purpose of the proposed trial was to assess the capability of UAVs for bait application to eradicate rodents and to compare this with bait application using helicopters. As part of this process DOC engaged with Island Conservation[3] (IC) and Zero Invasive Predators (ZIP) to learn from their experiences.

DOC's Wānaka Operations team were planning an eradication of Norway rats from Mou Tapu (120ha) in Lake Wānaka in winter 2022. The island's scale, difficult access and steep terrain make it an excellent trial site for bait application by UAV. DOC Wānaka agreed to work with NET to trial UAVs if practical. A Statement of Requirements was developed (DOC-6900538), and three operators were invited to submit proposals in February 2022. Two operators were shortlisted and a demonstration day was planned to assess performance before awarding a contract. NET abandoned the trial in June 2022 when it became apparent current capability was not sufficient to warrant financial investment at this stage. In the interim the operation was postponed to winter 2023 due to operational planning requirements.

This memo outlines the lessons learnt from that investigation and also from other operations in New Zealand and the Pacific where UAVs have been used for the application of bait for pest eradication. Background

Purpose

The purpose of this document is to summarise the current capability of UAVs for eradicating pests through the aerial application of bait, and compare it to aerial bait application using helicopters.

This document addresses the following questions:

1. How much bait can be spread per hour (productivity) and what scale is feasible for aerial bait spread by UAVs?
2. How does a baiting operation compare between UAVs and helicopters?
3. What is the relative cost for UAVs versus helicopters?
4. How reliable are current UAVs?
5. Other considerations, issues or constraints of using UAVs
6. What are the benefits for using a UAV for aerial bait spread relative to a helicopter?
7. What are the priority advancements required to improve UAVs for use for baiting applications?

Findings

Here we present lessons from investigations about the practicalities of using UAVs for aerial bait spread, relative to helicopters as the standard method.

1. **How much bait can be spread per hour (productivity) and what scale is feasible for aerial bait spread by UAVs?**

Productivity (bait spread per hour) is dependent on the prescribed bait application rate (kg/ha), the volume of bait that can be carried each load and distance to load site. These factors apply to helicopter and UAV baiting alike.

Current UAVs lift capacity ranges from 12kg to 45kg - in contrast to up to 900kg lift capacity for helicopters.

Productivity achieved in operations to date has ranged between 12 and 200 kg/hr (see **Table 1**).

The 12kg lift UAV (ENV-12) was used for a rat eradication on Kamaka, a 50 ha island in French Polynesia. For this operation each flight typically took 10 minutes before the UAV returned to the load-site to reload bait and swap batteries. The maximum productivity achieved was 80 kg/hr. Six or seven sets or batteries were needed to keep the UAV running continuously. Charging batteries is a constant task that takes as much time as flying and requires adequate generator capacity and fuel.

Baiting by UAVs can be significantly prolonged because of the small payload. With the currently available and proven UAVs, only small sites up to two or three hundred hectares could be attempted. Even these require multiple strategically located loading sites to maintain efficiency. Given the current capabilities, these platforms are best suited for treating groups of small islands or atolls where either helicopters or hand baiting are financially or logistically challenging. The largest baiting operation completed by drones to date is 184 ha (North Seymour Island) and the largest total volume of bait applied is 6,210 kg at a rate of 30 kg/ha on Kamaka, French Polynesia. Some operators provide the option of running two UAVs at once to reduce the overall duration of an operation.

A limited demonstration of a larger 45 kg payload capacity platform shows the potential for higher rates of efficiency with an estimate rate of 200 kg/hr. These larger platforms with longer durations will be critical to completing eradications on islands larger than a few hundred hectares where there are only a small number of land-based loading sites.

Larger refuelling and loading equipment are needed for helicopters but much larger areas can be baited (thousands of hectares per day with multiple helicopters).

