Tokelau Kimoa/Rat, Feral Pig and Feral Cat Eradication Feasibility Assessment

Author: Paul Jacques (Island Conservation)

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1. Executive Summary

Eradication of rodents, feral pigs and feral cats from Tokelau would bring many benefits, both to terrestrial and marine biodiversity and to the livelihoods and well-being of the community. The restoration of native biodiversity following the removal of invasive mammals is a nature-based solution to maximise the resilience of the islands to the threats posed by human-induced climate change.

The proposed eradication is sustainable if biosecurity measures are improved and maintained for the movement of people and goods between Apia (Samoa) and each nuku, and if long-term management can prevent the reintroduction of domestic pigs and cats onto the motu.

The eradication is achievable provided that the community agree with the proposed methodology and are willing to support all recommendations. The key dependency is the acceptability to the community of slaughtering all or most of the domestic pigs prior to the eradication of rodents and restocking the communal pig pens only after the caution period has expired.

The proposed eradication is technically feasible and within the current limitations of a range of tools. This document will be submitted for consideration to the Taupulega of each nuku and other stakeholders. The dependencies summarised in section 8 will need to be considered carefully as these must be resolved before a Tokelau-wide eradication can proceed. If the proposal is considered acceptable then a trial eradication using ground-based techniques could be conducted on several islets during 2024. This would have the advantage of demonstrating the benefits of eradicating invasive mammals to the local community, including increased abundance of resources including coconut fruit and crabs.

2. Introduction

Eradication of invasive mammals, especially rats, has been a long-term goal of leaders in Tokelau, including the Taupulega (village councils) and the Ministry for Economic Development, Natural Resources and Environment (EDNRE). This feasibility assessment was highlighted as a priority in the Tokelau Invasive Species Strategy and Action Plan (TISSAP) for 2020-2027, (EDNRE 2020).

This assessment was delivered by Island Conservation as the Pacific Regional Invasive Species Management Support Service (PRISMSS) Predator Free Pacific Programme Technical Lead, under contract to the Secretariat of the Pacific Regional Environment Programme (SPREP) and was funded by the NZ Ministry of Foreign Affairs and Trade (MFAT) under the “Managing Invasive Species for Climate Change Adaptation in the Pacific” project. A site visit was undertaken in September and October 2023 to consult with the Taupulega of each nuku and to gather information to support the assessment.

The goal of this assessment is to assess the feasibility of permanently eradicating rats, feral cats and feral pigs from the entire territory of Tokelau and preventing the reinvasion of these species in the future. The intended audience are the decision makers of Tokelau, and, by extension, the community. The assessment will also be socialized amongst practitioners in the field of invasive mammal eradications for peer review.

3. Site and target pest description

3.1 Location and physical environment

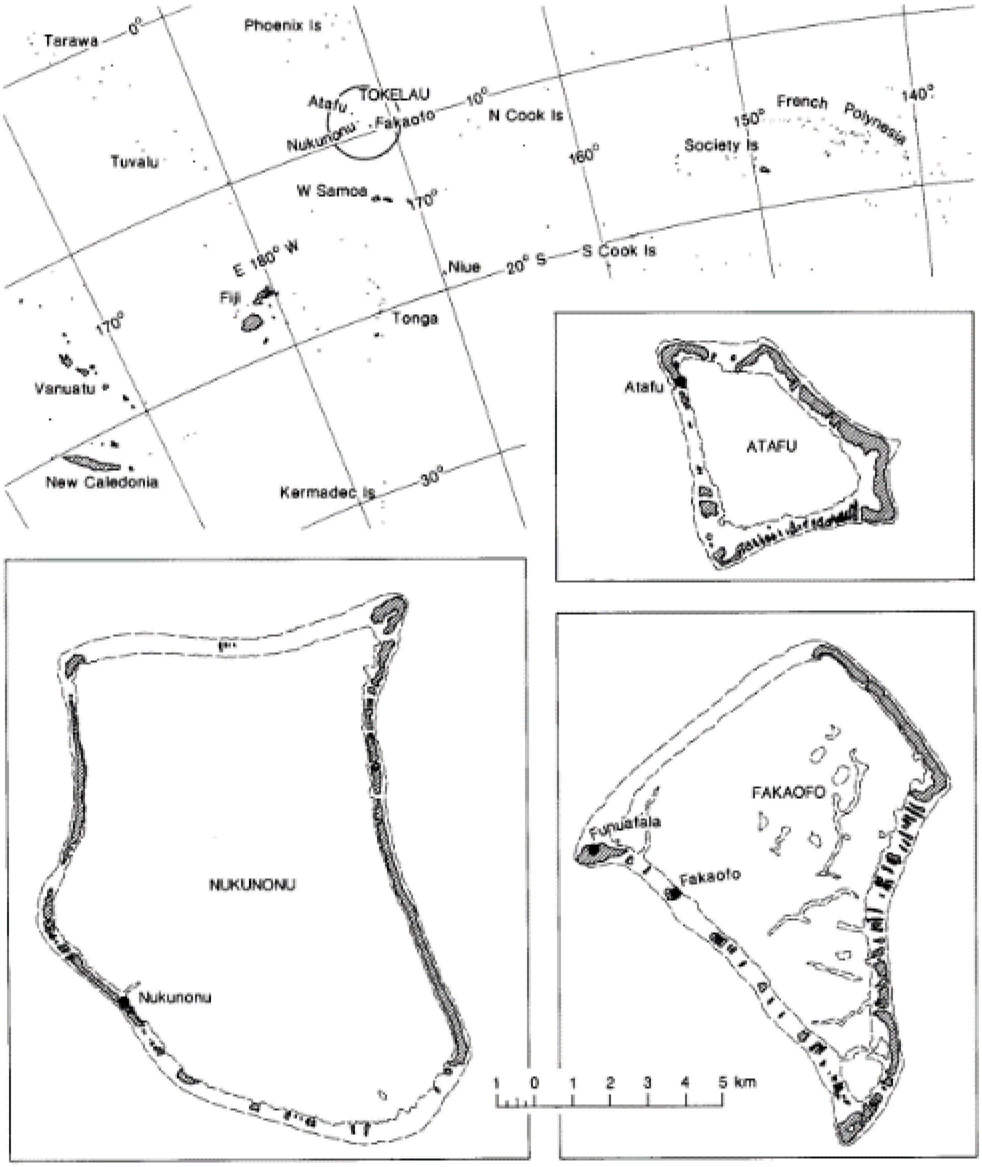

Figure 1 - map of Tokelau showing the three Nuku and their location within the South Pacific (taken from Thompson 1987).

Tokelau comprises three ring-shaped low-lying coral atolls (known as nuku), Atafu, Nukunonu and Fakaofo, situated between latitude 8–10º S and longitude 171–173º W in the central Pacific Ocean. Tokelau lies north of Samoa, East of Tuvalu, South of Kiribas and northwest of the Cook Islands. The total land area is 896.2ha made up of sand islets known as motu with a maximum elevation of about 5 metres. Although the total land area of each nuku is similar, the area of the lagoon is much smaller at Atafu relative to Fakaofo and Nukunonu. Table 1 below summarizes physical characteristics of each atoll.

The motu are mostly small (about 70% are less than 2 hectares) but each nuku has several much larger motu. Many of the motu lie close together along the reef, separated by channels with gaps of typically 30-100 m at low tide (Pierce et al.), but more isolated groups of motu are also found at each Nuku. The motu are largely comprised of coral-derived sand and rubble overlying hard coral

limestone (Parham 1971). Soils are characterised as highly alkaline, highly porous and nutrient poor, with high surface salinity and low humus content (Tokelau factsheet). Steep beaches occur in places on the ocean side, with coral boulders driven up to an elevation of up to 5 metres. Like all coral atolls the nuku are dynamic systems and are subject to change through wave-driven erosion and accretion over time.
Most of the vegetation of Tokelau "is highly disturbed, but nevertheless is dominated by native species. The only major exception is village areas, where alien weedy species predominate" (Art Whistler in Pierce et al 2012). On the uninhabited motus the vegetation is dominated by planted and regenerating coconuts and a small number of other littoral forest species which may dominate in places, notably Pandanus tectorius, Tournefortia argentea, Guettarda speciosa, Pisonia grandis (puka), Cordia subcordata, Hernandia nymphaeifolia and the seashore shrubs Pemphis acidula and Scaevola taccada. The understorey is dominated by seedlings of these species plus the ferns Asplenium nidus and Phymatosorus grossus. (Art Whistler in Pierce et al 2012).

Table 1 - physical characteristics of the nuku of Tokelau.

Nuku (west to east)	*Atafu*	*Nukunonu*	*Fakaofo*
Number of islets	68	44	65
Total land area (ha)	281.7	318.9	295.6
Area of largest islet (ha)	111.4	145.4	81.9
No. (*%*) of Islets over 20ha	3 (*4.4%*)	3 (*6.8%*)	5 (*7.7%*)
No. (*%*) of islets 5-20ha	4 (*5.9%*)	8 (*18.2%*)	2 (*3.1%*)
No. (*%*) of islets 2-5ha	9 (*13.2%*)	5 (*11.4%*)	14 (*21.5%*)
No. (*%)* of islets with an area of under 2ha	52 (*76.5%*)	28 (*63.6%*)	44 (*67.7%*)

3.2 Climate

Tokelau has a wet tropical climate, moderated by Easterly trade winds from April to November. Between December to March west or north-west monsoon winds usually equal or exceed the frequency of the easterly trades (Thompson). Wind speed over the oceans surrounding Tokelau averages 10 knots and strong winds (including cyclones) are not usually common (Thompson).

Daily temperature varies very little across the year, with an average of 28 degrees Celsius. Rainfall is irregular but abundant, averaging 2800mm per year. About 60% of the annual rainfall occurs between October and March, with December and January being particularly wet (Tokelau Factsheet). Year to year variability in rainfall is quite moderate and is influenced by peaks and troughs in the Southern Oscillation Index (SOI). When the SOI is positive (La Nina), low rainfall periods are likely to occur, conversely high rainfall periods can be expected when the SOI is low (El Nino) (Thompson).

The effects of climate change pose an existential threat to the long-term survival of Tokelau. The frequency of severe tropical cyclones has increased in recent years, and these combined with rising sea levels are contributing to the inundation of low-lying areas with adverse consequences for food and freshwater resources.

3.3 Biodiversity values

Although the biodiversity of Tokelau has been negatively impacted by the introduction of vertebrate, plant and invertebrate pest species, there are still important values worthy of protection, and the potential exists for restoration of native ecosystems through eradication of pest species.

Limited surveys of native biodiversity have been conducted in Tokelau. Surveys were conducted by Wodzicki and Laird (1970) and Pierce et al. (2012). Additional observations were made during the site visit in September/October 2023, but due to limited coverage it was not possible to make accurate population estimates for most species. Highlighting the limited surveys of avifauna to date, at least 3 bird species were seen during the 2023 visit that had not previously been recorded in Tokelau.

Seabirds dominate the avifauna of Tokelau; 14 species are present (TISSAP, EDNRE 2020) with other species using the surrounding waters to feed during the breeding season or on passage migration. Significant populations of black and brown noddies (*Anous minutus and A.stolidus*) and white terns (*Gigis alba*) breed on each nuku (Pierce et al. 2012). Atafu and Nunkunonu are recognised as Important Bird Areas (IBAs) due to the high numbers of breeding noddies and white terns, estimated at 30,000 and 20,000 pairs respectively (Birdlife International 1 & 2). There are colonies of red-footed boobies (*Sula sula*) on all three atolls, with Brown boobies (*Sula leucogaster*) also nesting on Atafu and Nukunonu. There is at least one large colony of sooty terns (*Onychoprion fuscatus*) on Nukunonu. Pierce et al. noted increases for at least seven species of seabirds relative to the estimates by Wodzicki and Laird (1970); the Taupulega have also noted increases in seabird numbers since the 1960s, apparently due to reduction in the traditional practices of harvesting seabirds (TISSAP, EDNRE 2020).

Half a dozen species of Arctic-breeding waders spend the northern winter in Tokelau, with immatures of some species present all year. Tokelau is an important wintering ground for the Alaskan-breeding Tiafee/Bristle-thighed Curlew (*Numenius tahitensis*), which is classified as vulnerable by the IUCN. Land birds are represented by just two species; the Pacific Pigeon (*Ducula pacifica*), which was common only on Atafu during the 2023 site visit, and the Long-tailed koel (*Eudynamys taitensis*) a winter migrant from New Zealand. Table 24 in appendix (from Pierce et al 2012) summarises avifauna population estimates for Tokelau in 2012.

Table *25* in appendix details species seen during the site visit in 2023.

In his extremely thorough assessment of the vegetation of Tokelau, Art Whistler stated that the native flora comprises 36 native vascular plant species. The low species richness and composition of species is in common with other atolls such as Tuvalu and the Northern Cook Islands, and is attributed to the atolls small size, low elevation harsh physical conditions, and the lack of variety of habitats on the atolls (Whistler, in Pierce et al. 2012). Art Whistler recommended that two native species be red-listed due to their declining populations and restricted range, the subshrubs Hedyotis romanzoffiensis and Achyranthes velutina, plus a plant of cultural importance, Solanum viride, an early Polynesian introduction.

Pierce et al recorded six species of reptiles in 2012, including the endangered green turtle (*Chelonia mydas*) plus three skink species and two geckos. They noted anecdotal evidence suggesting that turtles have declined significantly in recent decades. Only two were seen during the site visit in 2023.

Coconut crabs (Birgus latro) are common and widespread. Many sub-adults were seen during the site visit in 2023, including in the bush on the inhabited motu. The burrowing land crabs Tuerkayana rotundum and Tupa (*Cardisoma carnifex*) were locally common; the latter was locally abundant in the Pulaka pits on Fakaofo and Atafu.

The invertebrate fauna includes many spiders including at least one probable endemic species (A. Beavis in Pierce et al. 2012).

Figure 2 – Sooty terns nesting on Motu Akea, Nukunonu, October 2023.

3.4 Land use and tenure

1. On each of the three nuku only one or two motu are permanently inhabited – table x below gives approximate population figures. The human population fluctuates due to frequent

movements of people to and from Samoa, New Zealand and Australia. On the outer motu there are small fales where families go for picnics and sometimes spend the weekends.

Table 2 – population of each nuku

Nuku	Home Islets	Population
Atafu	Atafu	541 (2016 census)
Nukunonu	Nukunonu, Motuhaga	448 (2016 census)
Fakaofo	Fale, Fenua Fala	483 (2006 census)

Due to the poor nature of soils agriculture is limited to subsistence level. Only a limited number of food species are cultivated on the home islands, namely: breadfruit (Artocoarpus altilis), taro (three species), banana (Musa sp. 2 varieties), papaya (Carica papaya), pandanus (Pandanus odoratissimus), pumkin (Curcurbita sp.) and coconut (Cocos nucifera) (Tokelau factsheet).

On the outer motu food crops are limited in number. Coconut is abundant throughout. In the past copra (the meat of the coconut that is dried and pressed to extract the oil) was harvested but nowadays coconut is harvested only for domestic use. On a few motu at Atafu and Fakaofo conditions permit the cultivation of the Giant Swamp Taro/Pulaka (Cyrtosperma chamissonis) and in even fewer places the "true" taro (Colocasia esculenta) is grown. To allow for the cultivation of Pulaka, pits are dug that extend down to the brackish water lens – these pits are mostly found on uninhabited motu under coconut forest.

Land is either privately or communally owned. Most of the outer motu belong to individual families, but on each nuku there are also motu that are designated as communal reserves for harvesting natural resources.


Figure 3 - A Pulaka pit on Motu Akea, Fakaofo, Tokelau, September 2023.

The physical characteristics and limited natural resources of the atolls mean that Tokelau is one of the world's smallest economies. Tokelau is highly dependent on two primary sources of revenue – fisheries (including licence fees) and development assistance from New Zealand.

Domestic animals

Domestic Pigs.

In Tokelau nearly all families keep pigs for meat. On each hundreds of pigs are kept in a single, very large concrete-walled pen, divided up inside into many smaller enclosures, where each family feeds and houses their pigs. The animals are fed at various times during the day, on coconut and food scraps.

On Fakaofo, in addition to the communal pen on Fenua Fala, pigs belonging to residents of Fale are penned on the small nearby motu of Te Afua tau lua (1.5 ha), where there are many fenced enclosures in various states of repair. Some pigs free-range on the island, apparently because their enclosures have fallen down. Table 3 below summarises characteristics of the pig pens; locations of the pig pens are shown in Figure 4.

Table 3 - Physical characteristics of communal pig pens, Tokelau.

Nuku, Motu	Area of pens	Habitat within pen
Atafu, Atafu village	3.63 ha	Cordia subcordata forest, coral rubble.
Nukunonu, Nukunonu village	0.65 ha	Cordia/coconut forest, coral rubble
Fenua Fala	0.45 ha	Coconut forest, shrubs, coral rubble
Te Afua Tau Lua (whole motu)	1.51 ha	Coconut, Pandanus, shrubs, coral rubble

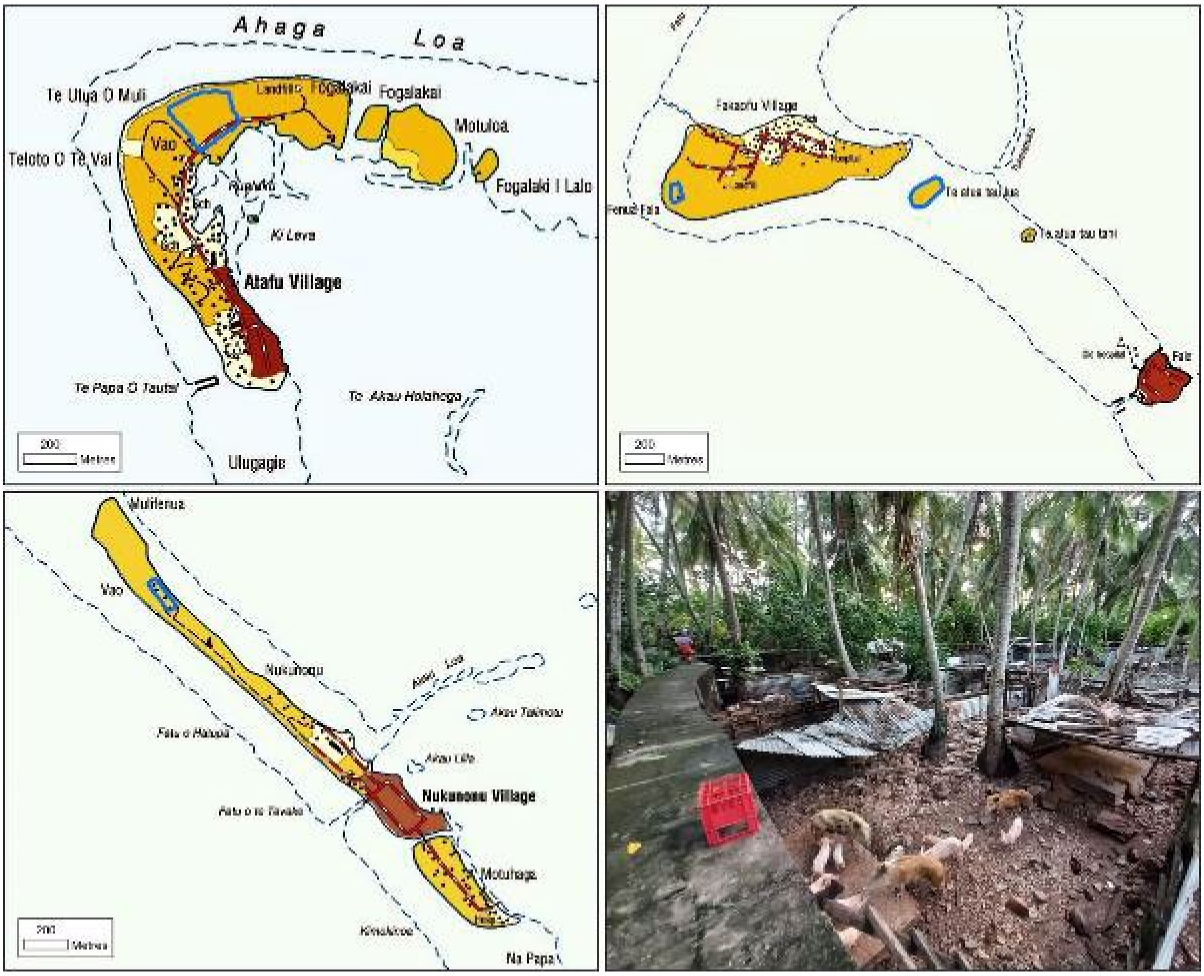

Figure 4 - Maps of the village motu with the pig pens highlighted in blue, with a photo of the pig pen on Fenua Fala bottom right.