Table 1: Examples of aerial baiting operations using UAVs

Date	Location	Area (ha)	Bait volume	Productivity	Who	Drone model	Notes
Jan 2019	North Seymour Island, Galápagos Islands, Ecuador	184	3000 kg 6 kg/ha	2 days with 2 UAVs, 15 kg payload (**87-97 kg/hr**)	Envico, Island Conservation	ENV-12	Mechanical issues limited spread to half the island on the first application (the second application completed in full by UAV) Fine tuning of application rate not possible Issues with data flow. Night operations demonstrated
Dec 2021	South Ōkārito, New Zealand	175	350 kg 2 kg/ha	7.2 ha/hr 24 h over 2 days **14.6 kg/hr**	Envico, ZIP	ENV-12	Trickle sow with 4 m effective / 10 m max swath along sensitive boundary DOC-6861201
		110	220 kg 2 kg/ha	6.5 ha/hr 17 h over 2 days **12.9 kg/hr**			
		75	300 kg 4 kg/ha	Approx. 3.5 ha/h **14 kg/hr**			
Mar 2022	Ngerkeklau, Palau	8	700 kg 40 kg/ha	1 day with 1 UAV 45 kg lift **200 kg/hr** 1 day with 1 UAV 12 kg lift **96 kg/hr**	Envico, Island Conservation	ENV-50 then ENV-12	1st application completed via heavy lift drone, but mechanical failure occurred while attempting the first application on a 2nd larger island. Second application on smallest island completed via small drone.
Jun 2022	Kamaka, French Polynesia	50	6,210 kg 30 kg/ha	10 days with 1 UAV 12kg lift **80kg/hr**	Envico, Island Conservation	ENV-12	See case study Appendix 1. Case Study: field experiences in the Pacific (Island Conservation)

Oct 2022	Wallis Islets (9), Wallis and Futuna, French overseas territory	148	5,450 kg 20 kg/ha	9 Days with 1 UAV 12kg lift **70 kg/hr**	Envico, Island Conservation	ENV-12	Two applications without incident. Support via barge

2. **How does a baiting operation compare between UAVs and helicopters?**

Proximity of loading sites

The bait loading site and UAV personnel need to be within 2 km of the area being baited as UAVs don't have the endurance to ferry bait further than this without severely affecting productivity. Bait therefore also needs to be available at all potential bait loading locations.

In comparison for helicopter operations, a single bait loading site/landing zone can be used – even for large baiting operations. Load sites can be positioned away from treatment area if required (usually due to needing an accessible site for loading support or for efficiencies associated with storage and handling of bait) as helicopters are capable of ferrying bait long distances.

Effects of wind on operations

UAVs are more susceptible to windy conditions than helicopters. This predominantly impacts endurance and sow rate. Since flight lines are pre-programmed well in advance and there is currently limited ability to reprogramme flight lines on the day of the operation, an operation may have to be stopped or delayed if strong winds are encountered.

Groundspeed is particularly important for UAVs as the current bucket configurations do not have the ability to manually adjust the flow rate – so the sow rate is entirely reliant on overall groundspeed.

Helicopters can spread bait in constant wind up to 20 knots, compared to 15 knots for small UAVs. Larger UAVs could fly in similar conditions as helicopters, however with an impact on endurance and/or payload capacity. Helicopters typically spread bait about 30 m above the ground at approximately 50 knots groundspeed. Operators experienced issues with wind drift on Kamaka Island and had to re-fly areas on different flight paths to account for that.

Requirement for Visual Line of Sight Operation (VLOS)

Flight rules in New Zealand for UAVs require constant line-of-sight visual operation or extended visual line-of-sight operations where an operator in communication with the pilot in command maintains visual sight of the drone[4]. Constant communication with the UAV is also required to enable uninterrupted control and enable a live video feed to confirm bait dispersal is happening in real-time. It is possible for baiting to be completed without constant communication, but this is dependent on local regulations and the desire for a live video feed. On Kamaka Island, an antenna was installed along with 500 m of optical cable between the antenna and the load site[5].

3. **What is the relative cost for UAVs versus helicopters?**

Daily rates for UAVs are currently more expensive when compared to helicopter daily rates and have higher fixed costs associated with regulatory approval, scoping and flight pre-planning. UAVs also require 2 to 3 personnel per UAV to operate. For mainland-based operations like those in New Zealand this means that the 12 kg payload capacity UAVs are not likely to be cost-effective for treating anything other than small sensitive areas. However they may be more cost-effective if integrated as a rapid response tool that could be carried in the back of a vehicle to an operational site.

In island scenarios, the greatest potential cost-efficiencies between helicopters and UAVs depends on chartering and shipping logistics. UAVs can be carried as commercial freight on airlines with personnel – eliminating the need for costly charter fees and shipping logistics generally associated with helicopters.

Proposed UAV operations for the rat eradication on Mou Tapu Island, Lake Wānaka would cost approximately three to four times that of a helicopter operation and take approximately 4 days for each application by UAV compared to 1 to 2 hours using a helicopter. Helicopter support would also still be required for a UAV operation to position teams and bait and provide contingency to complete bait spread in case of UAV failure.

It is hard to determine productivity costs, but spot treatment of 100 ha might take 10 – 15 minutes for a helicopter compared to one or more days for a UAV. For remote islands where UAVs are the only viable option, expedition style deployment of a UAV team is still an expensive option, typically costing approximately NZD $6000+ /day.

In a recent operation in South Ōkārito the daily hire rate for the UAV was $5000 per day of operation, with disbursements over and above this cost. Sow rates ranged between 7.2-6.5 hectares per hour so a simple extrapolation gives $69-$76/ha.