Domestic and stray cats

Domestic and stray cats are abundant on all of the home islets**.** Keeping and breeding cats has been encouraged to control rat numbers around homes, and it has recently become fashionable among the young people to keep cats as pets (Puka Solomona pers. comms.). Cats appear to be effective at keeping rat numbers down in dwellings, but they must have a negative impact on native biodiversity, e.g. cats were witnessed stalking Pacific Golden Plovers on the school field on Fenua Fala during the feasibility visit. Numbers have spiralled out of control and this has contributed to the transport and spread of feral cats to the outer motu (Hefo Wright pers. comms.).

Dogs

Dogs are absent from Tokelau - they are not permitted to be kept on Tokelau by order of the Taupulega.

Chickens

Chickens were once kept in pens on the home islands but were let go, possibly due to a disease outbreak. Moderate numbers of Feral chickens now frequent the gardens, pig pens and rubbish dumps on the home islets and have been spread to some of the outer motu.

3.5 Human history and cultural values

The atolls of Tokelau have been occupied by Polynesian people for about 1000 years. A period of wars in the 18th century unified the previously independent atolls. European contact occurred from this period, with missionaries (first Catholic, then Protestant) arriving from the 1820's onwards (Whistler in Pierce et al. 2012). The male population of the atolls was decimated by Chilean "Blackbirders" (slave traders) in the 1860's. Tokelau was made a British protectorate in 1889. Since 1925 Tokelau has been under the administration of New Zealand.

System of Government

Tokelau is classed as a non-self-governing territory of New Zealand. The Administrator of Tokelau is appointed by the New Zealand Minister of Foreign Affairs to supervise the governance of the territory. The position is currently held by Don Higgins. The official head of state is King Charles III. New Zealand statute law does not apply to Tokelau unless expressly extended to Tokelau. Under the Tokelau Amendment Act (1996) the General Fono have power to make rules for the peace, order and good government of Tokelau. The rules of the General Fono have legal effect in Tokelau (tokelau.org.nz).

The head of government in Tokelau is known as the Ulu-o-Tokelau – this office rotates between the Faipule (leader) of each nuku for a one-year term. The parliament, called the General Fono, meets three times per year and comprises elected representatives from each nuku. There are seven government departments including the Department of Economic Development, Natural Resources and Environment (EDNRE), which leads environmental protection work in Tokelau. A Council for the Ongoing Governance of Tokelau, based in Apia, Samoa, has executive authority – the council consists of the Faipule (leader) and Pulenuku (village mayor) of each of the three Nuku. Each nuku has a village council of elders called the Taupulega who are the traditional governing authority in Tokelau and who grant the authority of the General Fono and council. The Taupulega manage all services at the village level and meet regularly to discuss issues of concern. Other important groups are the Fatupaepae (Women's group) and the Aumaga (Men's group).

Tokelau has for some years been moving towards greater self-governance and is supported in this by the Government of New Zealand and the UN Special Commission on Decolonization (tokelau.org.nz).

Visitors can travel to Tokelau by invite of the Taupulega only, and they must pass a police-check and be signed off as medically fit to be allowed entry. Tokelau is a strongly communal society that "places considerable emphasis on collective effort and reward" (tokelau.org.nz). The Inati system of resource sharing is a prime example of this, whereby resources such as fish, flour and rice and divided are periodically equally amongst all members of the community.

3.6 Existing infrastructure

The villages are comprised of solid, spacious houses, mainly concrete in construction, with a mosaic of gardens, open spaces and communal buildings. Except for Fale, all of the home islets have significant areas of forest, with the village occupying less than half of the land area of the motu. Fale is distinctive for being very densely populated and surrounded entirely by cast concrete walls.

The roads are unpaved but well maintained. On Fenua Fala (Fakaofo) and Nukunonu there are cars and utility vehicles, whilst on Atafu most families use battery-powered golf carts to travel around the village. There is a primary and secondar school and a hospital on each nuku.

Each nuku has solar electricity generation and back-up diesel generators. The power supply appears to be reliable. There is a cellphone tower on each nuku and cell coverage and mobile data are supplied on the Teletok network. Recently many families have acquired Starlink hardware due to the much lower fees and faster internet provided by this service.

Figure 5 - Pacific Golden Plovers roosting on a solar panel array, Atafu, Tokelau, October 2023.

Tokelau has no airport so people and equipment must travel by boat. Only two vessels visit on a regular timetable, the passenger vessel MV Mataliki and the freighter MV Kalopaga (which can also carry about a dozen passengers). These vessels depart from Apia, Samoa, about twice a month and each alternately travels first to either Atafu (westernmost nuku) or Fakaofo (easternmost nuku).

Each village has a large concrete wharf adjacent to a channel cut through the outer reef to the open ocean to allow passage of barges and smaller boats. Each nuku has two barges each; these are used to transport people and goods back and forth from the passenger vessel MV Mataliki and the freight vessel MV Kalopaga. There are many aluminium dinghies with small outboard motors, used for travel between motu and for fishing within the lagoon and outside the reef.


Figure 6 - Houses and outbuildings are clustered close together on the motu of Fale, Fakaofo.

3.7 Target species ecology and impacts

Rodents

The only species of rodent confirmed to be present in Tokelau at the time of writing is the Pacific rat, Rattus exulans. The presence of European rats has been suspected in the past, e.g., large rats were reported by local people from Fenua Fala, Fakaofo (Pierce et al. 2012), but none have been caught.

Extensive field surveys were carried out at all three nuku in 2012 by Ray Pearce and team; traps and spotlight searches were used to detect rats. In September/October 2023 a limited number of motu on each nuku were surveyed for rat presence. Traps, and Trail Cameras baited with various combinations of fish, chicken, coconut and peanut butter, were used; traps were mostly compromised by the high density of landcrabs, even when set on vertical trunks.

Biometrics

The Rattus exulans in Tokelau are large for their species; Pierce et al. report that a sample of seven Rattus exulans caught from Tokelau motu, Nukunonu were larger than any individuals of the same species trapped at the nearby Phoenix Islands. During the 2023 field visit the large size of the Rattus exulans was again noted; Table 4 summarizes biometric data from 2012 and 2023.

Twenty-six rats were caught during the 2023 field visit. All appeared to be Rattus exulans, although five individuals (three male and two female) had tails that were markedly shorter than their bodies – this may have been due to injury. Nevertheless, tissue samples from these five, along with samples from two exceptionally large individuals, were sent to Eco Gene (Landcare Research, Auckland), who confirmed them to be Rattus exulans. Tissue samples from all twenty-six individuals caught will be genotyped and archived at Ecogene. Samples taken in 2012 were provided to Auckland University for DNA analysis (Pierce et al, 2012).

Table 4 - Biometrics of Rattus exulans in Tokelau

Sex	No.	Mean head and body length (and range in mm)	Mean tail length (and range in mm)	Mean weight (and range in g)	Source
Male	9	147.5 (125-172)	153.2 (120-207)	87.3 (70-118)	Jacques and Hanley-Nickolls 2023
Male	5	147 (129-159)	157 (149-162)	96 (67-128)	(Pierce et al. 2012)
Female	16	139.5 (129-155)	152.9 (115-189)	74.7 (58-94)	Jacques and Hanley-Nickolls 2023
Female	2	111.5 (105-118)	120.5 (118-123)	63 (58-68)	(Pierce et al. 2012)

Table 5 - Rattus exulans are exceptionally large in Tokelau – this male, caught on Atafu in October 2023, weighed 118 grams.

Diet

Rats are omnivorous, and their diets are highly variable, likely in response to available prey (Harper & Bunbury). In a two-year study of the life-history of Rattus exulans on Kure Atoll, Hawaii, Wirtz found that their diet was composed of approximately 62 percent plant material, 30 percent of insects, and 8 percent of vertebrate flesh, mainly seabirds (Wirtz).

Lifecycle, breeding and home range

The Pacific rat can breed all year round on tropical islands with little seasonal difference in rainfall (Harper and Bunbury). This is likely to be true for Tokelau. Breeding may be reduced, however, in the drier months (May to September) compared to the wetter parts of the year (October to March) as peaks in breeding activity are likely to coincide with periods of increased rainfall and soil humidity levels (Griffiths). Very small juveniles were seen on trail cameras on several motu during the September/October 2023 field visit, and one was trapped on Fakaofo, indicating recent breeding.

PLANNING ISSUE:
Do rats breed year-round in Tokelau?

The life span of the Pacific rat is between one and two years during which time a female will typically breed up to six times, with the average litter being seven or eight (Griffiths). Home ranges are typically small. Breeding males have significantly larger home ranges than breeding females (Wirtz). Using a live-trapping grid on Kure Atoll produced mean home ranges of 0.18ha for adult males and 0.08ha for breeding females. The smallest home range recorded was 0.012ha (120 square metres). Home range size was not affected by density fluctuations or breeding activity (Wirtz).

Distribution and habitat use

Invasive rats have wide fundamental niches, so in the absence of competitors (e.g., other rat species) they will occupy all available habitats on islands at varying densities depending on the habitat suitability and presence or absence of predators (Harper and Bunbury). All invasive rat species are commensal, i.e. they will also live in and around human habitation.

In Tokelau Rattus exulans are distributed widely on all three Nuku. They use the forest floor but are also arboreal, feeding in the tree canopy, and may be active both diurnally and nocturnally (Harper and Bunbury).

There are a handful of motu on each atoll that may be rat-free. In 2012 Pierce et al reported that trapping and spotlighting had produced nil returns on several motu in the Hakea area of Atafu and considered it possible that rats may have already been eradicated from these motu. No sign was found on some of the isolated southern motu of Nukunonu. (Pierce et al 2012 and Hefo Wright pers. comms.). In 2023 the isolated motu of Te Papaloa on Fakaofo and Motu Akea on Nukunonu were both considered to be probably rat-free. To confirm absolutely that certain motu are rat-free would require sustained sampling effort over time. The risk of a false negative is high and must be weighed against the cost of eradicating islets that may have no rats. Relying on old data is not an option as islets that were rat-free may have been re-invaded subsequently. If an islet appears to be rat-free but is within swimming distance of islets with rats then it would be wisest to bait it regardless.

PLANNING ISSUE:
Establish which motu are currently rat-free. If these motu are certainly free of rats at the start of the operation this would improve efficiency.

Abundance and density

On tropical islands with little seasonal difference in rainfall, Rattus exulans can often exceed population densities of well over 100 rats ha (Harper and Bunbury). The limiting factor on population size is probably food (Wirtz). Drought can also have a significant impact on rat populations (Pierce et al. 2008).

The highest density of Rattus exulans recorded in the literature is from Tokelau; Wodzicki (1969) used the capture-mark-recapture method to estimate a peak density of 288 rats per hectare on various islets of the Nukunonu and Atafu atolls (Wodzicki 1969 in Harper and Bunbury).

The abundance of Rattus exulans populations in Tokelau is not uniform but varies from motu to motu, as noted by Wodzicki in 1970, Pierce et al. in 2012 and during the site visit in 2023. Certain motu have very high rat abundance, for instance in 1970 on Fenua loa motu, Fakaofo, Wodzicki reported that "…parties of half a dozen rats could be seen almost everywhere."

In 2012 Pierce et al reported that "When rats were present they were generally at low levels on Atafu, whereas on Nukunonu they were generally common to abundant and active from mid afternoon on through the night." They attributed the low numbers on Atafu to a sustained rat-baiting programme there.

During the field visit in 2023 the highest rat abundances noted were on the motu of Te Kamu, Nukunonu, where many rats were watched actively foraging in the daytime. A trail camera set on a small pile of opened coconuts recorded a peak of 33 rats in a single frame. As in 2012, rat abundance on motu visited on Nukunonu was generally high. Abundance varied from low to moderate on Fakaofo. As in 2012, Atafu had recently had extensive rat control; outside the control area rat numbers varied from low to moderate.

Figure 7 - Pacific rats feeding on a coconut pile, Fenua loa, Nukunonu, October 2023 (image taken from a trail camera picture).

Impacts

Invasive rats are recognized as the main cause of animal extinctions on islands and are one of the most important threats to remaining insular biodiversity (Jones et al. 2016, Doherty et al. 2016). Rats cause serious deleterious effects to native species through predation and competition (Harper and Bunbury 2015), and taxa directly affected include landbirds (Harper and Bunbury 2015), seabirds (Jones et al. 2008), lizards (Thibault et al. 2016), turtles (Caut et al. 2008), plants (Wolf et al. 2018), terrestrial invertebrates (Gibbs 2009), and crustaceans (Pitman 2006). Pierce et al. (2012) estimated rat impacts on biota in Tokelau, suggesting that rat impact was low to moderate on populations of tree nesting seabirds (noddies and white terns) and high to severe on ground nesting seabirds (Black-naped and Sooty terns), Lizards and invertebrates.

The decimation by rats of "connector" species (such as burrowing seabirds, turtles and landcrabs) disrupts nutrient flows among pelagic, island and coral reef ecosystems (Graham et al 2018) causing profound impacts on the health of island ecosystems and their surrounding reefs.
The cumulative impacts of rats on island biota combine to alter critical ecosystem functions both above and below ground. For example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen, and pH are lower on rodent-invaded islands relative to rodent-free islands (Fukami et al. 2006). This results in greatly reduced nutrient flows from islands back to their surrounding reefs. On islands in the Chagos archipelago that are invasive rat-free productivity, structure and functioning of adjacent coral reef ecosystems is measurably higher, reef fish grow faster and fish communities have much greater biomass relative to islands that have invasive rats (Graham et al. 2018).

Where rodents co-exist with other predators (such as cats) the collective direct effect of introduced predators on seabirds is greater than the sum of the individual impacts because rats also act as a food resource to higher level predators when seabirds are absent from the islands (Moors and Atkinson 1984), meaning higher-level predators can sustain larger populations.

In Tokelau, impacts of rats recorded in scientific literature have focussed on the serious economic impact to the coconut crop. Wodzicki (1969) reported that green coconuts 5–25 cm. long are gnawed on the palms and subsequently fall to the ground and disintegrate. He found that the worst rat damage was not correlated with high densities of rats but was associated with islets that were humid and densely undergrown with shrubs and usually bird-nest fern (Wodzicki 1970). He also noted variation amongst coconut trees, with certain sweeter, thinner-husked varieties being more susceptible to rat consumption. Wodzicki concluded that "we still do not know what ultimate factor sends rats to the top of coconut palms and makes them gnaw nuts." (Wodzicki 1970).

Rats have long been a nuisance in the villages of Tokelau, causing damage to furnishings and electrical wiring and creating risk of spreading infectious diseases such as leptospirosis. In 1970 Wodzicki reported a "steady and continuous influx of rats into the school buildings and dwellings" on Fenuafala, Fakaofo. At Fale village, Fakaofo, the concrete and stone wall that surrounds the village provides "suitable dry habitat in which rats breed and stay during the day and from which they forage into the dwellings at night" (Wodzicki 1970). Domestic cats have been introduced to villages and have proliferated in number recently and a consequent reduction in rat numbers has been reported from villages. Conversely Wodzicki in 1970 noted that on Fale "although the village has scores of emaciated cats, the writer failed to see a single cat carrying a rat during his six weeks stay at Fakaofo".

Feral pigs

Diet

Pigs are omnivorous, eating large amounts of vegetable matter and also animal protein. On tropical atolls a major food source are the seedlings and saplings of coconut (cocos nucifera). They can be readily attracted by piles of opened coconuts, which they consume voraciously. Animal protein is readily consumed and includes invertebrates, crustaceans, lizards, ground-nesting birds and their eggs, and turtle nests. Sows require approximately 25% protein in their diet to successfully raise young (Choquenot et al. 1996).

Breeding and Home range

Feral pigs are opportunistic breeders, capable of breeding year round if conditions are favorable (Tep and Gaines). Four small piglets were captured by the field team during the visit to Tokelau in September/October 2023, indicating recent breeding.
Piglets reach breeding age at between 10 and 12 months (Wodzicki, 1950). Adult females have a gestation period of 112-114 days and an average litter contains seven piglets (Tep and Gaines).
Little information is available regarding the size of feral pig home ranges and distance of juvenile dispersal on Pacific islands. Whilst pigs in temperate regions tend to group together in mobs of ten or more animals, on tropical islands pigs may be more solitary. This is the case in Niue (Griffiths) and appears to be true in Tokelau, at least from very limited surveys conducted in September/October 2023 (see abundance and density below).

Distribution and habitat use

Within Tokelau Feral pigs are only confirmed to be present on Nukunonu, although there may be a population on one or two motu in Atafu (Taupulega pers. comms.). In Nukunonu they are present on at least eight motu (Pierce et al.); on Fenua loa, on the chain of interconnected motu running south from Te Puka I Mua, and on the two motu to the south-east of Nukunonu village. Pigs were previously present on Te Fakanava (Pierce et al.) and on Tokelau motu but have now been extirpated from both motu (Hefo Wright pers. comms.). No sign was found on either motu during searches during the 2023 field visit.
Pigs are reportedly present only in the southern part of the large motu of Fenua loa, however their distribution there requires further research. There is very high potential for pigs to spread through the 16 closely-packed motus north of Fenua loa, a further 40 hectares of habitat.