Logistics for positioning UAVs can be cheaper than repositioning helicopters because they can be transported by land on a trailer. However, these potential savings are outweighed by the need to maintain radio connection. This requires installation and management of repeaters, hiring of a barge for moving a team around an island as it is baited or access to multiple landing sites on or off the island.

Operational costs are expected to reduce as UAVs become more capable and services more available. At the current time, UAV operations are likely to cost more and pose more risk compared to helicopter operations. As technical advances in UAV payload capacity and endurance increase, they will become more competitive. Given the nascent nature of the technology - less than three years old - it is reasonable to expect that it will come at a premium compared to existing methods.

4. **How reliable are current UAVs?**

Reliability is a key issue for when deciding whether to use UAVs. To date, a total of 16 T of bait has been applied by UAVs across 750 ha, spanning five projects in five different countries. The nascent nature of the technology for aerial bait spread means operators typically don't have spare UAVs available to complete baiting in case of failure.

The baiting operation of North Seymour Island in the Galápagos Islands in 2019 was completed, in part, by hand baiting due to mechanical issues with the UAV. The issue was resolved in time for the second bait application by acquiring additional spare parts and sifting bait for anomalies.

In March 2022, Envico's 50 kg lift drone suffered problems with its electronic controllers requiring it to be substituted with a smaller 12 kg lift model (ENV-12) for a rat eradication in the Pacific. The smaller UAV required many additional flights compared to the planned operation, but the baiting was successfully completed)[6]. Around the same time, another operator's UAV was out of action for several months after a crash that required it to be sent to Australia for repairs and no backup was available.

The operations on North Seymour Island, Palau, and New Zealand all used novel experimental UAVs during some of their UAV aerial baiting operations. The recent successful operations on Kamaka, and on Wallis and Futuna showed a dramatic increase in reliability and efficiency for the smallest 12kg payload UAV.

Over the course of the five projects done to date, mission planning, communications, reliability and data flow issues have dramatically improved and it can be expected for these to improve over time with further operations. The software systems, workflows and operational protocols are able to be scaled up from the smallest 12kg UAV to the larger 45 kg and 200 kg UAVs currently in development.

In terms of aerial bait application using helicopters, there are helicopter operators with aerial baiting capability can be found in many localities around New Zealand and logistical support for helicopters is well established.

5. **Other considerations, issues or constraints of using UAVs**

Pre-flight planning and data requirements

One of the most significant considerations for UAVs is the need for high-resolution imagery and digital terrain models to develop flight plans. All flight paths, treatment zones, altitudinal tiers and exclusion zones must be pre-programmed and derived from digital data. Flight plans must be redone if additional flight parameters are added later, errors are discovered in the accuracy of the programmed flight lines, or there are changes such as flight direction due to wind. This is a significant change from working with piloted helicopters where flight parameters can be changed and adjusted as required in real time. The level of detailed planning and communication required for UAV operations should not be underestimated. Until more autonomous flight and mission planning is available, any operational changes on the day may result in significant delays. To combat this, more robust advance planning could be done to minimize disruptions or prepare for alternative scenarios, but this would come at additional cost. Given the relatively small scale of the UAV projects completed to date and difficulty and delays related to changing mission plans, improved mission planning is going to be absolutely critical as UAVs increase in endurance and payload capacity if they are to remain competitive.

For the Ōkārito operation, a spiral flight path was programmed, however this flight path left small triangular areas where no bait was applied. Parallel flight lines would avoid this issue.

Currently available UAVs have potential to replace manned helicopters at small-scale sites where safety is a concern for ground baiting (e.g. cliff faces). Aerial spread of bait by helicopter in remote and exposed places can mean operating where there is limited ability for search and rescue. Increased endurance, baiting capacity and Beyond Visual Line of Sight (BVLOS) operations are needed to make UAVs a viable alternative in this scenario.

Envico Technologies Ltd is developing a large lift combustion engine UAV with a 200 kg payload using funding from DOC's Tools to Market programme. One of the milestones is approval for BVLOS operation. BVLOS will likely require specialist pilot qualifications and training on top of the Civil Aviation Authority (CAA)'s current Part 102 requirements[7] . Bait spreading by UAV also requires certification for agricultural operations - the same as for helicopters.

Constraints with use of lithium batteries

Lithium batteries for battery powered UAVs are a logistical constraint because they can't be flown commercially. They must be transported by land intra-island and by sea internationally, or caches of batteries must be kept in other countries. This means transport takes time and is expensive.

Operators are currently investigating hybrid power systems to address power capability.

Endurance issues for battery operated UAVs

In the Ōkārito operation which used a UAV with 15-20 kg lift capacity, flight times were limited to 11 minutes, but this depended on how quickly the UAV was unloaded. The flight distance was around 1500m from the load site. The amount of bait transported on each load was originally 20kg, but was decreased to 15 kg to improve the range. This was then decreased again to 10 kg to reduce the time taken to recharge the batteries. Three petrol generators were used to recharge the batteries. Delays were experienced while waiting for batteries to charge. More batteries or the ability to fast-charge the batteries would increase the amount of flight time for the UAV.

Autonomous terrain following

Expressions of interest for the Mou Tapu rat eradication indicated that UAVs could fly at a consistent height above the ground relative to contours based on a 3D model of the island. However, the UAV used on Kamaka in June 2022 (a steep, 50 ha volcanic island in French Polynesia) flew at a uniform 250 m above sea level (ASL) because it couldn't autonomously follow terrain (the coastal perimeter was flown at a standard 170 m ASL). Its performance was limited by the power required to constantly adjust flight speed. Power (especially battery) is a limitation triggering new development into hybrid UAVs and larger combustion engine UAVs.

Precision or targeted baiting

Most operations to date have applied cereal baits to target rodents at a range of application rates up to 40kg/ha. Small UAVs could be more effective for the precise application of baits at lower densities than required for broadcast of cereal baits. For example, one operator has used a UAV to deliver baits within 2 metres of Argentine ant nests. Another example could be application of meat baits being developed for stoats and feral cats that are likely to be applied at low density (e.g. one bait per several hectares) or in response to a specific detection. To be useful for targeted baiting, UAVs need to be able to fly several kilometres beyond line of sight. Otherwise, a helicopter would be required to position a UAV team close enough to a treatment site to operate with line-of-sight visual control, negating any efficiency.

Conflicts with helicopter operations

In the Ōkārito operation, UAV operators and helicopters wouldn't operate in adjacent blocks, and would always maintain one block between them due to tentativeness from helicopter pilots, and safety concerns.

Variable sowing rates

While a constant sowing rate is set, this is dependent on the forward flight speed of the UAV. Any changes to this forward speed (such as a head wind, or the UAV changing altitude or turning a corner) would impact the sowing rate at that location – for example oversowing at the corners due to reduced speed.

Reduced carbon emissions

One of the drivers for UAV development is the promise of reduced carbon emissions relative to helicopters. There is potential for this with the development of larger capacity platforms, but this can't be meaningfully assessed as current capabilities of UAVs and helicopters aren't comparable.

6. **What are the benefits of using UAVs for aerial bait spread compared to helicopters?**

UAVs can accurately fly pre-programmed flight lines and apply bait precisely across flat terrain, either trickle boundaries or via specific placement of individual baits. They can also fly at stable altitude and have a much tighter turning circle than a helicopter. Bait flow can be turned on and off accurately in relation to a programmed boundary.

Spreaders for UAVs appear to be performing well with uniform distribution and accurate delivery of the desired bait application rate. They are typically fixed in position below the UAV rather than hanging and swinging from support cables, reducing the potential risk of injury to ground personnel. Spreader buckets on UAVs use an auger to deliver a more measured flow of baits to the spinner mechanism than the typical helicopter "aperture" style mechanism. UAVs can add a camera to watch and record for bait-flow interruptions. This is more difficult for helicopters, which require certification for any such modification/addition to the airframe.

No-fly zones can theoretically be automated for UAVs, but mistakes have also happened to date through programming or operator error.

In some cases where an island is out of range of direct flight by helicopter (approximately 600km offshore), and where self-recovery necessitates a second helicopter on site, UAVs provide a viable option for aerial baiting. Shipping a helicopter is unaffordable for small island projects. UAVs can be packaged and sent on small vessels that are more available and cheaper than a ship capable of transporting a helicopter.

Envico Technology Ltd has automated the entire bait application monitoring and bait density map process, eliminating the need for additional GIS personnel to be on the ground to download and analyse baiting data.

7. **What are the priority advancements required to improve UAVs for use for baiting applications?**

1. Improved flight capability for carrying loads, including endurance and payload)
2. Improved communication capabilities to enable consistent radio connection over large areas with steep terrain;
3. Improved mission planning and ability to adjust flight parameters such as orientation and exclusion zones during operations;
4. Approval for Beyond Visual Line of Site operations (BVLOS) (CAA, DOC);
5. Metered flow of bait relative to ground speed and terrain;

6. Autonomous terrain following over steep/varied ground and associated technology developments to adjust speed and/or flow rate during a flight to maintain the desired ground application rate[8];
7. Reduction of operating costs to be competitive with helicopters;
8. Ability to accurately apply bait in winds up to 15 knots;
9. Alternative power sources which would simplify logistics by avoiding the constraints of lithium power units;
10. Proven reliability.