PLANNING ISSUE:
Confirm which islets feral pigs are present on for each Nuku.

Table 6 - Distribution of pigs within Nukunonu atoll.

Motu name	*Location within Nukunonu atoll*	*Size (ha)*
Te Puka I Muli	East	8.0
Te Kamu	East	8.5
Te Puka I Mua	South	6.3
Te Afua	South	3.5
Fenua loa	West	145.4
TOTAL		*171.7*

Abundance and density

Limited investigations of abundance and ranging behaviour were conducted on Te Kamu and Te Puka I Muli during the field visit in October 2023. These islets are interconnected by a causeway which includes several smaller vegetated islets, the whole area comprising about 30 hectares. Five cameras were placed approximately 150 metres apart, three on Te Kamu and two on Te Puka I Muli. Cameras were baited with piles of ten opened coconuts and were left out for one night. Seven individual pigs were recorded on camera, two of which were seen on both islands on cameras more than 1500 metres apart. From this limited trial it is clear that at least some pigs range widely across the complex of interconnected islands, and that pig ranges on these small islands overlap strongly. It is not possible to estimate the population size on Te Kamu and Te Puka I Muli from this limited survey, but it is clear that pigs are readily detectable using coconut piles as bait.
All sightings were of solitary pigs, except for a single occasion where one pig joined another one already feeding at a coconut pile. Pigs seen on appeared healthy camera and included some large boars.

Table 7 - Individual pigs seen on trail cameras, Te Kamu and Te Puka I Mua

Individual	Cameras seen at	Linear distance between sightings
Sooty boar	Te Puka 2, Te Kamu 3	1869 metres
Tan sow	Te Kamu 1, Te Puka 1&2	1643 metres
Tan boar	Te Puka 1&2	185 metres
Stripy boar	Te Puka 2	*One camera only*
Stripy weaner	Te Kamu 2	*One camera only*
Blotched boar	Te Kamu 2	*One camera only*
Tan weaner	Te Kamu 2	*One camera only*

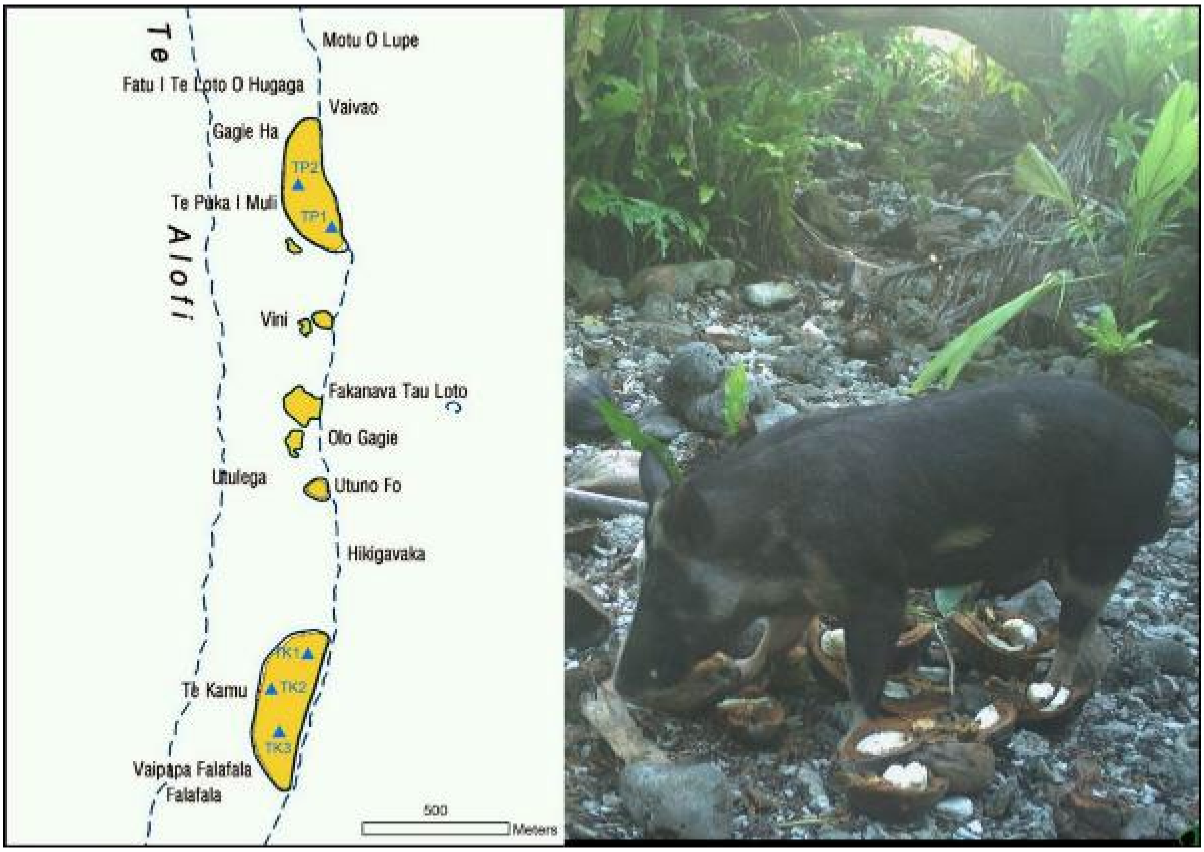

Figure 8. Location of cameras on Te Kamu and Te Puka I Muli and a boar at a coconut pile on Te Kamu.

Impacts

Feral pigs are "ecosystem engineers" that create habitat change and destruction through their rooting, wallowing, trampling, and feeding behaviors. Feral pigs also affect water quality and change the composition of trees in forest communities (USDA). They are a major agricultural pest, for example in Niue a few pigs can destroy an entire taro patch either by eating the tubers or because they find cultivated soils attractive sites to root for invertebrates (Griffiths).

Threats to native fauna from wild pigs are pervasive across taxonomic groups, and species on islands throughout the non-native range of wild pigs are particularly vulnerable (Risch et al). Consumption by feral pigs is known to cause local extinctions of populations of ground and burrow-nesting seabirds (McDonough et al.), and negatively impact populations of land crabs (Pitman et al.) and turtles (McDonough et al.). In a study on islands in Florida, USA, Feral pigs were documented predating 100% of monitored sea-turtle nests, which suggested that once feral pigs detected the presence of nests, this resource was sought out until it was exhausted (McDonough et al).

A stark example of the impact of pigs on ground nesting seabirds comes from Clipperton Island in the eastern tropical Pacific, where many thousands of Masked and Brown Boobies bred before humans arrived in 1892, bringing pigs with them. By 1958 predation by pigs had reduced the vast booby colonies to about 500 Brown and 150 Masked Boobies. Pigs were eradicated in that year. In 2003 the recovery of the Booby colonies was assessed using aerial photography; a minimum of 25,000 Brown Boobies and 112,000 Masked Boobies were counted, a significant proportion of the world's population for both species (Pitman et al.).

On Tokelau the continued presence and inevitable spread of feral pigs through the motu poses a critical threat to native species including populations of ground-nesting seabirds (e.g. Brown Boobies, red-tailed tropicbirds and Sooty terns), and Green Turtles (Pierce et al. 2012). Coconut crabs will also be impacted, and can be expected to be extirpated from motu where feral pigs occur. Feral pigs will continue to cause habitat change and limit the recruitment of tree species including coconut. Feral pigs also pose a threat to human health; several people have reportedly been gored by boars on Te Kamu and Te Puka I Muli (Nukunonu Taupulega, pers. comms.).

Feral cats

Diet

Cats are above all opportunistic, taking available prey (Fitzgerald and Karl 1979). In an overview of diet studies from the Northern and Southern Hemispheres, Pearre and Maas (1998) found their main prey to be mammals, with birds secondary, and reptiles and insects more frequent at lower latitudes and during warm seasons (see also Fitzgerald 1988). On islands, mammals were again most important, followed by birds, especially when seabirds are present (Fitzgerald and Turner 2000, Bonnaud et al. 2011). Eggs of ground nesting birds are also taken (Bonnaud et al.). In New Caledonia, lizards represented a significant proportion of feral cat diet (Palmas et al.). From these studies it is reasonable to conclude that on Tokelau, the main prey for cats is likely rodents and reptiles, supplemented by invertebrates and at times of the year by ground nesting sea birds.

Breeding and Home range

Generally home range size for feral cats is negatively correlated with food availability and density of other cats (Glen et al). When food is scarce, density of feral cats declines, and home ranges are expanded or abandoned completely as cats roam widely in search of prey. (Harper). Home range of male cats is typically large and encompasses the ranges of several females, whereas female home ranges are typically much smaller (Glen et al.). No data could be found for home range sizes of feral cats on tropical atolls.

Distribution and Habitat use

On Tokelau feral cats have been deliberately introduced to many motu to control rat numbers around fales, or in some cases dumped on motu due to overcrowding on the main islands (Hefo Wright pers. comms., Pierce et al). During the feasibility visit in September-October 2023 cats were detected on trail cameras on six motu. Further distribution data is from sightings, reliable reports and surveys by Pierce et al. (2012). The known range of cats, shown in Table 8 below, is greater than 50% of the total land area of Tokelau. It is highly likely that the range of feral cats is even larger, given the widespread practice of releasing cats onto motu and the very close proximity of motu facilitating the spread of feral cats.

Abundance and density

Very little exist for abundance and density of feral cats on tropical islands. One study from the Solomon Islands reported feral cats as "abundant" in tropical rainforests on four islands with densities ranging from between 0.31 and 2.65 individuals per km^2 (Lavery et al.).

On Tokelau, on motu where feral cats are present, they were readily detected on trail cameras set for one night and baited with fish, chicken or beef. On the long motu of Na Utua, Atafu, for example, 3 cameras were set in the forest at a wide spacing over a distance of 1800 metres. Cats were detected before nightfall on all cameras, with one camera picking up a cat within one hour of being set. The rapid detection of cats (five individuals in total) on all three cameras suggests moderate to high abundance of feral cats.

Abundance of cats is very high on the inhabited motu. Many of these are true house cats, but there are also many strays (i.e. animals socialised to people but living wild) and true feral cats (wild living animals that are not socialised to people) in the village areas and throughout the surrounding forest. House cats are not spayed so breeding is uncontrolled, continually adding more individuals to the already high population. On Nukunonu thirteen cats were counted at once coming to a chicken bait outside our accommodation during the feasibility visit.

Table 8 - known distribution of feral cats in Tokelau

Nuku	Motu	Size (ha)	Notes	Most recent source
Fakaofo	Fale	4.9		Jacques/Hanley-Nickolls 2023
Fakaofo	Fenua Fala	39.9		Jacques/Hanley-Nickolls 2023
Fakaofo	Mulifenua	27.1	May be throughout NE Motu (125.3 ha)	Jacques/Hanley-Nickolls 2023
Nukunonu	Nukunonu	26.7		Jacques/Hanley-Nickolls 2023
Nukunonu	Motuhaga	7.8		Jacques/Hanley-Nickolls 2023
Nukunonu	Te Fakanava	10.1		Hefo Wright Pers. comms 2023
Nukunonu	Fenua loa	145.4		Pierce et al. 2012
Atafu	Atafu	41.4		Jacques/Hanley-Nickolls 2023
Atafu	Te Oki	41.1		Pierce et al. 2012
Atafu	Na Utua	111.4		Jacques/Hanley-Nickolls 2023
Atafu	Fenualoa	11.9		Jacques/Hanley-Nickolls 2023
TOTAL		*467.7 ha*		

PLANNING ISSUE:
Confirm which islets feral cats are present on for each Nuku.

Impacts

Feral cats are one of the most successful and harmful invasive predator species, leading to dramatic loss of biodiversity across the globe (Palmas et al.). They are significant drivers of extinction and endangerment of native fauna (Bonnaud et al.), adversely affect populations of landbirds, seabirds (Ratcliffe et al.), reptiles, invertebrates and amphibians (Bonnaud et al.). The availability of rats as a constant food source amplifies the abundance of cats and therefore their impact on native species.

In Tokelau species including Red-tailed tropicbird, Black-naped tern, Sooty Tern, ground-nesting boobies and Green Turtle hatchlings are all threatened by feral cats (Pierce et al.). Feral cats have certainly reduced populations of ground-nesting seabirds significantly, for example on Tokelau Motu at Nukunonu, Pierce at al. documented cat tracks representing at least 3 individuals converging near a sooty tern colony, on which they were impacting (chicks and adults had been killed). This colony was still extensive in 2012 but could not be found in 2023, instead a much smaller colony of sooty terns were breeding on the southern motu of Motu Akea.

Feral cats also pose a disease risk to humans and marine mammals. The *Toxoplasma gondii* parasite, which can only reproduce in cats, can cause serious illness in humans and has been shown to cause mortality of endangered dolphin species in New Zealand (NZ Department of Conservation).

Figure 9 - one of five individual cats detected across 3 trail cameras set for one night on Na Utua, Atafu, October 2023. The camera was baited with fried chicken.

3.8 Historical pest control

Rat control using Vertebrate Toxic Agents (VTAs)

There is a long history of use of VTAs to control rats on Tokelau, beginning in the 1960s when Dr K Wodzicki who conducted trials using Zinc Phosphide and the anticoagulant Warfarin (Wodizicki 1969).

For many years the Taupulega have used anticoagulant rat baits to manage landscape-scale rat control on each nuku to protect flowering and fruiting coconuts (EDNRE 2020). In 2012 Pierce at al reported that the product Ridrat, containing the second-generation anticoagulant Bromodiolone, was in widespread use at a landscape-scale on all three nuku, particularly on Atafu. Ridrat blocks were nailed to coconut trees in July-August when the coconuts were beginning to flower. They reported that sustained, annual baiting on Atafu appeared to have reduced numbers in some places and may have succeeded in eradicating rats from the Hakea Motu. Baiting was less sustained on Fakaofo and Nukunonu and this may have explained the higher rat numbers compared to Atafu. In the past decade landscape-scale rat control has continued, with Pestoff blocks (containing Brodifacoum) now used in place of Ridrat.

During the feasibility visit in September/October 2023 a large baiting operation had recently been completed on Atafu covering about half of the atoll. Pestoff blocks had been nailed to each coconut tree that bore green fruit. On Nukunonu and Fakaofo there were no reports of recent landscape-scale anticoagulant use.

Risks of ongoing baiting

Pierce (2012) cautioned against the ongoing annual use of anticoagulants, and this is echoed by the Tokelau Invasive Species Strategy and Action Plan (TISSAP), (EDNRE 2020). Due to the environmental persistence of these products, long-term use poses a threat to populations of wading birds (including the IUCN Vulnerable Tiafee/Bristle-thighed curlew) and possibly also to the Kaleva (long-tailed cuckoo), through secondary poisoning by consumption of landcrabs and lizards containing toxin residues. There is also an ongoing risk to human health through consumption of landcrabs containing toxin residues, and via the potential for toxin accumulation in pigs, particularly in the liver, which is a favoured food of Tokelauan people.

The TISSAP notes that “the Taupulega ranks total eradication of Kimoa (rats) as a priority, which if successful, would lead to the cessation of brodifacoum being used in Tokelau altogether”.

3.9 Other pests

Vertebrates

Several Myna birds, both common (Acridotheres tristis) and Jungle (Acridotheres fuscus) were reported in 2011 and at least one pair nested , producing an egg. They were thought to have arrived on an NZ Naval ship, presumably having come on board in Samoa. No further sightings were made and clearly they did not establish a population, as these bold and vocal birds are unmissable if present.

Although a native species the laika/black noddy (Anous minutus) is considered a pest around the villages as their guano collects on rooves and impacts water quality. There has been some local reduction in numbers at Fakaofo due to severe pruning and some felling (for mealy bug management) of breadfruit trees in which they nest (EDNRE 2020).

Invertebrates

Yellow crazy ants (YCAs) are present on all three nuku. Abundance has been very high at times in certain places. on Atafu Village Motu YCAs were considered a significant pest by residents before treatment of the entire motu in 2015, after which YCA numbers declined and were no longer considered problematic by 2018 (EDNRE 2020). YCAs have also been treated on Nukunonu. On Fakaofo YCA numbers exploded on Fale but have declined since 2012.

Other invasive ant species may be present; some stinging red ants were collected from Fakaofo and Atafu during the 2023 feasibility visit and sent to Monica Gruber for identification.
Other pest invertebrates that have a significant impact on food production include the Seychelles Mealybug (Fakaofo only), Spiralling Whitefly (Fakaofo and Nukunonu) and Coconut Rhinoceros beetle (Fakaofo and Nukunonu) (EDNRE 2020).

Mosquitoes are widespread and are locally abundant on motu that have pulaka pits. In the TISSAP mosquitoes are listed in the second priority group of pests for control and/or eradication (EDNRE 2020).

Weeds

Some significant weed species are present. The priority species for control as listed in the TISSAP are Sphagneticola trilobata (or Wedelia) and Mikania micrantha (Mile-a-minute vine).

4. Why do it?

4.1 What is the goal?

To permanently eradicate rats, feral cats and feral pigs from the entire territory of Tokelau and to prevent reinvasion of these species in the future.

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

Table 9 - Objectives, outputs and desired outcomes of eradicating invasive mammals in Tokelau

Area	Objective	Output	Outcome
Biodiversity	Rats, feral cats and feral pigs are eradicated from Tokelau.	Implementation of the eradication project and subsequent report Monitoring and reporting of outcomes	Tokelau is mammalian pest free and remains so Noddy, tern, booby and tropicbird populations increase on the motu. Populations of Threatened species including the IUCN Endangered Green Sea Turtle and the Vulnerable Tiafee/Bristle-thighed curlew are secured. Land crab numbers increase on the motu. Motu and reef ecosystems are improved and maintained in a healthy and functioning state
Climate Resilience	Rats, feral cats and feral pigs are eradicated from Tokelau.	Implementation of the eradication project and subsequent report Monitoring and reporting of outcomes	Improved productivity and resilience of the fringing coral reef through greater nutrient input from increased populations of “connector species” leading to restoration of local accretion processes.
Food security	Rats, feral cats and feral pigs are eradicated from Tokelau.	Implementation of the eradication project and subsequent report Monitoring and reporting of outcomes	Improved coconut harvest by eliminating consumption by rats. Increase in native species for sustainable harvest. Increase in seabirds will produce more and bigger

			"indicator flocks" that will assist fish harvest. Increase in abundance of fish due to increased productivity of the coral reef.
Biosecurity	Tokelau remains free of Mammalian pests	Implementation of biosecurity and ongoing reporting	Tokelau is mammalian-pest free and remains so
People of Tokelau	Community is supportive of eradication and ongoing biosecurity	Community attitudes are measured and reported	The local community benefits (including improved yield of resources, improved health and income) from the eradication
Partnerships	Work collaboratively with Tokelauan leaders and other groups to achieve conservation outcomes	The success of partnerships is reported on	Cost and effort are reduced, and positive relationships are built
Employment	Tokelauans are trained and employed as project staff to achieve eradication	Training program Employment contracts	Eradication effort provides an income source for the local community
Knowledge	Capacity and knowledge are increased and shared	Project documented	Future projects benefit from knowledge gained in this one. Tokelauans can provide leadership to other Pacific nations as the first mammalian pest-free territory in the Pacific.

4.3 What are the ecological and climate-change resilience benefits of eradication?

Eradicating rats, feral cats and feral pigs will benefit virtually all native taxa of Tokelau by removing the burden of depredation and competition for resources. Based on result monitoring of past eradications on tropical islands we can expect major increases in abundance and breeding success of seabirds, landbirds, reptiles (including sea turtles), invertebrates (including land crabs), and plants. The direct threat of regional extinction posed to species such as the IUCN Green Sea Turtle (*Chelonia mydas*) will be lifted and threatened species can be expected to recover naturally without the need for human intervention. Recolonisation by native species that have previously been extirpated could also occur, as has happened following the eradication of invasive mammals on other islands (Ortiz-Catedral et al. 2009). On this point the TISSAP notes that "other species, including shearwater species, may be able to recolonize Tokelau and contribute to regional biodiversity and future food security for Tokelau" (EDNRE 2020).

The restoration of seabird colonies is an ecologically important change that has been well documented following eradications of invasive mammals. Direct benefits to breeding seabirds include an increase in nest site occupancy, nesting attempts, hatching success, and reduced nest depredation (Jones et al.).

The resurgence in abundance of "connector species" (i.e. species whose life cycle connects the atoll and the deep sea) including seabirds, land crabs and sea turtles, will promote the restoration of important ecosystem services by restoring nutrient pathways between the deep ocean, atoll and the surrounding coral reef (Benkwitt et al. 2021). Following invasive rat eradications on the Chagos archipelago in the Indian Ocean, seabird-derived nutrients increased significantly in soil, leaves, marine algae, and herbivorous reef fish, and seabird-derived nutrients extended out to at least three hundred metres from the shore of the islands (Benkwitt et al. 2021). Reef fish grew faster and had 48% higher biomass overall compared with reefs around rat-infested islands. Rates of two critical ecosystem functions, grazing and bioerosion, were over three times higher around rat-free islands (Graham et al.).

Crucially for Tokelau, restoration of these natural ecosystem services that link deep sea, atoll and reef may contribute to the survival of the atolls in the face of rising sea-levels caused by human-induced climate change. Atolls are dynamic ecosystems and there is evidence that atoll islets can vertically accrete (grow) in pace with rising sea levels (Masselink et al. 2020, Steibl et al. 2023). However for this to be occur, the local accretion processes must be restored. The reef is the "sediment factory" from which the island building materials are derived (Steibl et al. 2023); improved productivity of corals and greater biomass of reef fish (including bioeroders such as parrotfish), due to restored nutrient transfer, directly contributes to the restoration of accretion processes. Eradication of invasive mammals and consequent restoration of native ecosystems is a nature-based solution that, coupled with other nature-based solutions (e.g. marine-protected areas, native forest restoration) may increase island resilience to climate change impacts.

4.4 What are the potential unintended ecological consequences of eradication?

There are few anticipated unintended ecological consequences of eradication, provided that all three species targeted are successfully removed. There are no other invasive mammal species present on Tokealu, so there is no possibility of mesopredator release caused by removing other mammals. The impact of removing rats on invasive ant populations is poorly studied and may warrant further research (Monica Gruber pers. comms).

PLANNING ISSUE:
Test whether removing rats influences population size of invasive ants.

Once rats are removed there will probably be some prey-switching to lizards and birds by domestic and stray cats around the villages. Whilst management of domestic and stray cats is out of scope of this report, a plan for managing these ecologically damaging animals is recommended.

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

Positive social consequences

There are many positive social benefits that could result from the eradication of mammalian pests and the consequent rebounding of native biodiversity. Improvements in food security can be expected, for example sustained increase in coconut yield, increases in land crabs and other natural resources. Longer term (over decades) marine resources will also improve. The full restoration of seabird-driven nutrient cycles will promote increased biomass of reef fish; greater seabird numbers will also increase the number and size of indicator flocks that are used by Tokelauan fishermen to locate Tuna (Pierce et al 2012). A one-off eradication of rats would also benefit food security by removing the risk of food-chain contamination posed by long-term use of anticoagulant rat bait (Pierce et al. 2012).

A positive benefit that has been observed following other mammal eradications is a reduction and, in some cases, local extirpation of mosquitos. Rats are the only host for mosquitos on uninhabited islets, and the sudden removal of rats can greatly reduce mosquito populations (Wodzicki 1970). Removal of rats and reduction of mosquitos would also eliminate or reduce significant potential sources of communicable diseases such as dengue fever (Griffiths).

The proposed eradication would directly offer a significant employment opportunity for local people over several years, and longer term opportunities to improve financial wellbeing may arise through improved harvest of natural resources (e.g. Copra) and sustainable tourism. The proposed eradication offers a significant educational and training opportunity, particularly for young people in Tokelau, and a chance to study how nature-based solutions can repair and restore fragile atoll environments and potentially buffer them from human-induced climate change. The eradication could present significant training opportunities for young people in fields including terrestrial and marine biodiversity monitoring, surveying techniques, Geographical Information Systems (GIS) and working with drones. If the eradication proceeds Tokelau stands to become the first nation on earth to successfully eradicate all of its invasive mammalian pests, offering a leadership opportunity for Tokelau to support and assist other island nations who face similar ecological threats.

Negative social consequences

Other eradication projects have seen some division within communities, with some people set against the eradication often because of unfounded fears about potential health risks of toxin use. Education and open communication is important from the start of a project to minimise social division. In Tokelau anticoagulant bait has been used for a long time, with no apparent human health issues so far, and it will be important to emphasise that the same toxin will be used during the eradication.

Some temporary changes in behaviour would be required during the eradication (e.g. treatment of food waste and rubbish) that may cause some perceived inconvenience. The most profound change would involve the removal of domestic pigs for a period of six months (or until bait has fully broken down see section 5.5 below). This would certainly create some controversy (based on conversations with local people) but would be necessary to ensure a successful eradication.

Some long-term changes in behaviour would be required to implement biosecurity protocols to prevent reinvasion. It is hoped that these would be readily adopted to protect the gains made by eradicating mammalian pests.

The natural restoration of seabird populations may increase the numbers of laika/black noddy (Anous minutus) around villages, exacerbating concerns about the contamination of water supplies, but it is believed that this can be manages through local controls.

4.6 What outcome monitoring is recommended?

Pre- and post-eradication outcome monitoring of a variety of "indicator" species and taxa would be used to measure changes in biodiversity values. This work could be done by local staff trained by specialist monitoring staff, e.g. from Island Conservations Impact Monitoring Team. Table 10 below summarises possible biodiversity outcome monitoring measures based on previous eradications.

Table 10 - possible biodiversity outcome monitoring measures

Species/Taxa	Sampling method	Location
Pacific Pigeon	Line transects	Roads through forest on Fenua Fala, Nukunonu village and Atafu village
Seabird nesting	Nesting seabirds (15m plot)	Random selection of motu
Seabird nesting	Count of nesting seabirds (circumnavigation of perimeter of motu)	Random selection of motu
Sooty Tern	Number and size of colonies	At tern colonies
Brown Booby	Total counts	Boat surveys across lagoon
Turtles	Total counts	Boat surveys across lagoon
Coconut	Coconut seedling/sapling counts	Motu with feral pigs e.g. Te Kamu and Te Puka I Muli, Nukunonu
Vegetation cover	Photographs in 4 cardinal directions and ground cover	Random selection of motu
Vegetation cover	Vegetation description	Random selection of motu
Skinks	Strip transect (400m x 1m)	Random selection of motu
Landcrabs	Strip transect (400m x 1m)	Random selection of motu, include motu with feral pigs
Marine	Coral & fish transects	Outer reef

5. Is it achievable?

5.1 Is eradication the most appropriate pest management tactic?

Eradication of rats has long been a goal of the Taupulega and the EDNRE. Rats are a significant economic burden to Tokelau that require ongoing management. Annual control of rats brings only short-term benefit, as populations recover through immigration and breeding to reach pre-control levels within months. Apparent local eradications e.g. on the Hakea motu, Atafu (Pierce et al. 2012) will not be sustained due to eventual reinvasion of rats through swimming. Eradication would relieve the ongoing expense and risk to wildlife and human health of near annual landscape-scale use of anticoagulant toxins.

The presence of three sympatric, generalist, invasive mammals has caused drastic ecological changes that will continue to worsen without intervention, for example as pigs spread across the motu. Currently there is no management of feral cats and feral pigs on the motu. Long-term control of feral cats and feral pigs would be costly and likely ineffective (pig populations can recover to pre-control levels in 3-5 months (Garabedian & Kilgo)), requiring significant resources and use of tools that are currently unavailable in Tokelau, i.e. dogs and rifles. The ecological and social benefits described in section 4 above can only be fully realised by eradication of all three species.

Eradication of invasive mammals is a well-proven method for restoring tropical island ecosystems, and the scale and terrain of Tokelau are well within the current limitations of recommended eradication tools and techniques. Being geographically isolated with limited and predictable transport arrivals from overseas makes Tokelau “defendable”, i.e. reinvasion by pest species could be limited provided that strict biosecurity practices were maintained.

5.2 Principles of eradication

All eradications, regardless of the target species, are grounded in three fundamental principles (Cromarty et al. 2002):

- All individuals of the target species must be put at risk by the proposed removal technique(s).
- The technique(s) must remove target species individuals at a rate faster than they can replace themselves (i.e., breed) and,
- Immigration must be zero, or effectively managed to zero (identify and respond effectively to new incursions).

For rodent eradications, these principles are applied as follows (see Howald et al. 2007):

- Deliver a highly palatable bait containing a toxic rodenticide into every potential rodent territory.
- Ensure bait is available for long enough so every rodent has access to a lethal dose.
- Time the baiting operation to when the rodent population is most likely to consume the bait (i.e., lowest alternative food availability).
- The short-term risks and impacts to non-target wildlife, people, and the environment from disturbance and the rodenticide are minimized wherever possible, i.e., the benefits of the eradication must outweigh the costs.
- Biosecurity procedures must be able to sustain the eradication, with effective prevention, detection, and/or an effective response to any incursion.

These principles have been further developed into recommended Best Practice Guidelines to maximize the probability of successfully removing rodents from tropical islands (Keitt et al. 2015), which is used to inform this feasibility assessment.

5.3 What tools will be used?

Table x below presents tools that are considered suitable for use in eradicating invasive mammals in Tokelau. Alternative tools that were considered but discounted are described in Appendix 1. The proposed sequence in which these tools will be rolled-out of is presented in section 5.3 below.

Table 11 - Tools considered suitable for eradication on invasive mammals in Tokelau.

Species	Technique	Tool	Notes
Rats	Aerial Baiting	Helicopter with underslung spreader bucket	Range of size from Squirrel to micro copter
Rats	Aerial Baiting	Drone with spreader bucket	Electric or petrol. Range of size from 50kg to 10 kg payload
Rats	Ground Baiting	20x20 metre grid cut and marked by ground team, bait hand-spread	Range of tools for marking grid from traditional compass to RTK system
Rats	Ground Baiting	Bait stations	For use in and around buildings
Feral pigs	Ground Hunting	Baited ambush hunting using rifle with thermal scope.	Requires 2 trained shooters
Feral pigs	Trapping	Pig brig and/or cage traps	
Feral pigs	Trapping	Snares	
Feral pigs	Ground Baiting	Sodium nitrite or similar toxic bait	In crab-proof bait stations
Feral pigs	Ground Hunting	Detection dogs	Team of trained dogs with 2 handlers
Feral cats	Aerial Baiting	Brodifacoum poisoning through consumption of poisoned rats	*Dependent on rat eradication*
Feral cats	Ground Baiting	PAPP or 1080 sausage	
Feral cats	Trapping	Victor 1.5 leghold traps	
Feral cats	Shooting	Baited ambush hunting using rifle with thermal scope.	

Feral cats	Detection/hunting	Detection dogs	Trained dogs with 2 handlers
All species	Detection	Trail cameras	Thermal or infra-red. Coupled with AI for image recognition.

Kimoa/rats

Eradication of rats is undertaken by broadcasting rat bait containing rodenticide toxin using aerial or ground-based tools or a combination of both. There is no precedent for using traps other than for for very small islands (Howald 2007). Aerial baiting uses helicopter or drone to broadcast bait. Ground baiting requires a team of willing workers to cut and mark a grid of points across the treatment area, at a spacing designed to ensure delivery of bait into every rat territory. Rat bait is then spread by hand at each point. Dwellings and other buildings are treated using rat bait contained within bait stations to prevent access by children and domestic animals.

Success rate of rat eradications on islands in the tropics is high (89% for aerial applications, n-47) but is lower than the success rate on islands in temperate latitudes (96.5% for aerial applications n=116) (Keitt et al.). The reasons for this difference include higher insect and crab densities resulting in competition for bait, year-round or unpredictable timing of breeding rats and increased or unpredictable availability of alternative, natural foods (Keitt et al.). Awareness of these potential issues is crucial when planning an eradication, to improve the chances of success.

Rodenticide selection

Rodenticides have been used in the vast majority of rodent eradication campaigns worldwide (99.5%), with a 73-94% success rate, depending on the target species (Howald et al. 2007; DIISE 2018). The second-generation anticoagulant Brodifacoum has become the preferred choice for eradication operations, having been used in at least 71% of campaigns and 91% of the total area treated, (Howald et al.). The major advantage of anticoagulant rodenticides over other classes of rodenticides is the delayed onset of symptoms (~2-3 days) meaning they do not induce bait shyness. Brodifacoum outperforms other anticoagulants because it is highly potent and can be lethal after a single feed whereas first generation anticoagulants e.g. diphacinone require consumption to be sustained over a period of several days to achieve mortality (Howald et al.).

Due to its long track record of success Brodifacoum is recommended as the preferred rodenticide for eradicating rats on Tokelau. This toxcant is already in widespread use in Tokelau, so to eliminate any possibility of bait shyness, use of brodifacoum and any other rodenticides should be stopped at least 18 months prior to an eradication attempt.

DEPENDENCY:
Rodenticide use must be stopped at least 18 months prior to an eradication attempt.

Bait formulation

The rodenticide is contained in a grain-based matrix to form a pellet bait that is highly palatable to rats. The bait pellet formulation is designed to persist on the ground long enough for all rodents to be exposed yet degrade quickly enough to minimize the risk of exposure to non-target species. The bait is coloured (usually green or blue) to further reduce their attractiveness to birds. Weather conditions play an important role in bait persistence, and utilizing a proven formulation for the tropics is recommended. The product recommended for use in Tokelau is Brodifacoum 25W: a 1 or

2g pelleted bait containing 25 ppm brodifacoum, designed for use on islands with wet to very wet climates (manufactured by Bell Laboratories, Inc.).

DEPENDENCY:
Conduct a ground-based eradication to trial the uptake by rats of the recommended bait formulation on isolated motu on Tokelau during 2024.

Bait application rate

The application rate of bait must be tailored to the targeted site to ensure that enough bait is available for a long enough period that every rat can consume a lethal dose. Two applications of bait are made, a minimum of 21 days apart, to ensure that any young rats that emerge from nests following the first application are exposed to bait. Typical application rates for rat eradication on tropical islands are 20 or 25kg per hectare, totalling 40 or 50kg per hectare for both applications.

A bait availability trial in-situ is recommended prior to eradication to inform the bait application rate selected for the eradication, and to understand the rate at which bait availability will decline during the eradication (Pott et al.). Bait availability should also be monitored during the eradication.

DEPENDENCY:
Conduct a bait availability trial at the recommended bait application rate in Tokelau in 2024.

Aerial broadcast

Aerial broadcast of rodenticide bait is achieved with a helicopter or Unmanned Aerial Vehicle (UAV or Drone) with a suspended bait bucket containing a motorized spinner that throws the bait across a pre-planned swath either side of the flight line of the machine. Swaths are overlapped, usually by 50%, to minimize the risk of leaving gaps in bait coverage. The coastline of an island is usually baited using a specialised deflector bucket that throws bait only on the inland side of the machine. Aerial operations are continuously monitored using Geographical Information Systems (GIS) software to map flightlines to track progress and detect any potential gaps in coverage.

Since the 1990s Aerial broadcast by helicopter has become the most common tool for rodent eradications (Howald et al.). The largest island eradicated of Pacific rats (Rattus exulans) to date using a helicopter is Hauturu/Little Barrier Island at 3083 hectares, around three times the total land area of Tokelau. Types of Helicopters used in eradications range in size from large machines e.g. Eurocopter AS350 (or Squirrel) to relatively tiny micro-helicopters. Smaller machines are cheaper but can carry much less bait, so are more suited to use on small islands. Helicopters can be transported in shipping containers to remote islands – for example two micro-helicopters were recently transported from France to Palau, in a single 20-foot shipping container, to undertake a rat eradication on Ulong Island (B. DesMonstiers pers. comms).

Drones have begun to be used recently to undertake aerial baiting and this tool is still in the development phase, with larger drones capable of carrying heavier loads of bait expected to be available within the next few years. To date rats have been eradicated on about 20 Islands using battery-powered drones with a maximum payload of 10 kg of bait. Because of the small payload drone operations are much slower than helicopter operations, requiring many return flights from the loading site to cover an island. To maximise efficiency the “ferry time” (the distance/time between the landing zone and the baiting area) must be kept to a minimum – a motorized barge anchored in the lagoon is an ideal mobile loading platform for tropical islets, used recently in Wallis and Futuna (B. DesMonstiers pers. comms.). The drones currently used for eradication operations are battery operated, with two lithium batteries that last about 15 minutes (up to three flights) before they need to be charged. Three sets of two lithium batteries are used for one drone, with two sets of batteries being charged at any one time. Usually two petrol generators are running more or less continuously to charge batteries whilst the drone is operating (Jacques 2022).

Drones are relatively much smaller than helicopters and can be easily transported in airline cargo, although the lithium batteries must be shipped separately. To date drones have been used to carry out eradications on islands that are too remote to be economically viable to treat with helicopters, and too rugged to bait by hand.

Figure 10 - a battery operated drone with bait spreader bucket attached at the loading site during a Pacific rat (Rattus exulans) eradication on Kamaka, French Polynesia.