Appendix 1. Case Study: field experiences in the Pacific (Island Conservation)

Account of baiting using UAV on Ngerkelau, Ngerchur, and Ulong, Palau, by David Will

Initial scope of work was to treat a total of 210 ha across three islands in Palau totalling 10,000 kg of bait at an application rate of 40 kg/ha.

Pre-operational scoping was conducted to generate flight plans and maps at different altitudinal tiers based on digital surface models. Flight plans were complex and took upwards of two months to develop.

The baiting operation started with the smallest island of Ngerkeklau (8 ha) using the ENV-50 with a 50 kg payload. The island was successfully treated, although there were several instances of mechanical failure that required emergency shutdowns and issues with bait bridging in the hopper resulting in inconsistent bait flow. A make-shift agitator was installed that solved the bridging issues.

A mechanical failure at the end of the first application resulted in the UAV landing in shallow water causing irreparable damage. After significant discussions it was determined to attempt the first application on the next larger island Ngerchur (30 ha) with the second backup UAV. After completing three coastal flights a significant mechanical failure occurred that almost resulted in the catastrophic loss of the UAV, however with significant effort it was successfully landed on the dock without further damage.

With the failure of both ENV-50 UAVs, it was then decided that the backup machines (ENV-12) were to be flown out from New Zealand to complete the second application on Ngerkeklau Island. Any further attempts on Ngechur and Ulong were abandoned until mechanical issues could be addressed, at significant financial and reputational cost to Island Conservation.

The second application on Ngerkeklau was completed via the ENV-12 without incident with a total of 43 flight over two days due to weather. Completing the second application via the ENV-12 at two different altitudinal tiers built confidence in the platform for future operations in the Pacific, particularly since many of the technical and planning components were transferrable between the ENV-12 and ENV-50.

Account of baiting using UAV on Kamaka Island, French Polynesia by Paul Jacques

The amount of work required to bait a 50 ha island (actually about 57 ha in 3D) is formidable: 284 flights were completed, with about 70 flights being the highest achieved in one day.

3600kg of bait was spread across the island, 2850kg by UAV (ENV-12) and the rest by hand during the first application. 3560kg was applied by drone during the second application.

Due to the small payload of the UAV, the baiting operation took a long time. The first application of bait to the whole island (50 ha) took 5 days to complete (including a rain day) and a further 4 days were required to finish the coastal run, steep slopes, low bait density areas and further hand-baiting of coast, caves, and upper faces.

For each flight, the UAV is loaded with bait (2 people, 1 min), two batteries are connected (1 person, 1 min), then the UAV completes its flight line (2 people, 10-12 mins) with the pilot monitoring the UAV's position and another person monitoring the video feed of bait spread. When the UAV returns to the loading area, the batteries are removed (1 person, 1 min) and transported down the hill to the pulley system (1 person, 2 mins), slung down to the charging station (2 people, 1 min), charged (1 person, 30 mins), sent back up the hill (2 people, 3 mins) and then put back on the UAV (1 person, 1

min). With six sets of batteries the operation can run continuously but only just, and a team of at least 7-8 staff is required.
Bait availability was high even after 7 days and the prolonged nature of the baiting may have some pluses, as fresh bait was regularly topped up in some zones, particularly the coast.
There have been plenty of technical challenges due to gear, terrain and weather (particularly wind).

Figure 1. ENVICO 12kg drone at Kamaka, June 2022. Photo: P. Jacques

Figure 2: ENVICO 12kg drone being reloaded at Kamaka, June 2022. Photo: P. Jacques

Appendix 2. Case Study: field experiences in the NZ by Zero Invasive Predators

Subject: Shared lessons of ZIP's drone use during South Ōkārito phase 1 aerial operation
Date: 1/12/2021
Authors: Ann De Schutter and Finlay Cox

Context
Ann met with Nicholas Braaksma from (ZIP) to discuss how things went for Okarito with drones and general GIS updates (minutes: DOC-6859651). Finlay concurrently was in correspondence with Nicholas. This memo summarises lessons/outputs (with some discussion/thoughts of authors incorporated) for internal use. ZIP intend to release a formal report on the project as a whole, diluted lessons of drone use will be covered.