PLANNING ISSUE:

Monitor the development of heavy-lift drones with a view to potential use in Tokelau.

Hand broadcast

Hand-broadcast of anticoagulant rat bait has been used to successfully eradicate rat on many islands since the 1980s (Howald et al). Traditionally compasses and measuring tapes have been used to measure out a baiting grid. The spacing of the grid varies depending on the species targeted; typically for eradications of Pacific rat (Rattus exulans), which can hold very small home ranges, a grid of 20 x 20 metres is used. Recent innovation has seen the use of Real Time Kinematic equipment, a digital measurement system, improving accuracy and efficiency (Oyston).

To be successful hand broadcast requires a well organised project team to lead a well-trained and highly committed team. The risk of leaving a gap in baiting (and therefore failure) due to human error is high and the project must be well designed and continuously monitored to minimise this risk.

Treatment of buildings

Within the villages bait would be contained in locked bait stations (illustrated in Figure 11 below) to prevent young children and domestic animals from accessing bait. Bait stations would be placed around and under houses, and inside sheds and outbuildings, and at fales on the motu. Large cereal blocks, (containing the same formulation of brodifacoum as used in the cereal pellets), are staked in place to prevent rats removing bait from the stations. Bait stations would be checked on a regular schedule and bait replaced as needed.
On Fale rats live in the sea walls that surround the village. Wodzicki trialled aluminium tubes as bait stations to target these wall-dwelling rats whilst excluding crabs from taking the bait (Wodzicki 1970). Treatment of wall-dwelling rats will need to be considered during operational planning.

> PLANNING ISSUE:
> *Consider the best approach for targeting wall-dwelling rats at Fale. Conduct a trial if needed.*

Figure 11 - Protecta brand bait stations containing brodifacoum 25ppm bait in blocks.

Aerial or ground tools for kimoa/rat eradication – which is more likely to succeed?

Aerial broadcast of brodifacoum bait has provided the highest success rate for eradicating rodents from islands (Keitt et al). Hand-broadcast operations may have a higher failure rate for sites where rats frequently forage in the canopy, as bait is only broadcast on the ground with this tool. It is unknown whether this is a risk on Tokelau and this should be investigated prior to an eradication attempt. The largest hand broadcast operation to date, on Tetiaroa, French Polynesia (c450 ha), failed to eradicate rats from most of the nine islets targeted, despite excellent project management and field delivery. However there are major differences between this site and Tokelau, e.g. two sympatric rats species (Rattus exulans and R.rattus) and high densities of landcrabs.

Human error is possible with all tools, but this risk is greater with hand-broadcast, especially at scale. This risk can be reduced with excellent supervision of teams and the use of innovative technology e.g. the RTK system.

Economics must also be considered in selecting the preferred tools for eradicating rats on Tokelau. Helicopter broadcast would likely be the most expensive method due to the high cost of transporting the helicopters plus the contract and fuel costs. Drone broadcast has much lower transport and fuel costs but high contract fees. Contract fees could be minimized if a local team were trained up to become drone operators, but this would require considerable resourcing in advance. Hand broadcast has low transport and contract costs but higher personnel costs.

PLANNING ISSUE:

Conduct a literature review of aerial and ground broadcast eradications where only Rattus exulans were present– is success rate lower with ground techniques?

Combined aerial and ground approach

A combination of tools may be appropriate for Tokelau, e.g. aerial application using heavy-lift drone for the largest motu plus any adjacent motu that are within rat-swimming distance, in combination with hand-broadcast on the smaller motu delivered by a trained team of local staff. Using aerial broadcast for the larger motu and ground broadcast for the smaller motu could balance costs and risks, keeping costs down relative to a fully aerial operation and limiting the risk of failure with ground tools by treating the larger, more difficult motu aerially. Table 12 shows some possible treatment area sizes for each nuku for ground and aerial tools. Maps in appendix 2 show these proposed treatment area boundaries. Note that the proposed area for ground eradication is between 96 and 138 ha for each nuku, an achievable size for a team of approximately 20 people. For example, a local team recently completed a ground eradication of Pacific Rats on the 100 ha atoll of Nadikdik, in the Marshall Islands, taking approximately five weeks to set-up the grid and complete the baiting (Jacques 2023). The expected time required for each tool in Table 12 is derived from records from other ground operations and includes five days of training; for the aerial tool time estimates are given for a battery powered drone with a payload of 10kg.

Table 12 - possible combined aerial and ground approach, treatment area details

Nuku	Size (ha)	Resource	Expected time required for two applications
Atafu - ground	96.1	20-person team	25 days
Atafu - aerial	185.6	Drone, 10 kg payload	30 days
Nukunonu - ground	138.0	20-person team	28 days
Nukunonu - aerial	181.0	Drone, 10 kg payload	30 days
Fakaofo - ground	118.9	20-person team	24 days
Fakaofo - aerial	176.7	Drone, 10 kg payload	30 days

Figure 12 - A drone broadcast operation from a barge, Wallis and Futuna, 2022 (photograph by Baudouin DesMonstiers).

Figure 13 - A team resting before heading back into the forest to cut grid-lines for a ground-broadcast operation, Nadikdik Atoll, Republic of the Marshall Islands, 2023.

Feral cats

Experience from past eradicates shows that a suite of tools, either delivered simultaneously or in sequence, will be required to eradicate Feral cats (Nogales et al.).

Aerial Baiting

Secondary poisoning through consumption of live and dead rats that have consumed brodifacoum-laced rat bait broadcast for the rat eradication would be the primary tool for initial reduction of the feral cat population on Tokelau. The LD50 (average lethal dose) for brodifacoum in cats is 0.25 mg/kg (Dept. Conservation 2021) and cats are estimated to need 416 g of fresh toxic matter to get a lethal dose based on liver and muscle assay of rats following brodifacoum poisoning (Fisher et al. 2004).

The scale of the population reduction (or "knock-down") from this tool is impossible to estimate as it is influenced by factors that will vary significantly between motu e.g. the population size of rats. Feral cats are commonly killed through secondary poisoning by brodifacoum spread during aerial operations targeting rodents, and, under ideal conditions, kills of 80% or more can be expected for cats (Dept. Conservation 2021).

Ground Baiting

Ground baiting using an acute toxicant is often utilised as a follow-up tool in cat eradications. Sodium monofluoroacetate (1080) or para-aminopropiophenone (PAPP) encased in meat-based sausages are both used for targeting cats in New Zealand and Australia. These baits are expensive to manufacture in large quantities and the cost of purchasing and distributing baits across the entire range of feral cats on Tokelau (at least 470 ha) would be prohibitive. However, as a low-disturbance tool for locally targeting detected cats, these baits have utility, provided they can be delivered in a way that prevents immediate consumption by landcrabs.

Trapping

Leghold and cage trapping of feral cats is a tried and tested removal tool that has been utilised in most eradications of feral cats (Nogales et al.). However on tropical islands these tools can be compromised by land crabs. This tool needs to be trialled on Tokelau to fine-tune delivery under local conditions.

Shooting

Shooting using spotlights (and more recently thermal scopes) has been used in many eradications of feral cats. Effectiveness of this tool is limited by thickness of the vegetation. Coupled with food piles monitored with trail cameras (see section 5.6) this tool has utility for removing remaining individual cats that cannot be targeted with other tools (e.g. trap-shy individuals).

Detection dogs

Trained cat detection dogs from New Zealand have been used during previous eradications to search for cats during mop-up and validation phases (Dept. Conservation). They may have value for locating remaining cats, enabling handlers to dispatch detected cats with a .22 rifle.

> PLANNING ISSUE:
> *Trial cat removal techniques e.g. leghold trapping and test non-toxic bait delivery technique on Tokelau.*

Feral pigs

Feral pigs have been eradicated from temperate islands but there is little precedent for eradications from coral atolls. Methodology can be adapted from work done in New Caledonia, Wallis and Futuna and the Marshall Islands. As such the approach on Tokelau will be experimental at first, with a finalized eradication plan to be informed by the results of initial trials.

As for cats, it is almost certain that eradication of pigs will require a suite of tools to be delivered in sequence, beginning with passive tools that create the least disturbance to the wider pig population.

Ground Hunting

From limited trials done in September/October 2023 it appears that pigs can be readily attracted to piles of opened coconuts. Based on a trial on a coral atoll in the Marshall Islands (Jacques 2023), it is expected that if coconut piles are replenished daily for a few days without disturbing pigs, individuals will readily return each day/night at regular and predictable intervals. During an initial monitoring phase trail cameras will be used to monitor the food piles and photos will be analysed to identify individuals and estimate the time of day or night they can be expected to return to the food pile. Most pigs are expected to be on their own – these individuals would be targeted by shooting from a pre-planned ambush site overlooking the coconut pile. If groups of pigs are present, they will be targeted with net traps rather than shooting, as it is unlikely that more than one pig out of a group can be shot at close range in forested habitat.

A high-powered bolt-action rifle fitted with a sound moderator and a thermal scope would be used to shoot pigs. This tool would only be used by an experienced marksman as it is highly important that pigs are dispatched first time and not missed and allowed to escape, as pigs will change their behaviour after a negative experience and become much harder to eliminate.

Trapping

Net traps have been used to great effect to reduce pig populations on tropical islets in Wallis and Futuna (B. DesMonstiers pers. comms.), see Figure 14 below. If groups of pigs are detected on camera during the initial monitoring phase then net traps will be employed as they are the preferred tool for capturing groups of pigs. Net traps are a passive tool that creates little disturbance provided that they are pre-baited for a period with opened coconuts and monitored with a trail camera to observe pig interactions, before setting the trap once pigs are feeding regularly without trepidation.

Snares

Snares are a passive tool that are used widely in New Caledonia and Hawaii to reduce populations of feral pigs. Depending on the pace of progress of removing pigs with shooting and net traps, snares could be used simultaneously. They could also be used to target individuals that may be trap or bait shy. Site selection is very important – snares work most effectively when set on regularly used game trails. Staff should be trained by an experienced operator before setting snares to minimise the chance of escapes.

Ground Baiting

The vertebrate toxic agent Sodium nitrite, encapsulated within a palatable bait matrix, is used to control feral pigs in Australia and is in the process of being registered for use in New Zealand. This is a passive tool could be applied in Tokelau, subject to approval, to eliminate any isolated individuals or groups of pigs that may remain after other passive tools have been exhausted. The toxic bait would need to be dispensed in a crab-proof bait stations to prevent baits being decimated by crabs before pigs could consume them. Treadle-operated bait stations have been used to deliver sodium-nitrite baits in New Zealand to prevent access by non-target species – once pigs learn how to use these bait stations and feed without trepidation, non-toxic pre-feed is replaced with toxic bait**.**

Figure 14 - "Pig brig" net trap set in Wallis and Futuna.

Ground Hunting using dogs

Ground hunting using dogs to chase and "bail" pigs is an "aggressive" tool that is very effective but causes significant disturbance and can cause pigs to change their movement patterns and behaviour**.** For this reason, ground hunting is proposed as the final method to locate and remove the last remaining pigs. This tool may not be necessary; trials on Tokelau during 2024 will shed light on the effectiveness of more passive tools under local conditions. If ground hunting with dogs is required, it would probably only be necessary on the large motu of Fenua loa. A minimum of two experienced pig dog handlers would manage a small team of dogs (maximum 6 animals) to hunt and remove pigs. Temporary fencing could be used to divide up the motu into smaller management units and preventing pigs from running too far when being pursued by the dogs.

DEPENDENCY:

Trial an eradication of feral pigs using passive tools on isolated motu in Tokelau during 2024. Assess the effectiveness of these tools under local conditions.

5.4 What is the proposed eradication design?

The proposed eradication design is proposed is based on operational plans for other multi-species eradications targeting sympatric populations of rodents, feral pigs and feral cats (e.g. Auckland Island, New Zealand, (Dept. Conservation 2021)). Distinct operational phases are outlined marking progress in population reduction and changes in strategy for the eradication of each species.

Sequence of target species

Table 14 below details the proposed sequence for eradication of each target species. Where feral pigs are present, (Nukunonu), they must be removed prior to eradicating rats. Pigs will certainly consume the rat bait in large quantities, and this creates risk of failure of the rat eradication by locally disrupting the availability of baits to rats (Dept. Conservation 2021).

The rat and feral cat eradications would begin at the same time, as the primary tool for eliminating feral cats is secondary poisoning caused by cats consuming rats that have consumed brodifacoum. The "mop-up" phase of the cat eradication continues beyond the end of the rat baiting as the last remaining cats are searched for using a grid of trail cameras and eliminated using a suite of tools. This coincides with the validation phase of the rat eradication, and the same grid of trail cameras will be used to search for any remaining rats, alongside other monitoring tools (see section 5.6).

Sequence of Nuku

Because the three Nuku of Tokelau lie relatively distant from one another, eradication operations can proceed independently, provided that biosecurity measures are strictly observed for movements between the Nuku, to prevent reintroduction of invasive mammals. Rather than running operations concurrently on each Nuku it could be more efficient and economically sound to complete eradication on one Nuku before transferring resources (including some trained staff) to the next. This would allow for lessons learned to be adopted as the eradication effort progressed across Tokelau. Considering the scale of the three Nuku, it could be wise to start on the smallest, Atafu, before scaling up to attempt Nukunonu and Fakaofo. The feral pig population would need to be addressed on Nukunonu prior to a rat eradication, and this could be done whilst the rat and cat eradication were being undertaken on Atafu.

Duration of Operations and ideal timing.

The duration of the eradication operations would inevitably vary depending on a number of factors including methods selected, number of local workers available, rapidity of detection and elimination of remaining animals etc. The amount of effort required will vary with each phase, with the rat eradication requiring by far the most effort and resources. If the operations were well resourced and run sequentially, moving from one Nuku to the next, the eradication could probably be completed in three years. This timeframe would also allow the project team to target the best annual weather window for the rat eradication on each Nuku, which is likely to be during May to September, the drier months of the year, when rat breeding may be reduced.

5.5 Can all individuals be placed at risk?

Rats

For eradication of rats a single tool will be used to target all individuals., i.e. broadcast (aerial or ground) of rat bait containing brodifacoum This has proved to be sufficient to eradicate rats on many islands around the world (Howald et al.), however it is essential that the principles of eradication set out in section 5.2 above are observed. and that a high standard of operating discipline is maintained throughout the operation.

The greatest risk to the success of the rat eradication is the failure to remove every individual rat in the built environment. The villages present a major challenge to distributing rat bait into every rat territory due to the presence of children and non-target animals (domestic pigs, cats and chickens), alternative food for rats (rubbish, garden produce, tree fruits) and the challenges of accessing properties (e.g. baiting under houses) and ensuring that bait remains available for long enough.

These issues are not insurmountable, and islands with similar human populations to each Nuku of Tokelau have been eradicated of rats (e.g. Lord Howe Island, population 347 people **REF.).** For the eradication to succeed it is essential that all community members grant access to their properties to allow bait stations containing rat bait to be placed and maintained. Consultation with individual landowners may be necessary to discuss concerns and to determine the location of bait stations to put all rats at risk; specific details for each property would be recorded in individual property agreements. Access to unoccupied properties would also need to be negotiated.

The elimination of alternative food sources prior to the rodent eradication would also be essential, and project staff would need to work with landowners to develop effective measures to manage rubbish, food waste, stock feed, compost, and specific food crops. On the inhabited motus the municipal rubbish dumps and any other piles of rubbish would need to be removed or burned and buried.

DEPENDENCY:
100% of the community are willing to allow access to their motu to undertake baiting and to their residences to deploy and manage bait stations. The community must also be willing to comply with guidelines to manage waste and food crops during the eradication.

The extensive communal pig pens on all three nuku, (including the pens on Te Afua tau lua motu on Fakaofo), provide very large areas of complex habitat and food for rats (see Table 3 above for the physical characteristics of the communal pig pens). There is no question that if the pens were left unbaited the rat eradication would fail. It is also very important to avoid exposing domestic pigs to rat bait to avoid brodifacoum entering the human food chain. Therefore, it would be necessary to remove all pigs from the pens prior to baiting. Using bait stations in the pig pes will not be a viable option because pigs will certainly break into the stations and consume the bait.

Pigs would either need to be slaughtered or relocated off-island prior to the rat eradication. The pig pens could be restocked six months after the rat eradication has been completed, once the rat bait and any rat carcasses present have completely broken down. There is a lot of rubbish in some of the pens that should also be cleared up before an eradication, as this provides habitat and alternative food for rats.
An agreement on how best to manage domestic pigs must be reached with the Taupulega of each Nuku before planning for a rat eradication can proceed any further. Two possible solutions that satisfy the principles of eradication are detailed in
Table *13*

Table 13 - Feasible options for managing domestic pigs during the rat eradication.

Option Number	Strategy	Issues
1	Slaughter all pigs. Tidy up pig pens and remove food and rubbish. Bait pens as for rest of island. Restock pigs after the caution period has expired.	May not be enough freezer space available to utilize all pig carcasses.
2	Slaughter the large pigs. Remove weaners only and transport them to the pig	Requires agreement to be reached for people to look after the pigs

	enclosures on next Nuku. Tidy up pig pens and remove food and rubbish. Bait pens as for rest of island. Return the weaners after 6 months.	on the next Nuku. Feeding costs could be compensated.

DEPENDENCY:

It is essential to find a socially acceptable solution for management of domestic pigs through the rat eradication, that also satisfies the principles of eradication, before moving to the project design phase.

Feral pigs and feral cats

Feral pigs and feral cats are intelligent and wary animals that learn quickly and adapt their behaviour when threatened. For these animals a suite of tools will be used in sequence, beginning with passive tools that create little disturbance to individuals not directly targeted, ensuring that survivors remain naïve, and concluding with more aggressive tools to hunt down and destroy the last individuals. Independently, each tool will not remove the whole population but collectively the sequences for feral pigs and feral cats is designed to put every individual at risk,

Trail cameras will be used throughout to monitor pig and cat populations to help managers decide adaptively which tools should be used where to target individuals or groups of animals.

Figure 15 - The communal rubbish dump on Fenua Fala, Fakaofo, Tokelau, September 2023.

5.6 Can the target pests be detected at low abundance?

A variety of tools, some species-specific, would be used to search for surviving animals and to validate the success of eradication.

Trail cameras for all target species

Trail cameras would be used throughout the feral pig and feral cat eradication to monitor the decline in population and to detect survivors for targeting. The trail camera grid would also be used to validate the success of the rat eradication and this tool would allow a rapid response if any rats were detected.

A grid of cameras would be set-up across each Nuku at close spacing (e.g. 200 x 200 metres, or one camera every four hectares). A closely spaced grid will greatly increase the probability of detection for individuals of all species. Cameras would be set at likely places where animals will be encountered, e.g. game trails, behind beaches, near food sources etc. Cameras would be regularly rebaited using a combination of non-toxic baits depending on the species targeted (e.g. coconut for rats and pigs, chicken or fish for cats). Camera data would be collected periodically by swapping out the SD card, or automated systems could be used whereby data is transferred from the camera to a base computer, either through the ell network or by using a drone to fly to and remotely download data from each camera (David Will, pers. comms.). Automatic image processing software would be used to sort through the image, greatly increasing efficiency of classifying image data by species. Only the images of the target species would be retained. For pigs and cats, it is possible to identify individuals by the patterns and colours of their coats; a database of known individual feral pig and feral cats will be created so that animals can be “checked-off” the list as they are removed enabling the number of individuals remaining to be tracked and progress of the eradication techniques assessed.

By collecting data prior to the eradication attempt for feral cats and feral pigs it will be possible to calculate the detection probability of these species. This information can then be used during the final “validation” phase of the eradication to estimate how long camera monitoring should continue with zero detections of those species before the eradication can be declared a success.

eDNA for all target species

This is an emerging technique that is increasingly being used to detect the presence of species from tiny fragments of DNA material detected within water and sediment samples. This tool has recently been used to reveal the presence of previously undetected invasive rat species in Palau (David Will pers. comms.). This tool has possible application in Tokelau, for instance use for broadscale survey of motu, at least one year after eradication, to detect any populations of surviving mammalian pests that could then be re-treated before spreading to other motu. Another use could be confirmation of the potential rat-free status of certain motu before the rat eradication, creating efficiencies and reducing costs.

Other detection tools for rats

Other detection tools for rats require greater effort to set and check than eDNA but could be used on a local scale, e.g. to follow up on a positive result from an eDNA sample. These include tracking tunnels, wax tags and chew cards.

Tern colonies and turtle nests

Post-eradication monitoring of ground nesting species like terns and turtles could reveal the continued presence of mammalian pests as these species are targeted for food by all three species of invasive mammals. Looking for prints of feral pigs and feral cats in the sand surrounding colonies is a simple method of surveillance that requires little effort.

5.7 Can pests be killed faster than they breed?

Rats

Eradication of rats is designed to be of short duration, exposing all individuals to a high chance of mortality using a single tool. Eradication is timed for the period of the year when breeding activity is expected to be lowest, and a second application of bait is undertaken to eliminate any young that may have emerged from nests following the first application. Rats are short-lived animals that increase their numbers rapidly through breeding when resources are available. If isolated populations of rats remain after eradication the population will recover quickly. The key challenge following eradication is to detect any survivors and re-treat the area where they are located with a third application of bait. Detecting a few surviving rats after a large-scale rat eradication can be likened to looking for a needle in a haystack, but the proposed grid of cameras at close spacing will greatly increase the chance of detecting survivors. The proposed use of eDNA at least one year after the eradication could have value in searching for recovering populations of rats that could then be retreated if detected promptly.

Feral pigs and Feral cats

For feral pigs and feral cats effort must be sustained using multiple tools to continually reduce the population to zero. The eradication must be well resourced to achieve this and the expectation of a potentially long campaign should be set with stakeholders.

It is imperative to take care in the design and delivery of the operation to keep these animals naïve to prevent the behaviour change of surviving animals that makes them very difficult to remove and increases the cost and duration of eradication.

Once the populations of feral pigs and feral cats has reached low numbers, detection of individuals should continue to be possible using the closely spaced grid of trail cameras. Home ranges of remaining feral cats may increase following the removal of rats and the decline of the wider cat population, and this should result in an increased probability of detection of survivors provided that the density of trail cameras remains unchanged (Glen et al.)

Table 14 - Proposed sequence of eradication of invasive mammals, Tokelau

Target species	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
Feral Pig	Pre-eradication population monitoring using baited trail cameras	Targeted removal of pigs using passive tools	Mop-up of remaining pigs using ground hunting with dogs	Validation of eradication using baited trail cameras			
Pacific rat					Aerial and ground baiting with approx. 50kg/ha Conservation bait 25ppm Brodifacoum. Baiting around and under buildings using bait stations	Validation of rat eradication using trail cameras, chew cards, tracking tunnels (and possibly eDNA testing after a year or more).	
Feral cat					Knock-down of cats using secondary poisoning through consumption of poisoned rats	Mop-up of cats using passive tools, remaining cats detected using camera network	Validation of cat eradication using baited trail cameras

6. Is it sustainable?

6.1 Can immigration of the target pest be managed?

To meet the principles of eradication, immigration of the target pests must be zero, or effectively managed to zero, i.e. new incursions are identified quickly and responded to effectively. Geographically, Tokelau is well positioned to defend against immigration. There is no possibility of the target pest species swimming to Tokelau or swimming from one Nuku to another. Furthermore, boat movements from overseas are strictly limited - only two vessels visit Tokelau regularly, on a predictable timetable, and both from the same port of origin (Apia), meaning that biosecurity should be more manageable than for other islands with many different boat movements from different ports of origin.
A detection network (using a combination of detection tools e.g. trail cameras, chew cards) should be left in place following eradication and a team tasked with regular checks of this network. This is in effect an "early warning system" to alert managers if an incursion of pests has occurred. The network should be particularly intensive around the potential points of origin of incursions, i.e. the wharves on each Nuku. Innovative eDNA tools present the possibility of highly efficient landscape-scale checks for the presence of populations of pests. The ongoing owners of this work could be the EDNRE.

For feral pigs and feral cats, the source of the current feral populations comes from release of domestic animals held within Tokelau. If rats are eradicated, then the need for people to keep domestic cats will be largely removed and cat numbers around the villages may decline. If people wish to keep domestic cats after the eradication is complete, it would be ideal to neuter all cats to prevent breeding and the proliferation of stray and feral cats. The community should be educated about the importance of preventing reintroduction of cats to the motu.

Community education is also required concerning the importance of not reintroducing pigs to the motu. The practice of letting some pigs out of the pens to fatten up before re-capturing should be stopped, as this may lead to pigs dispersing through the motu. The risk of domestic pigs accidentally escaping into the wild also needs to be eliminated; the communal pig pens should be inspected regularly and if necessary, strengthened in places where escape is possible.

6.2 Can dispersal be managed?

During operational planning for a rat eradication dispersal must be considered, so that motu within rat-swimming distance of one another are treated simultaneously (or within a short window of time) to minimise the chance of rats swimming back to motu that have already been treated. The Pacific rat (Rattus exulans) is known to be a poor swimmer relative to other Rattus species. The greatest recorded distance swum by an individual Pacific rat in open sea water is 130 metres (Whitaker 1974). Many motu are connected by open coral reef divided by short channels at low tide, however it is considered unlikely that Pacific rats would willingly cross stretches of open reef of more than 200 metres. Based on this, a buffer of 200 metres could be used as the minimum distance between management units when planning delivery of a rat eradication on each Nuku of Tokelau.

For treatment of the large motu over 20 hectares in size that cannot be completed in one day, the exposed baiting front will be re-sown and overlapped with a buffer to manage the risk of rats immigrating into the baited area from unbaited parts of the island. This is especially important if there has been a break in baiting for more than a day due to bad weather, which may have degraded the quality and palatability of the bait on the ground.

For feral cats and feral pigs the operational window is longer than for rats. These species are also more readily detectable than rats using trail cameras due to their larger home ranges. Dispersal can be managed by using passive tools to knock-down the population to low density (limiting the chance of pushing animals, particularly feral pigs, which may swim to other motu if they are threatened), and by relying on the high probability of detecting survivors on camera and eliminating them.

PLANNING ISSUE:
Review literature and assess the risk of Rattus exulans crossing open reef to reinvade islets.

Figure 16 - a very large boar detected on camera outside the pig pens on Nukunonu motu, October 2023.

7. Is it acceptable?

7.1 Do key stakeholders support eradication?

The key stakeholders are the community of Tokelau and their leaders, including the Taupulega of each Nuku and the EDNRE, who have staff based on each Nuku and in the Tokelau Office in Apia, Samoa.

Support from Leadership

Eradication of kimoa/rats is a long-term goal of the Taupulga and the EDNRE, and this feasibility assessment was outlined as a priority in the TISSAP for 2020-2027 (EDNRE 2020). The Taupulega of each Nuku were consulted during the Feasibility assessment visit. Each Taupulega expressed their support for this assessment and the importance and urgency of eradicating invasive mammals from Tokelau. It was noted that their ancestors had complained about the impact of rats for many generations, and they have a strong desire to see the eradication happen to benefit future generations. The Taupulega stated a wish to work with the EDNRE department during all phases of the proposed eradication and to add their traditional knowledge to help resolve difficulties. The Taupulega are invested in this work and had many questions about the potential eradication operation that reflected their wealth of local knowledge and their concern for the people and environment of Tokelau. Issued raised by the Taupulega are summarized in appendix 3.

Dogs and firearms are not permitted in Tokelau. This issue was raised by the Taupulega and whilst it was stated that it would need further discussion, there was provisional support for the use of these tools during the eradication provided that their use was limited and they were only handled by trained professionals.

Support from the community

Many community members were spoken to on an informal basis about the potential eradication. Most were very supportive and understood the importance of the proposed eradication. Many had questions and some had concerns, mostly regarding human health (summarised below). In Tokelau the community comply with guidelines issued by the Taupulega, and the universal support from the Taupulega for the concept of an eradication is a very good start to ensuring that the community will comply with rules that will need to be put in place to improve the chances of successful eradication of the target species.
As discussed above the management of domestic pigs will probably be the most controversial issue associated with the eradication. This will require discussion to resolve a way forward and sensitive negotiation with the community will be required.

The eradication of feral pigs on Nukunonu may be seen as a negative by some. Men and boys visit the communal motu of Te Kamu and Te Puka I Muli to gather coconuts and sometimes they chase piglets and weaners to capture them and bring them back to stock their pig pens. The large pigs are not hunted as dogs and firearms are not permitted in Tokelau, and these large animals are rightly regarded as dangerous. Harvesting the pigs shot during the knock-down phase and sharing these with the community could be a way to reduce tension caused by the removal of the feral pig population.

Health and environmental concerns

Concerns expressed by Taupulega and community members about the impact of the eradication on human health and natural resources are summarised in Table 15 below. These concerns are answered again under headings in section 7.3 below. It will be important to address these concerns and any other that arise during the planning phase of the eradication. The community should be educated regarding the nature of the toxin and the precautions required. This will help to reduce misinformation concerning the hazards posed by the toxin, which is a frequent source of social disquiet during operations using vertebrate toxins. Bait containing brodifacoum is currently used in Tokelau, especially Atafu, and has been in widespread use for many years, which if made clear, should reduce issues with social acceptability of this toxin.

Table 15 - concerns regarding human and environmental health noted during the feasibility assessment visit September/October 2023.

What is the toxin and how dangerous to humans is it?
How will bait be used around households?
How long until it would be safe to harvest crabs?
How is the marine environment affected by the toxin or by poisoned rats that enter the sea
Can bait/poisoned rats be excluded from water supplies?
Will the toxin poison the coconut harvest?

7.2 Does the project have institutional and political support?

The project has institutional support so far from within Tokelau (Taupulega, EDNRE) and from outside Tokelau; this feasibility assessment was managed by the Secretariat of the Pacific Regional Environment Programme (SPREP) and funded by the New Zealand Ministry of Foreign Affairs and Trade (MFAT) under the "Managing Invasive Species for Climate Change Adaptation in the Pacific" project.

The EDNRE have driven this work to date. Although project roles would not be defined until the planning phase of the eradication, EDNRE would naturally be the best fit as the lead agency to manage the eradication, with guidance from traditional leaders (Taupulega) and technical support from other agencies e.g. SPREP and Island Conservation.

Other government agencies would need to be involved and consulted regularly e.g. Health and Education Departments. The work offers a significant educational opportunity for the youth of Tokelau, and the schoolkids also need to be educated about the precautions required around the toxin, the need to prevent reintroductions of pests and so on.

The Police would need to be kept informed and their assistance could be required for aspects of the work. Representatives of the health service, a teacher and a police officer were briefed about the proposed work during the feasibility visit and were supportive.

There is no known political opposition to the proposed eradication so far.

7.3 What human health, non-target and environmental impacts are likely?

A comprehensive assessment of environmental effects is usually part of operational planning. Below is a summary of expected impacts with some specific details to re-visit concerns that were raised during the feasibility assessment visit.

What is the toxin and how dangerous to humans is it?

Brodifacoum is an anticoagulant toxin that is primarily used to kill rodents and other pest mammals. Anticoagulants (blood thinners) are also taken by people with heart conditions. The toxin works by steadily lowering the amount of Vitamin K in the blood, reducing the ability of blood to clot and leading to death from haemorrhaging.
Baits containing brodifacoum are toxic to humans if they are consumed in large quantities. The lethal dose of rodent bait containing brodifacoum for an adult human is about 5000 grammes (5kg)

(NPCA 2011); this amounts to more than 2200 bait pellets. The lethal dose for a child is lower and it is important to supervise young children at all times when bait is present on the ground.
It should be noted that brodifacoum is cumulative and is stored in the liver of mammals, including humans, where it can remain for many months, so although the risk posed by this toxin is very low in a well-planned and controlled poison operation, repeated exposure over time has the potential to cause a health risk.

The people most at risk of primary exposure during the operation would be the project team members actively handling and applying the bait, as small amounts of the toxin can be absorbed through the skin and the lungs if precautions are not taken (SPREP). Team members would be trained in the safe handling of bait and would be issued with personal protective equipment.

Secondary exposure to brodifacoum is possible through consumption of animals that have themselves consumed bait containing the toxin. In Tokelau the most likely pathways for secondary exposure would be through consumption of domestic pigs (particularly pig liver, which is a popular food in Tokelau, Pierce et al.), and crabs. Eliminating the risk of exposing domestic pigs to bait is very important. Consumption of crabs is managed by way of a moratorium (see below).

Brodifacoum is classified by the World Health Organisation as non-mutagenic and unlikely to be carcinogenic (WHO). Vitamin K1 is recognized as an effective treatment, however it must be maintained for a relatively long treatment period.

How will bait be used around households?

Lockable bait stations containing bait blocks would be placed under and around houses, and potentially in the roof cavities of some buildings. Bare areas of coral or sand around houses are left un-baited, but in gardens and other vegetated areas bait pellets would be hand-broadcast.

How long until it would be safe to harvest crabs?

Rodent bait containing brodifacoum is not toxic to crabs due to the different circulatory physiology of invertebrates. However, crabs consume the bait in large quantity and secondary exposure of humans to brodifacoum through consumption of crabs is possible. Unlike in mammals, where brodifacoum can persist for many months, brodifacoum residues in crabs fall to low levels within three days after feeding on bait, and detectable residues have not been found beyond about eight weeks (Broome et al.). To eliminate any risk of secondary poisoning to humans, a six-month moratorium, starting when the bait has been laid, is placed on the consumption of crabs.

How is the marine environment affected by the toxin or by poisoned rats that enter the sea?

The tools proposed for broadcasting bait in Tokelau (Aerial broadcast using a micro-helicopter or a heavy-lift drone and ground broadcast by a trained team) are highly accurate and therefore very little bait is expected to enter the sea. For aerial broadcast with either helicopter or drone, a specialised deflector bucket is used when broadcasting bait around the coastline, meaning that bait only flies out on the inland side of the helicopter, minimising bait falling on the beach or into the sea. For ground broadcast the teams are instructed only to bait vegetated areas – no bait is to be thrown onto beaches or into the water.

If a small amount of bait or poisoned rats enter the sea, the impact on marine life is unlikely to be measurable. The enormous volume of the sea, the tiny quantity of toxic material and the vigorous mixing caused by wave action means that any toxic material would be rapidly diluted beyond measure. Furthermore, in laboratory studies most fish have shown no interest in cereal bait pellets (Broome et al.).

Low-level residues of brodifacoum have been found in marine invertebrates and some fish following some rodent eradication projects, persisting in some species for a short period of months after bait application (Broome et al.). Testing for brodifacoum residues could be undertaken in Tokelau following broadcast of rodent bait, and if residues were found, a moratorium on the harvest of some species could be proposed for a period of months until residues had disappeared.

Can bait/poisoned rats be excluded from water supplies?

Bait will be contained in bait stations around houses in the villages so would be excluded from rainwater collection systems. Rats can be expected to die within about one week of baiting. It is standard practice in rodent eradications to disconnect and block-off water tanks, and cleaning spouting and gutters before reconnecting following baiting.

Whilst the chance of bait entering water supplies can be eliminated, it is worth noting that brodifacoum has very low solubility in water, meaning it doesn't dissolve in water but tends to settle out in sediments.

Fate of uneaten bait in the environment

As uneaten baits disintegrate, brodifacoum is absorbed into the soil where it is then slowly degraded over weeks to months by soil bacteria. Soil type, temperature, and the presence of soil micro-organisms capable of degrading brodifacoum will all influence the degradation time.

Will the toxin poison the coconut harvest?

Because brodifacoum is insoluble in water it is not up taken by plants like coconut, and residues in crops have never been detected in field studies (WHO).

Non-target impacts – birds, crabs

Non-target impacts of the toxin on native biodiversity are expected to be close to zero. The majority of bird species in Tokelau are marine-feeding species that have no risk of primary of secondary exposure to brodifacoum. There is a limited chance of some individual wading birds (particularly Tiafee/Bristle-thighed Curlew and Tulee/Pacific Golden Plover) receiving primary, or, more likely, secondary exposure to the toxin through consumption of crabs that have eaten bait. There is also a low risk of exposure to the Kaleva/Long-tailed Cuckoo through the same pathway. These risks already exist in Tokelau through the ongoing use of brodifacoum for rat control (TISSAP, EDNRE), and eradication would remove these risks long-term by removing the need for ongoing control. Timing the rat eradication on each Nuku for June-July would minimize the risk of exposure to wading birds as most birds would be away on their arctic breeding grounds. This timing also sits within the drier period of the year (May to September) when rat breeding may be at the lowest.

Other native species including crabs, turtles, lizards, insects, fish and plants are expected to be unaffected by the toxin.

Table 16 - Tiafee/Bristle-thighed curlew, adult, probably recently returned from Alaska, photographed on Fale, Fakaofo, September 2023.

8. What will it take?

8.1 What is needed to effectively manage the project?

Management of the eradication project would need to be determined in the project design phase. Presented here is an overview of a proposed structure based on similar eradication projects.

Project Management

The lead agency would most likely be EDNRE. An overall Project Manager, employed or hosted by EDNRE and reporting to the Director of EDNRE, would be responsible for the day-to-day management of the project and would contribute to all decision making. A Project Lead, reporting to the Project Manager, would be based on each Nuku, in charge of managing the delivery of the project on their Nuku with an Assistant Project Lead to assist with logistics and planning. A Technical Lead from an external agency e.g. Island Conservation (IC) could be appointed to assist the Project management team. A monitoring/data management lead at each nuku would be tasked with leading the monitoring work and managing the result and outcome monitoring data.