Overview
Envico Technologies Ltd were contracted to treat treatment blocks as part of the South Ōkārito treatment area (15000ha). Two prefeed operations and one toxic operation were undertaken utilising RS5 6-gram 1080 bait. Sensitive boundary blocks couldn't be completed with helicopter due to risk, hand laid toxin was used on front country sensitive boundary blocks, drone used on remote blocks.
ZIP's conclusion was that drones have a lot of potential however the used drone and bucket (10-20kg payload with trickle bucket) was not well suited. Next operation they will push for larger size drone, 40-50 kg payload with a spinner broadcast bucket (which hadn't been designed for bait size at the

time). Envico had never laid 1080 bait before, learning curve, + operating off the side of the road (traffic, small loading sites) made it difficult. They are still developing technologies but were very quick to change what they could. ZIP would use drones again, in that gap between what is achievable helicopter vs. hand laying.
There are other drone operators in New Zealand. In phase 2 of the South Ōkārito project other operators will be investigated. One such operator ZIP is aware of is Airborne solutions with a helicopter background that are transitioning to drones, they do a lot of agricultural work.

Operational

Drone operators, and helicopters wouldn't operate in adjacent blocks. So always at least a block in between them due to tentativeness from helicopter pilots, and safety concerns.
These areas identified for sowing by drone were often close to the road. Multiple drone load sites (separate to main helicopter load sites but operating in parallel) were available and used to minimise ferry flight distance. Bait was transferred from bulk bags at the main helicopter load site and transported to each drone load site in ~10kg buckets to allow clean refills. ZIP staff transported 1080 and had oversight from CSL point of view as Envico did not hold a CSL for 1080. Three Envico staff operated the single drone with 3-5 ZIP staff supporting.

Bating operations

Prefeed 1:

- 2nd and 3rd of November 2021
- 2kg per ha
- 175ha
- 24 operational hours over two days
- 7.2ha per hour

Prefeed 2:

- 18th and 19th of November 2021
- 2kg per ha
- 110ha
- 17hrs operational hours over two days
- 6.5ha per hour

Toxic:

- 23 and 24th of Nov 2021
- 4kg per ha
- 75ha
- Operational hours over two days
- ha per hour not determined yet, approx. 3.5ha/hr

Flight Plan

Drone flight height was predetermined through Digital Elevation Models (DEM). Freeware google DEM was used which had 90m resolution. Flight height set at 60m above ground, but manual adjustments were required occasionally due to accuracy issues of DEM and/or vegetation obstructing predetermined flight height. LINZ DEM has error of 20m and would be better for flight line development. There was some dialogue of using real time radar altimeter which would have the highest accuracy (set a few metres above the canopy instead of above the ground). Pre flying would also work to record accurate DEM.
Open-source software to create pre-programmed flight lines: spiral design, outline of the shape, then spirals in, every time the drone turns a corner, greater distance between lines, triangular little gaps left. Depends on overall shape of the block, could be anywhere from 2m to 6-7m. For the first prefeed they didn't get them to go back. Because of delay in data delivery. Subsequent drops: for each spiral line change, they would fly another perpendicular line, to avoid those gaps. Parallel flight lines would be more efficient.

Sowing

Drone flight lines were spaced 20m apart. Baiting mechanism was not calibrated by ZIP but Envico's supplied specifications was a trickle sow or "effective swath" of 4m (2m either side of flight line) and "maximum swath" was 10m (5m either side). Sowing rate (flow and drone speed) was programmed to achieve a nominal rate equivalent to 2 kg/ha over the whole block (20m flight lines so within 4m strip sowing much higher rate and strips of 16m where there wouldn't have been bait, but these parcels dissolved gives 2kg/ha). Theory being an animal would only have to move up to 8m to get to a bait.

Drone was flying at 8-9 m/s (15-18k nots) but had to slow down going into the turn. The buckets flow rate was constant, so heavy sowing going into a turn. Also, when re-starting a flight line, the drone would start from a stationary hover and it would take about 30m of distance for a drone to get up to target speed. The bucket would begin sowing immediately at the constant rate, so again heavy sowing on this start up. Envico state they can adjust flow rate (by adjusting auger rate or "pwm", "power modulator") to flight speed to ensure constant sow rate, however this was not available on the used platform, and unclear if available at all.

The drone was fantastic at sticking to a line, wouldn't go off more than half a meter, very accurate, the density could be improved upon (as outlined above). Difference between low sowing on mainland NZ, and island eradications where the rates are much higher + also shorter timeframes/operating windows due to consents and/or working in parallel to helicopters.

No bait density plots were conducted after bait was sown.

Endurance

Their battery capacity and charging capacity, 3 petrol generators running to recharge. Flight times were maxed at around 11 minutes but depended on how quickly they unloaded, flight distance was around 1500m from load site.

Originally the drones were meant to take 20 kg, decreased to 15 kg to give them extra range. When they came back in, batteries were drained < 20%, took longer to charge batteries than flying. So, a lot of time waiting for batteries to charge before flying. Decreased load to 10 kg, so it would be quicker to charge.