Project governance could be provided by a committee comprised of representatives from the Taupulega and other agencies both within Tokelau, (e.g. Health Department) and outside Tokelau (e.g. SPREP, Island Conservation). This Governance group should be established early on, during the project design phase, to provide strong guidance throughout all phases of the project.

Phases of the project

Management of the project would guide the eradication through six phases: project design, planning, implementation, monitoring, reporting and review. The scope of work in each phase is briefly outlined below.

Project design

Project design could begin in earnest once this Feasibility assessment has been reviewed and if a decision to proceed is made by the authorities in Tokelau. Note that the dependencies highlighted throughout the document and summarised in section 8.9 are the key actions identified that need to be achieved before an eradication can commence – if these actions cannot be undertaken then the project should be abandoned.

The project design phase would involve the establishment of a Governance Committee and employment of the Project Management team and establishment of Memoranda of Understanding (MOU) with external agencies (e.g. SPREP, IC). The objectives, outputs and desired outcomes of the project should be reviewed, and agreement reached on the scope of the project. Tools should be reviewed and selected during this phase.
Consultation with the community should begin during this phase so that community members are well informed about possible impacts and are given the opportunity to input into the design of the project.

Project planning

During the first part of this phase the operational plan would be written by the Project Manager with collaboration from the Project Management Team and Technical Lead with input from the Governance Committee. The operational plan would include a detailed timeline of actions to manage the many things that need to be organised during this phase, summarised briefly here;

- Recruitment and training of the Field Delivery team and Data Management positions.
- Work contracted out (e.g. Drone broadcast) would be defined, tendered and contracts signed.
- Logistics to be organised and trialled if necessary
- Procurement undertaken including bait, fuel and other field equipment.
- Baseline monitoring of key indicator species established to prove comparison with outcome monitoring.
- Planning issues to be resolved.
- Agreements reached with community members on specific details of access to property, bait station placement.
- Development of a vertebrate pest biosecurity plan.

Project implementation

During this phase the Management team would oversee the delivery of the eradication by the field team and contractors. There would be a significant data management requirement. The success of this phase depends on the thoroughness of the scoping and planning carried out in the previous two phases. Because the delivery could occur independently on each Nuku, the project implementation phase may begin on one Nuku whilst the other two are still in the planning phase.

Project monitoring

Monitoring of the project will be vital to success, for instance to identify problems and resolve them quickly, and to inform the reporting and review of the project. What monitoring will be undertaken and who would carry it out will be defined in the operational plan. External assistance from specialists may be called upon to design and deliver some outcome monitoring e.g. marine surveys.

Project reporting

Reporting will be conducted by the project management team in collaboration with the technical lead, other agencies and the governance group. The outputs will include an operational report and may include scientific papers. Communications through media could involve collaboration specialist communications teams in other agencies e.g. SPREP or Island Conservation.

Project review

Capturing lessons learned from eradication projects is a very important process that contributes to the growing body of knowledge on the practice of eradicating invasive mammals. In particular, there is very little information published on eradication of feral pigs and feral cats on tropical islands, so this work would be an important opportunity to build knowledge to support other eradications of these species. A review could be conducted by an independent group with unput from the project management team and governance group.

8.2 What is the capacity and capability need?

Personnel with skills and knowledge are critical to the success of an eradication, but training can spread the necessary skills through the team, at least for most roles. The most important asset required of eradication staff is attitude. Staff must be “team players”, willing to collaborate, to learn and to follow instruction, and they must have good attention to detail. It is critical that tools are delivered with care to meet the principles of eradication. Enthusiasm for the work is another important asset, as the work can be monotonous and demoralising at times (e.g. cutting lines for ground broadcast).

The EDNRE has talented staff based on each Nuku and in the Tokelau Office in Apia. Current EDNRE staff could be mentored into Project Management team roles and some staff could be recruited from elsewhere in Tokelau or beyond. The Umaga on each Nuku has plenty of hard-working staff and, given sufficient training by technical staff, they could provide the bulk of the field delivery teams on each Nuku.

Some specialist work would need to be contracted out, including ground hunting of pigs and drone broadcast of bait. There are professional contractors available in New Zealand who have proven experience of delivering these services e.g. ENVICO technologies, based in Tauranga, have completed every drone broadcast rat eradication done to date. Contracted staff are expected to number no more than eight individuals.

Technical leadership, training in delivery of tools, monitoring and data management and peer review of operational planning could all be provided by specialist project partners such as IC.

8.3 Can all required permissions be secured?

The permits and consents required to use some of the tools proposed vary widely from place to place. As New Zealand statute law does not apply to Tokelau unless expressly extended to Tokelau, his probably means that some of the permits that would be required to undertake this work in New Zealand, e.g. Resource consent, Medical Officer of Health permission, are not required in Tokelau.

Equally some rules and regulations that must be followed in New Zealand such as the Drone Rules, under the Civil Aviation Act, may not need to be followed in Tokelau.

Where rules and regulations do not exist, care will obviously still be exercised, and best practice regarding safe use of toxins and other tools will always be applied.

Under the Tokelau Amendment Act (1996) the General Fono have power to make rules for the peace, order and good government of Tokelau, and these rules have legal effect in Tokelau. At least two local rules directly conflict with the proposed plans, i.e. the prohibition of dogs and firearms.

PLANNING ISSUE: *Determine what permits and consents are required for the tools selected and what rules and regulations apply to their use in Tokelau.*
DEPENDENCY: *Firearms use will be essential for eradicating feral pigs and may also be required for eradicating feral cats. Agreement will need to be reached on an acceptable strategy for firearm use during the eradication*
DEPENDENCY: *Trained Dogs will be essential for eradicating feral pigs and may also be required for eradicating feral cats. Agreement will need to be reached on an acceptable strategy for dog use during the eradication*

8.4 What are the infrastructure needs?

Tokelau has well-developed infrastructure that should already meet most of the needs of the eradication.

Transport

There is a good network of roads in each village and a variety of trucks, vans and utes are available to transport gear and personnel.

A lot of movements across the lagoon to the motu would be required during an eradication, and plenty of boats are available to facilitate this. The EDNRE owns several dinghies and there are many other good quality aluminium dinghies that could be hired.

Each Nuku has at least two barges, the largest of which are approximately three metres wide by nine metres long and have twin 75 HP outboard engines. These large barges would be excellent mobile landing and loading platforms for a drone broadcast operation, allowing motu to be baited from the lagoon whilst minimizing ferry times.

Figure 17 - Inter-atoll vessel MV Fetu alongside a barge on the ocean-side wharf at Nukunonu village.

Storage of bait

Bait must be stored somewhere dry and secure that is preferably rodent and insect-proof. There are various large sheds on each village motu that could provide storage options or shipping containers could be used – the quantities of bait required for each Nuku will fit within two 20-foot containers per Nuku. Each Nuku has open space near the wharf that could potentially be used for temporary storage of two shipping containers.

Accommodation

Each Nuku has a quarantine facility that was constructed to manage patients isolating due to the COVID-19 pandemic. These would provide ideal accommodation units for contract staff during an eradication, assuming that they are not required for continued patient management. There are also a variety of other options for housing staff including homestays and rental houses.

Figure 18 - dinghies in the lagoon at Fenua Fala, Fakaofo, Tokelau.

Figure 19 - The lagoon-side harbour on Fale, Fakaofo, Tokelau.

8.5 What are the logistical constraints?

Movement of people and gear

Reliance on the MV Mataliki and MV Kalopaga may cause delays at times as the timetable is prone to change for various reasons including weather, mechanical issues etc. It is not uncommon to be stuck in Tokelau for a while due to issues with either of these vessels.

The lagoons at Nukunonu and Fakaofo are large and can take more than an hour to cross in rough weather. Movements will need to be carefully planned and travel times taken into account.

Seasonal limitations

Weather delays are always possible when planning aerial broadcast. Fine weather is required for sowing the bait and is also preferable for several days afterwards to ensure that bait is not saturated and remains palatable to rats. Wind also affects aerial operations, particularly drones, which to date have been limited to broadcasting bait in wind speeds of less than 20 knots. Timing rat eradications for the drier part of the year should minimize weather issues.

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

Species of vertebrate pest that could arrive in Tokelau and the pathway these pests may arrive by are summarised in Table 17 below. Draft proposals for preventing introduction of vertebrate pests are suggested below.

No biosecurity practices currently exist to prevent the arrival of vertebrate pests into Tokelau. A biosecurity plan addressing vertebrate pests should be developed during the planning phase, in partnership with stakeholders including operators of the freight and passenger vessels and the transport office in Apia.

The highest risk of introduction of vertebrate pests to Tokelau from outside is the arrival of rat species from Samoa via the MV Mataliki or MV Kalopaga. Rats could either come on board whilst the vessels are docked at the wharf in Apia or hide away in equipment packed into containers or stored elsewhere on the vessels. Rats have been detected at least twice on the Kalopaga in recent years; both times they were trapped (Kalopaga crew, pers. comms.). The wharf is a high-risk location, as is the warehouse attached to the Tokelau office where equipment arrives and is sorted into containers for shipment to Tokelau. A workable strategy should be devised to bring the risk of introduction via this pathway as close to zero as possible. This plan should include inspections of equipment at appropriate points and regular checking of devices including traps and glue boards.

The biosecurity plan must also include the deployment and servicing of a detection network on Tokelau that has a high chance of detecting incursions promptly and an incursion response plan including methodologies tailored to species that could potentially arrive in Tokelau. The plan should also address the ongoing management of domestic pigs and cats to prevent reintroduction to the motu.

Table 17 - Biosecurity risks and mitigation measures

Species	**Source**	**Pathway**	**Likelihood**	**Prevention strategy**
Rattus exulans, Rattus rattus, Rattus norvegicus	Samoa	In boxes of food or other equipment on the MV Mataliki or MV Kalopaga	High	Inspection of gear in containers at the Tokelau Office before containers are sealed. Inspections and rat control on the vessels.
Rattus tanazumi, other rattus spp.	*Asia*	*Fishing boat, shipwreck or illegal landing*	*Low*	*Rapid surveillance and incursion response if a ship wrecks or a landing occurs.*
Pig (Sus scrofa)	*Tokelau*	*Deliberate or accidental reintroduction*	*Moderate*	*Regulation, penalties imposed, Education of community.*
Cat (Felis catus)	*Tokelau*	*Deliberate or accidental reintroduction*	*Low*	*Regulation, penalties imposed, Education of community.*

DEPENDENCY:

A biosecurity plan must be drafted and socialised to ensure acceptance of the community and stakeholders before eradication planning proceeds. This plan should also address management of domestic pigs and cats to prevent reintroduction to the motu. Biosecurity measures must be in place before the operational phase begins.


Figure 20 - the warehouse at the Tokelau liaison office in Apia where gear is collected and packed into containers ready for transport to Tokelau by boat.

Figure 21 - the MV Kalopaga at dock in Apia with the MV Mataliki at rear.

8.8 What are the planning issues?

Table 18 - Summary of planning issues highlighted throughout the document.

Do rats breed year-round in Tokelau?
Establish which motu are currently rat-free. If these motu are certainly free of rats at the start of the operation this would improve efficiency.
Confirm which islets feral pigs are present on for each Nuku.
Confirm which islets feral cats are present on for each Nuku.
Test whether removing rats influences population size of invasive ants.
Monitor the development of heavy-lift drones with a view to potential use in Tokelau.
Consider the best approach for targeting wall-dwelling rats at Fale. Conduct a trial if needed.
Conduct a literature review of aerial and ground broadcast eradications where only Rattus exulans were present– is success rate lower with ground techniques?
Trial cat removal techniques e.g. leghold trapping and test non-toxic bait delivery technique on Tokelau.
Review literature and assess the risk of Rattus exulans crossing open reef to reinvade islets.
Determine what permits and consents are required for the tools selected and what rules and regulations apply to their use in Tokelau.

8.9 What are the key dependencies?

The dependencies outlined throughout the document and the risks that they pertain to are detailed in Table 19 below. These dependencies must be addressed before an eradication can proceed.

Table 19 - Summary of risks and dependencies.

Risk	Dependency
Rats develop bait shyness	*Rodenticide use must be stopped at least 18 months prior to an eradication attempt.*
Lower than expected palatability of bait to rats	*Conduct a ground-based eradication to trial the uptake by rats of the recommended bait formulation on isolated motu on Tokelau during 2024.*
Bait sow rate is too low to put all individual rats at risk	*Conduct a bait availability trial at the recommended bait application rate on Tokelau in 2024.*
Proposed tools are insufficient to eradicate pigs	*Trial an eradication of feral pigs using passive tools on isolated motu in Tokelau during 2024. Assess the effectiveness of these tools under local conditions.*
Inability to put all individual rats at risk	*100% of the community are willing to allow access to their motu to undertake baiting and to their residences to deploy and manage bait stations. The community must also be willing to comply with guidelines to manage waste and food crops during the eradication.*
Inability to put all individual rats at risk	*It is essential to find a socially acceptable solution for management of domestic pigs through the rat eradication, that also satisfies the principles of eradication, before moving to the project design phase.*
Reinvasion of rats, reintroduction of feral pigs and/or feral cats	*A biosecurity plan must be drafted and socialised to ensure acceptance of the community and stakeholders before eradication planning proceeds. This plan should also address management of domestic pigs and cats to prevent reintroduction to the motu. Biosecurity measures must be in place before the operational phase begins.*

Inability to put all individual feral pigs and feral cats at risk	*Firearms use will be essential for eradicating feral pigs and may also be required for eradicating feral cats. Agreement will need to be reached on an acceptable strategy for firearm use during the eradication*
Inability to put all individual feral pigs and feral cats at risk	*Trained Dogs will be essential for eradicating feral pigs and may also be required for eradicating feral cats. Agreement will need to be reached on an acceptable strategy for dog use during the eradication*

8.10 What are the estimated costs and timeline?

A draft breakdown of estimated costs of the eradication is found in *Table 20* in appendix. Estimated costs are based on rat eradication using a combination of ground and aerial tools (as presented in section 5.3) and a feral pig and feral cat eradication utilising multiple ground-based tools. The figures given are rough estimates based on previous eradications; more detailed costing would take place in the operational planning phase.

The estimated cost of the eradication is NZ$5,782,200 across approximately four years. This figure includes the set-up costs of establishing a biosecurity network but not the ongoing costs of maintaining biosecurity. Maintenance costs (detailed in *Table 21*) are estimated at NZ$60,000 per year. Most of this cost is wages of staff to check and maintain biosecurity tools – these could be new staff or existing positions.

A cost-benefit analysis was listed in the TISSAP as one of the outcomes of this feasibility assessment. However, a worthwhile analysis weighing the costs of the proposed eradication against the expected benefits would require the services of an environmental economist to put a Total Economic Value (TEV) on improvements to non-market values such as biodiversity and ecosystem services. In fact most benefits of the proposed eradication are to non-market values (as opposed to market values that can be traded in competitive markets, like copra) that are not easy to put a dollar value to. However, the significance of benefits such as ecosystem services and the direct implications for climate change resilience should not be understated given the potentially existential threat posed to Tokelau by rising sea levels.

9. Conclusion and recommended way forward

The proposed eradication of kimoa/rats, feral pigs and feral cats on Tokelau is feasible because it lies within the technical limitations of a suite of possible tools, and all principles of eradication can be satisfied, provided that the dependencies outlined in section 8.9 can be addressed. Tokelau has good infrastructure in place to facilitate an eradication and there are few logistical constraints. Decision makers in Tokelau must now consider this feasibility assessment and decide whether to proceed with the eradication. In particular, they should review the dependencies and decide whether these are achievable, before the project can move to the next phase, i.e. Project Planning.

If the eradication proceeds Tokelau stands to become the first nation on earth to successfully eradicate all of its invasive mammalian pests. The people and biodiversity of Tokelau stand to benefit significantly from the eradication of mammalian pests, and because of its isolated position, there is a very high chance that Tokelau can secure the gains made and remain invasive mammal-free, provided that biosecurity practices are introduced and maintained.

Should the eradication go ahead it is hoped that the importance of this project to Tokelau can be recognised by the whole community. Ideally a collaborative approach would be taken whereby the community work alongside the project team to minimize risks of failure, including those that occur in and around the villages. Short-term sacrifices would be required and some long-term changes in behaviour (related to biosecurity), but it is hoped that any inconvenience will be seen as minor compared with the benefits that will continue to accrue into the future, improving the lives of generations of Tokelauans to come.

Figure 22 - Kiafee/Bristle-thighed curlew, Fenua loa, Fakaofo, September 2023.