Quite a bit of commute time and waiting for batteries. If they had more batteries and faster charger they could have the drone up for longer.

Boundary

Envico ensured them there were safety procedures in place to make sure that they could always see the drone. However, there were a couple of instances were drone lost signal, did a return to home manoeuvre, and went into an adjacent block (by about 20m). In addition flights through "flight corridors" where often not direct, increasing flight time in these areas and increasing risk of accidental spill.

Conflict with radio comms and wifi setup, so that may have been why they lost signal. For second op radio comms, wifi remove that part so they have a stable signal to the drone at all times, and having at least a block between helicopter and drone pilots.

Data

Drones were able to export data off the drone, and send it to them, either as csv (points, time, altitude, lat long, hopper status (on/off), pwm (how fast is the bucket sowing)) or shapefile (lines). Used csv, setup an automated script to turn points into lines. Sent data to ZIP for first one. For second one: get one of the field staff to sit with hem, looking over their shoulder.

Cost

Envico charged $5000 per day of operation. Flights and accommodation were above this and covered by ZIP. Sow rates ranged between 7.2-6.5 hectares per hour so a simple extrapolation gives $69-$76 per ha.

Appendix 3. Other UAV models available for aerial bait spread

Figures 2a & 3b: Aerospread's DJI M600 Pro capable of spot treating with 2 m precision

Appendix 4. Feasibility Template

Eradication feasibility assessment Current agreed best practice template

Version 1.2

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Version	Date	Comment
1.2	January 2023	First update by IEAG
1.1	August 2022	Final released by IEAG
1.0	August 2022	Draft version circulated to IEAG

This document can be cited in references as:
Brown, K.P, Broome, K.G., Golding, C., Horn, S., Reardon, J., Cox, F. 2023: Eradication feasibility assessment. Current agreed best practice template (Version 1.2). New Zealand Department of Conservation internal document DOC-7110779 Wellington, New Zealand.

New information and suggested improvements to this document can be made to Keith Broome kbroome@doc.govt.nz.

In the interest of forest conservation, we support paperless electronic publishing.

INTRODUCTION

Purpose

The purpose of this document is to provide a template for reporting on an assessment of the feasibility of eradicating pests from a site. It forms part of Department of Conservation current agreed best practice support created and maintained by the Island Eradication Advisory Group.

Rationale

Eradication is a tactic on a continuum of pest management options. Prevention (quarantine & advocacy - excluding pests from a site) is often the most cost-effective tactic. Eradication "the complete and permanent removal of all wild populations from a defined area by a time-limited campaign" (Bomford & O'Brian 1995), is the next most cost-effective option when feasible. ***Feasible projects are achievable, sustainable, and acceptable.*** Early detection (surveillance) and rapid response (incursion response) to the arrival of a pest at a site improves the feasibility of eradication by preventing subsequent pest re-establishment. Islands of manageable size with little or no risk of immigration also increase the feasibility of eradication success.

Feasibility assessment is critical to quality decision making for eradications and the subsequent project design, operational planning, and implementation. In addition to consideration of core technical eradication principles other social, political, institutional, management, environmental, logistical, biological, and legal factors must be considered. Feasibility assessment informs a decision to abandon or go forward with a project but does not make that decision. The decision facing managers is "is it worth attempting or not?"

Attempting eradication when feasibility is uncertain, is best approached using adaptive management (with clear stopping rules, rigorous monitoring, and frequent reassessment of information) provided eradication is the most appropriate tactic and the benefits justify the risks of failure. Equally when costs are low (e.g., only a few individual pests are present) applying the 'precautionary principle' to eradicate before any potential damage is caused can be better than delaying action to gather further information on harm.

When eradication is not feasible, containment and sustained control are long-term pest management tactics to consider. Containment is ongoing control to prevent pest species spreading beyond a defined area. Sustained control is the ongoing suppression of pests to protect highly valued resources at a site.

The outcome of feasibility assessment is:

- Clearly framed reasons for investing in eradication
- Confidence eradication is the most appropriate tactic to achieve desired outcomes
- Avoiding further investment in projects likely to fail
- A correctly sized and resourced project maximising the likelihood of success, addressing critical dependencies, and managing expectations of time and cost.

Process

Figure 1. Eradication project process diagram. This diagram is used with permission from the Pacific Invasives Initiative (PII) http://www.pacificinvasivesinitiative.org/

Figure 1 shows the stages in the life cycle of an eradication project and how stakeholder engagement, monitoring and evaluation, and biosecurity are ongoing activities relevant to every stage.

Documentation in each stage builds on that of the previous documents and forecasts information relevant to the next stage. For example:

1. ***Project selection*** considers costs, benefits, and feasibility to determine if projects are worthy of a detailed feasibility assessment.
2. **Feasibility** adds more substance to this by considering eradication design with a focus on project achievability, sustainability and acceptability, and forecasts planning issues and dependencies so decisionmakers can determine whether to proceed with project design.

3. *Project design* focuses on correctly sizing the project using information generated in the feasibility stage to ensure funding, timelines, project staffing and decision making are appropriate for the project to be successful. Biosecurity, monitoring, and evaluation are built into the project at this stage.
4. *Operational planning* focuses on the detail of eradication design and logistics needed to implement, sustain, and assess success of the project.
5. *Implementation* uses the operational plan to guide the eradication actions necessary to succeed.
6. *Sustaining the project* draws on all previous information and planning (especially the design stage) to secure and sustain the gains made and identify lessons for the future.

Documents in successive stages will use information from those preceding to allow them to 'standalone' for the reader so some 'cut and paste' repetition is inevitable. However, purpose and target audience differ for each so judgement is required to provide the right level of detail.

Complete a peer reviewed **feasibility assessment** before finally committing to an eradication project. This should fully evaluate the social and biological context and identify all issues to overcome so as to deliver and sustain the stated goals and predicted outcomes with the maximum chances of success. A good feasibility report will clearly articulate the goals of the project and the rationale behind them. It will provide a sound basis for investors to evaluate the costs, risks, benefits, and scope of a project. This information is directly relevant to the project design phase.

Engagement with iwi, whanau and hapu should occur at the project selection stage before a feasibility assessment is commenced. Identify all possible **stakeholders** during the feasibility stage and determine the level of interest, support, opposition, and social issues to resolve during consultation. Consultation with key stakeholders during the feasibility study stage before any decision to take the project forward has clear advantages (Griffiths et al 2012).

Identify all **biosecurity** risks for the project at the feasibility study stage. This includes the risks of quarantine failure, sabotage and target animals reinvading

Identify all necessary **trials and research** required to eliminate knowledge gaps in the biological and logistical aspects of the project. Some of these information needs may be driven by what stakeholders want to know. *Knowing about these requirements during the feasibility stage allows time and money to be built into the project design and informs the decision to invest further in the project.*

Reassess feasibility if at any time critical factors change or new issues emerge before project implementation. *For example, a change in stakeholder support may render the project untenable or the necessary ongoing biosecurity unsustainable* (Wilkinson and Priddel 2011, Oppel et al 2010).

Eradication feasibility assessments should be written by people experienced in pest management principles and knowledge of the site, values to be protected, pest species ecology, and the socio-political situation. Likewise, peer reviewers should have the relevant expertise and no conflict of interest in the project.

Without effective management even a feasible project will not succeed. It is important that the agency responsible for delivering the project has the capacity and capability to manage all aspects of the project to the highest possible standard. (Morrison et al 2011).

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To use this template, enter your text in response to questions and prompts provided. Planning issues and dependencies should be clearly identified in the context of the section in which they occur and summarised in section 8. Unnecessary template text can be deleted for final presentation.

PLANNING ISSUE: Insert a planning issue box wherever appropriate in the document

Planning issues are key issues needing time and resources to resolve and therefore further planning must be allowed for in the project design phase. Examples of planning issues are:

- *the filling of knowledge gaps such as non-target species exposure risk, target species detection probability; bait availability trials*
- *legal registration of a new poison bait product; a specific permission required or change in management plan*
- *design specification and procurement of critical infrastructure or logistical requirements (e.g., shipping)*
- *further consultation required to establish project governance, partnerships, or community understanding*

Wherever relevant in each section, identify critical further planning and consultation work required to enable quality project planning. Format planning issues like this to make them stand out, they will be summarised in section 8.8.

DEPENDENCIES: Insert a dependencies box wherever appropriate in the document

Dependencies are provisos which qualify a (feasibility assessment) finding that an eradication project is feasible. They are critical issues for the decision maker to weigh up when authorising a project to go forward to the design phase ("…it's only feasible if we can do this…"). Dependencies are specific to the eradication project and island situation being assessed (although not necessarily unique). Sections 5 and 6 will cover more general eradication principles. Examples of dependencies are:

- *the eradication of rodents from Motutapu Island was dependent on the ability to remove farm livestock from the island for several months*
- *the eradication of mice from Lord Howe Island was dependent on having access to bait in every household*
- *the eradication of deer from Secretary Island was dependent on being able to employ highly skilled hunters for the duration of the project.*

Wherever relevant in each section identify dependencies which directly affect feasibility. Format dependencies like this to make them stand out, they will be summarised in section 8.9.