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Appendix 1: draft budget

Table 20 - Estimated costs of eradicating kimoa/rats, feral pigs and feral cats

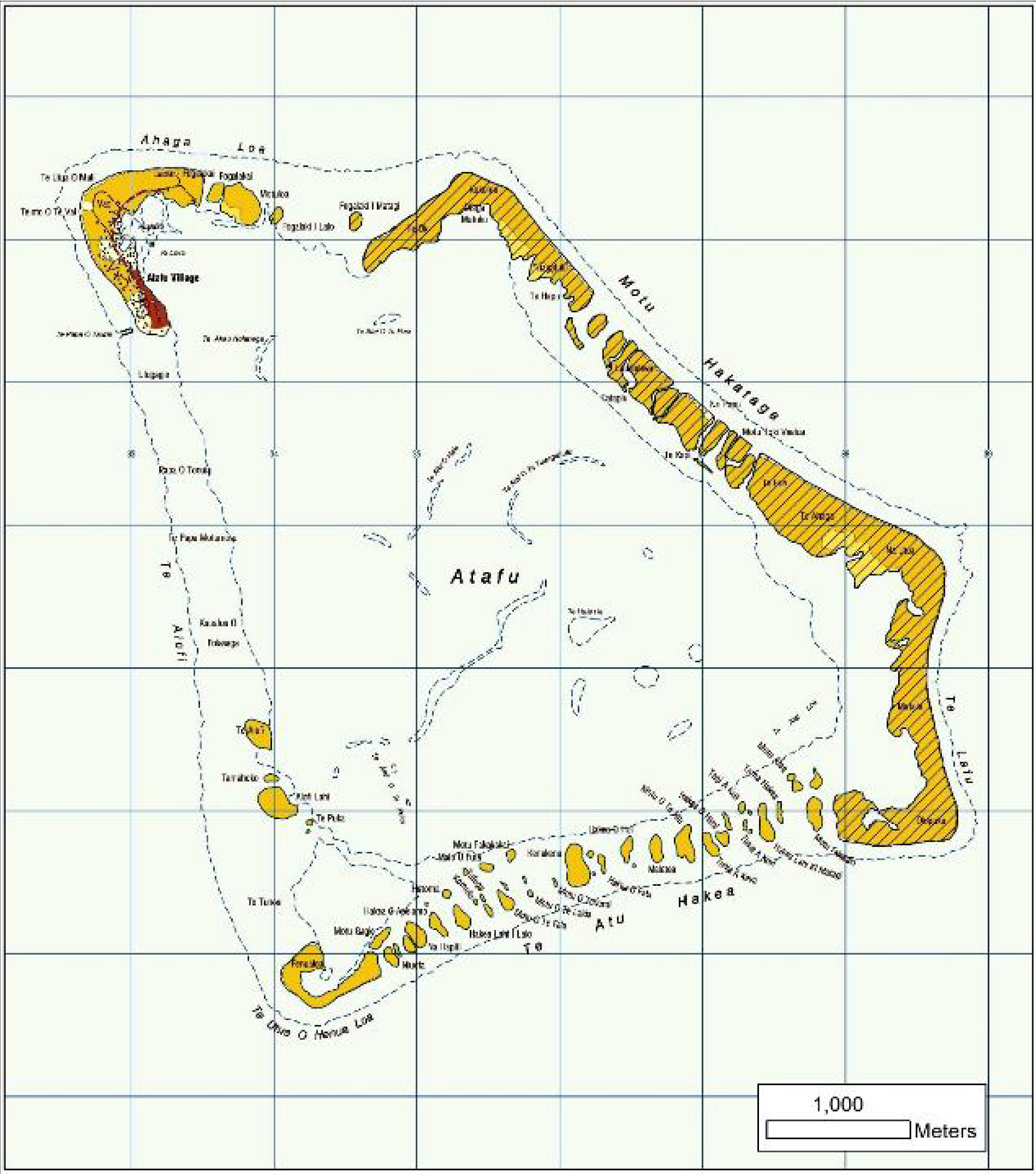
Type	Line Item	Estimated costs NZ$
Personnel	Project Management Team for 2 years per nuku	$900,000
	Technical Lead for 3 years	$300,000
	Monitoring/data management lead for 2 years per nuku	$600,000

	Wages, 20-person team for ground-based rat eradication & training, 1 month per nuku	$90,000
	Contract for aerial bait application for all nuku	$900,000
	Monitoring - set-up, training and ongoing staff time	$100,000
	Contract for removal of remaining feral cats, feral pigs	$200,000
Travel Costs	Airfares for contract staff	$70,000
	Boat Fares for contract staff	$12,000
	Food for contract staff @ $60 pp/pd	$65,000
	Accommodation for contract staff @ $100 pp/pd	$110,000
Transport costs	Transport of rodent bait	$80,000
	Transport of drone batteries	$20,000
	Shipping containers purchase x 6	$60,000
	Transport for other supplies and equipment	$20,000
Field supplies and equipment	RTK equipment	$120,000
	Handheld GPS units x 8	$4,000
	Ammunition	$3,000
	Rat bait (based on 25kg/ha over 2 applications + 10% contingency 49,291 kg in total)	$300,000
	VHF Radios	$2,000
	Trail cameras x 80	$30,000
	Traps and trapping supplies including 4 x pig brig traps	$26,000
	PPE & first aid	$4,000
	Bait stations x 200	$4,000
	Consumables (Flagging tape, batteries, pin flags etc)	$3,000
	Tools for cutting and marking bait lines	$3,000

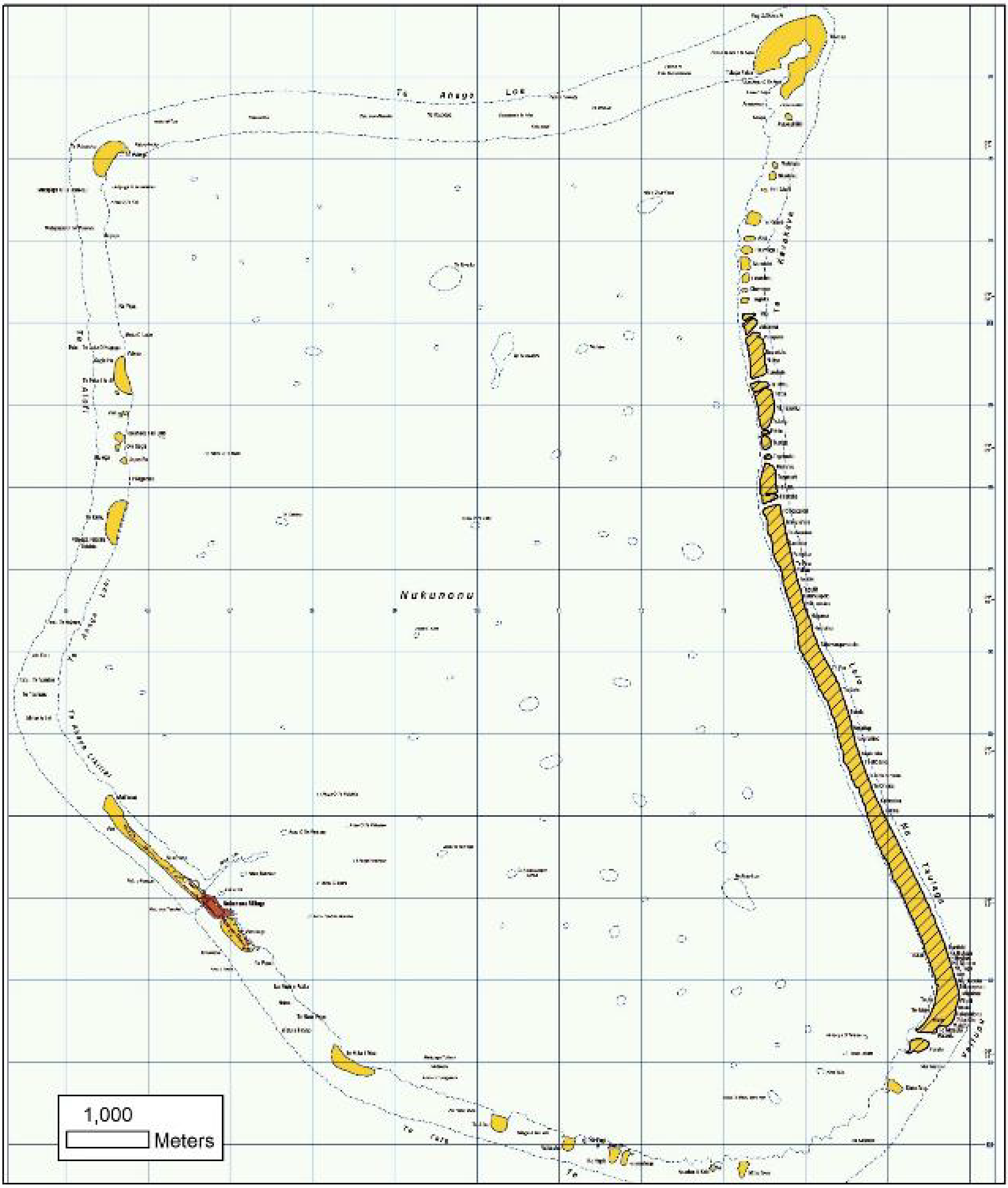
	Domestic animal risk management	$20,000
	Food waste management	$2,000
	Fuel for dinghies and generators	$200,000
	Boat hire	$60,000
Office supplies and equipment	Laptops, software, printers, white boards, office furniture	$20,000
Biosecurity set-up and equipment	Hardware, cameras for Tokelau office, nuku and boats	$100,000
	Set-up costs on nuku and at Tokelau office	$600,000
Sub total		$5,028,000
General and Administration (15%)		$754,200
TOTAL		**$5,782,200**

Table 21 - Estimated ongoing costs of maintaining a biosecurity network

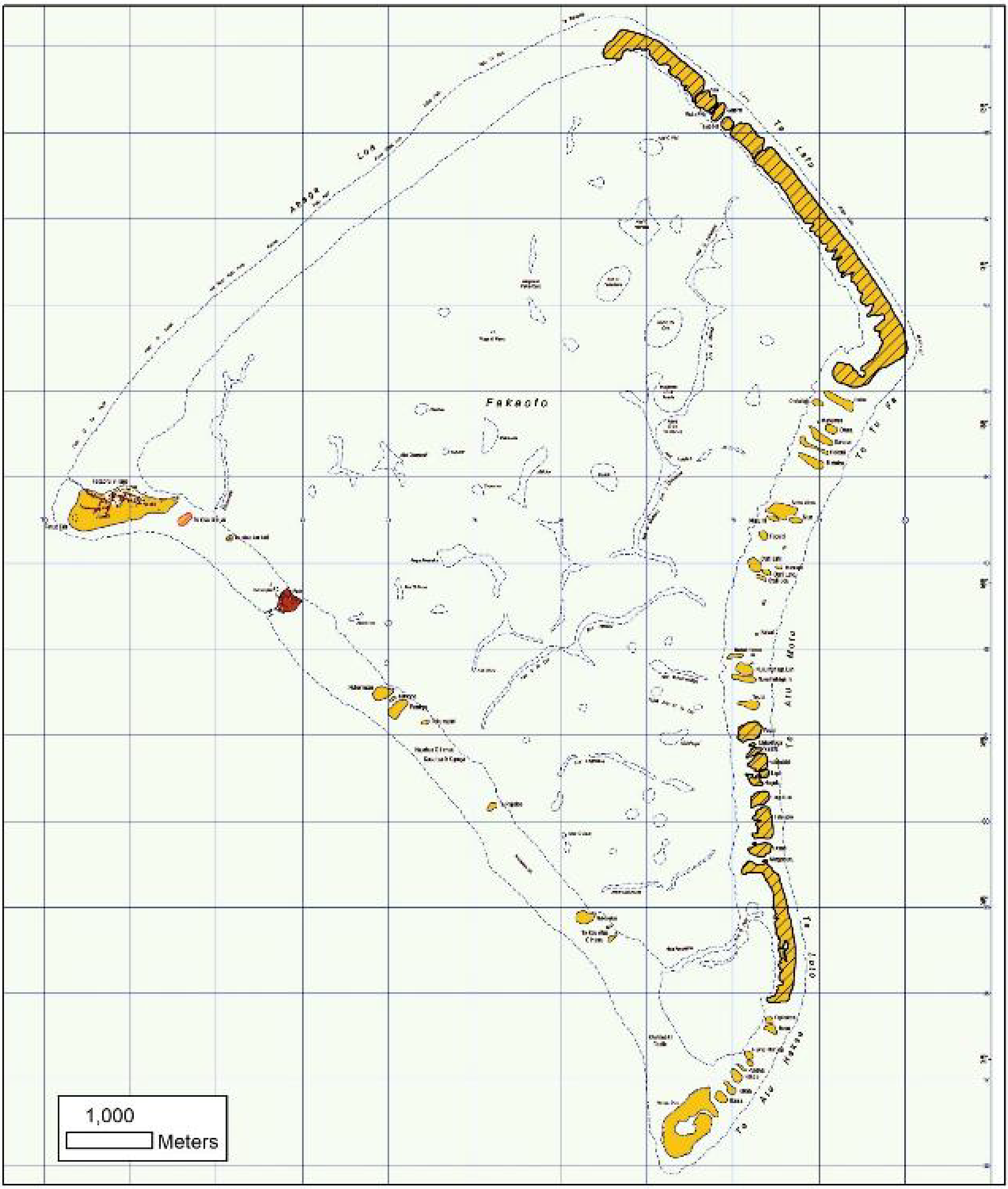
Type	Line Item	Estimated costs NZ$
Biosecurity ongoing	Ongoing check and maintenance costs at Tokelau office and boats	$30,000
	Ongoing check and maintenance costs at nuku 30 days/yr for 2 people	$18,000
	Hardware costs for nuku – cameras, traps, eDNA tests	$12,000
TOTAL		**$60,000**



Atafu proposed treatment zones
Black hatched area = aerial broadcast treatment zone, 185.6 ha
Un-hatched area = ground broadcast treatment zone, 96.1 ha



Nukunonu proposed treatment zones
Black hatched area = aerial broadcast treatment zone, 181.0 ha
Un-hatched area = ground broadcast treatment zone, 137.95 ha



Fakaofo proposed treatment zones
Black hatched area = aerial broadcast treatment zone, 176.7 ha
Un-hatched area = ground broadcast treatment zone, 118.9 ha

Appendix 3: Issues raised by Taupulega

Table 22 - summary of issues raised by the Taupulega of each Nuk

Nuku	Issue
Atafu	Pigs damage native vegetation, especially coconuts. Coconut crabs and small crabs are eaten by pigs. It is important to include pigs in the FS, There are feral pigs on the other motu of Atafu.
Atafu	Pigs are dangerous and someone will get hurt.
Atafu	Are you looking at ants?
Atafu	Would guns be part of the project to get rid of pigs?
Atafu	Is there a toxic bait for pigs? Is this an option?
Nukunonu	If you put out bait, and then have to wait six months before can eat crabs, how long does this go on for?
Nukunonu	There was a feasibility study in the 1970s, have you come across this?
Nukunonu	What about the coconut rhinoceros beetle?
Nukunonu	If we have space without bait eradication will fail – what happens on islands, placing of bait around households?
Nukunonu	Are you aware of the 2020 TISAP (Tokelau Invasive Species Action Plan)?
Nukunonu	Do you have an estimate of the budget?
Nukunonu	What is the bait?
Nukunonu	Whole heartedly support the project. How would you deal with pigs?
Nukunonu	Could you engage the NZ army to shoot pigs as a training exercise?
Nukunonu	Issue with subcontracting local workers: Can you provide advice on the cost of subcontracting locals to do the work? Can you include retraining of local workers in drone use and other methods?
Nukunonu	Is it possible to use local labour to assist to bring down the cost and keep the money in Tokelau?
Fakaofo	If we did the work today how long would it be until we could harvest crabs?
Fakaofo	How is the marine environment affected by the toxin?
Fakaofo	Lots of rats are living in and feeding on sea walls, how to target them without bait/dead rats ending up in ocean?
Fakaofo	Is there a breeding season for rats? Does that affect when/where bait will be spread?
Fakaofo	What does baiting inside houses involve?
Fakaofo	During the holidays families will often visit the other motu for picnics, leaving behind food waste. How would this affect the timing of the bait?
Fakaofo	How to stop bait/poisoned rats entering our water supplies?

Appendix 4: Alternative pest management tools and tactics

Table 23 below summarises tools and tactics that were rejected because of cost, efficacy, risk and/or availability.

Table 23 - tools and tactics that were considered but rejected.

Species	Method	Reason why method was rejected
Kimoa/rats	Trapping	Ineffective. Only possible on very small islands. Risk of escapes creating trap-shy animals renders this method ineffective at scale.
Kimoa/rats	Bait station grid across motu	Expensive. Labour intensive at large scale (Howald 2007). Efficacy likely lower than broadcast.
Kimoa/rats	Acute toxicant	Potentially low efficacy as acute toxicants can cause bait shyness (due to quick onset of symptoms) if rats consume sub-lethal doses.
Kimoa/rats	Genetic engineering	Techniques including RNA interference and transgenic rodents are under development. Probably at least 15 years away, unproven and potentially controversial.
Feral Cats	Disease – Feline panleucopania virus	Used on Jarvis and Marion Islands (Nogales 2004). Would infect domestic cats. Low humaneness.
Feral pigs	"Judas" pig	Used in many operations. GPS tracked pig released to help locate other pigs. Probably ineffective in Tokelau due to solitary nature of pigs.

Appendix 5: Bird population data and species lists

Table 24 - Bird population estimates from Pierce et al. 2012. Comparison is made with estimates by Wodzicki and Laird 1970. B = breeding, pB = pairs breeding, NB = non breeding.

Species	Tokelauan name	Atafu Sept 2011	Nukunonu Oct 2011	Fakaofo Jan 2012	Popn. Change since 1960's
Wedge-tailed Shearwater	Tanguoua	Offshore	Offshore	Offshore	No change
Christmas Shearwater		1	0	0	First record
Red-tailed tropicbird	Tavake-ulu-gahu	3	20+B	0	Increase at NN
White-tailed tropicbird	Tavake-ulu-puka	1	10+B	0	Increase at NN
Lesser Frigatebird	Katafa-koti	500+NB	500+NB	200+NB	Big increase at all nuku
Great Frigatebird	Katafa Gogo	<10NB	<10NB	<10NB	No change
Red-footed Booby	Takupu	1000+B	1500+B	600+B	Big increase at all nuku
Brown Booby	Fuakoo	10+B?	100+B	1 seen	Increase at NN
Masked Booby	Hakea	1 NB	0	0	No change
Pacific Reef Heron	Matuku	30-50	50+B	20+	Possible increase
Pacific Golden Plover	Tuli	50+	50+	Present	No data
Ruddy Turnstone	Vaha-vaha	20+	30+	Present	No data
Wandering tattler	Kolili	50+	50+	Present	No data
Bristle-thighed curlew	Tiafee	<10	c20	Present	No data
Brown noddy	Gogo	10,000+pB	10,000+pB	Abundant	Possible increase
Black noddy	Lakia	15,000+pB	5,000+pB	Abundant	Possible increase
Black-naped tern	Tovivi	60+B	100+B	40+	Increase at AT, NN
Sooty tern	Talagogo	39+NB	1600pB	1	Increase at NN
White tern	Akiaki	5000+pB	5000+pB	Abundant	Possible increase
Pacific pigeon	Lupe	6 motu	1 motu	Present	Apparent decline
Long-tailed cuckoo	Kaleva	Reported	Reported	Reported	No data

Table 25 - bird sightings from limited surveys done during Feasibility visit Sept-Oct 2023.

Species	**Atafu**	**Nukunonu**	**Fakaofo**
Pacific Imperial-Pigeon	Common on village motu	0	1 seen
Long-tailed cuckoo	0	5 heard or seen	4 heard
Pacific Golden-Plover	Common	Common	Common
Bristle-thighed Curlew	1 seen	3 seen	7 seen
Wandering Tattler	Common	Common	Common
Ruddy Turnstone	21 seen	30 seen	Common
Sanderling	0	0	1 seen Fenua fala
Pectoral Sandpiper	0	2 Juveniles	1 seen Fenua fala
Sharp-tailed Sandpiper	1 on Na Utua	0	0
White Tern	Common	Common	Common
Brown Noddy	Abundant	Abundant	Abundant
Black Noddy	Abundant	Abundant	Abundant
Sooty Tern	50+ could be breeding here	400+pB	6
Black-naped Tern	15+	20+	20+
Tahiti Petrel	0	1 seen just offshore from MV Fetu	0
Sooty Shearwater	0	66 between FF-NN from MV Fetu, all heading S	0
White-tailed Tropicbird	3 seen	0	2 seen
Lesser Frigatebird	Common	Common	Common
Great Frigatebird	0	2	5
Red-footed Booby	Common	Common	Common
Brown Booby	0	40	0
Pacific Reef-Heron	Common	20	10

Figure 23 - Akiaki/white tern pair on Fenua fala, Fakaofo, Sept 2023.