2021

Maukahuka Pest Free Auckland Island
Technical feasibility study report

Department of Conservation
Te Papa Atawhai

Maukahuka
PEST FREE AUCKLAND ISLAND

Te Rūnanga o NGĀI TAHU

DOCUMENT BUILD STATUS

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Disclaimer: This document represents thinking at the time of publication and is intended to present technical detail that informs an assessment of feasibility by technical advisors and relevant managers. Operational planning will refine programme methods and timelines. Operations are expected to adapt to knowledge gained throughout the project.

Project team: Finlay Cox, Veronika Frank, Stephen Horn, Rose Hanley-Nickolls, Paul Jacques, Estelle Pera-Leask, Rachael Sagar and James Ware.

Reviewers: Department of Conservation / Te Papa Atawhai Island Eradication Advisory Group.

Notes:

A **Glossary of terms** is available in Appendix 1.

Key supporting documents are listed in Appendix 2.

DOC internal documents are referenced in text (**DOC-xxxxxx**) and can be made available to external parties on request.

PEOPLE—NATURE
TOGETHER WE FLOURISH
TUIA TE TAIAO

Cover: View along the western cliffs of Auckland Island. *Photo: James Ware/DOC.*

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CONTENTS

Plate 1. Feral pigs (*Sus scrofa*) (A), house mice (*Mus musculus*) (B) and feral cats (*Felis cattus*) (C) are the species the Maukahuka project aims to eradicate from Auckland Island (45 889 ha), and are the last remaining mammalian pests in the New Zealand Subantarctic area (NZSIA; 76 000 ha). Following their eradication, the total pest free area in the NZSIA will expand by more than 250%, increasing habitat for over 500 native species. *Photo credits: Stephen Bradley and Finlay Cox/DOC.*

Maukahuka Pest Free Auckland Island Technical feasibility study report

Executive summary

Context

A project has been proposed to eradicate pigs, mice and cats from Auckland Island, the main island of the Auckland Islands in the New Zealand subantarctic islands area (NZSIA). The project is known as Maukahuka Pest Free Auckland Island. This report, completed by New Zealand's Department of Conservation (DOC), provides a feasibility study of the project.

The purpose of a feasibility study is to understand the costs, benefits, risks and technical challenges of a project and allow informed decisions on the project design to give it the best chance of success. It also allows a project with a high chance of failure to be 'shelved' before large sums of money are committed. Feasibility studies are a standard part of DOC's eradication best practice.

In this report we assess more than 3 year's work to understand the feasibility of eradicating pigs (*Sus scrofa*), mice (*Mus musculus*) and feral cats (*Felis catus*) from Auckland Island. The report addresses three key questions: why do it, can it be done and what will it take? It also provides a reference and justification for stakeholders, outlines methodologies for the eradication of each of the target pest species, identifies the scale of the undertaking so it can be considered and resourced appropriately, and highlights the next steps needed for quality project design. Findings from the work to date are addressed in detail in this document to inform project planning. We used an evidence-based approach and expert elicitation, including extensive field trials to reduce uncertainty and test methods. DOC's Island Eradication Advisory Group (IEAG) and several other experts have provided technical advice and review.

Background

Invasive mammals are a threat to global biodiversity, especially on islands where endemic species are particularly vulnerable. Auckland Island (45 889 ha; 465 km south of Bluff), New Zealand's fifth-largest island, our largest uninhabited island and the largest island of the Auckland Islands group (56 186 ha) is recognised for its outstanding natural heritage values. The Auckland Islands are a stronghold of taonga, harbouring remarkable and rare subantarctic plants and animals. Their isolation in the productive waters of the Southern Ocean has shaped extraordinary adaptions and unique biodiversity, represented by 500+ native species. There are diverse communities of seabirds, land birds, marine mammals, plants and invertebrates, many of them endemic and of conservation concern. Auckland Island is recognised internationally by its status as a United Nations Educational Scientific Cultural Organisation (UNESCO) World Heritage site, one of 213 recognised natural sites in the world and one of only two such sites in New Zealand. It is also a World Centre of Floristic Diversity (International Union for the Conservation of Nature; IUCN) and an Important Bird Area (Birdlife International). After nearly 30 years of pioneering pest removal work in the NZSIA, Auckland Island is now the last island of this area where mammalian pests remain.

Why do it?

The Auckland Islands are the most biologically rich of the NZSIA islands (Campbell, Antipodes, Bounty, Snares and Auckland islands; 76 000 ha); however, introduced pigs, mice and cats on the main (Auckland) island have inflicted severe ecological damage over the past 200 years and continue to erode the ecological integrity of the island. Native biodiversity is now severely diminished on Auckland Island relative to nearby pest-free islands in the archipelago.

Eradicating pigs, mice and cats from Auckland Island will achieve globally significant biodiversity benefits and many other consequential benefits, including leverage for other large-scale conservation work, capability development, and authentic collaboration with Ngāi Tahu ki Murihiku and other project partners. Successful eradication of mammalian pests would complete the vision of a pest-free NZSIA and enable permanent recovery of native wildlife over time.

It will also reduce the risk of incursions to other pest-free islands in the region and associated catastrophic consequences and response costs. In particular, there is considerable risk to the globally significant and unmodified Adams Island (9693 ha), which is within swimming distance (min. 548 m) of pests from Auckland Island and is a vital refugia for local biodiversity.

DOC administers the islands and has a clear mandate for the work. The eradication of pests from these islands is a vision shared by Ngāi Tahu ki Murihiku who are tāngata whenua and strongly support the goal. The project provides significant opportunities to strengthen and role model the relationship with iwi, hapū and whānau. Maukahuka would provide important momentum for the national Predator Free 2050 (PF2050) goal via development of capability in several fields of pest management technologies demanded by the step change in scale and by helping to leverage investment in conservation, including progression of conservation goals in other subantarctic areas. It aligns with the New Zealand Government's PF2050 objectives, the New Zealand Biodiversity Strategy, the protection afforded as part of the NZSIA World Heritage Area and will fulfil statutory obligations.

Eradication of mammalian pests is the only way to achieve the desired long-term benefits. On-going suppression of pests is not feasible because of the island's remote location, the complex logistics required to operate there, prohibitive ongoing cost and limited benefits (short-term relief for some native species at a few sites).

The most efficient and likely way to achieve success is via eradication of all three targeted pest species in sequential operations in short succession. This approach extracts the most value from the large investment in setup while minimising infrastructure maintenance compared with separate projects over a longer timeframe. The investment and effort to establish a specialised project team, supplier relationships and retain capacity and capability is large and would not be repeatable in the short term. Removing only pigs, or pigs and mice would drastically reduce the biodiversity benefits compared to removing all three pest species.

Removing pigs alone would lead to an increase in palatable plants and likely subsequent increases in mice and cat populations, in turn increasing predation on native birds and invertebrates, as is presently the case on Marion Island in the subantarctic Indian Ocean. This would severely limit the recovery of the island, preventing the return of endemic terrestrial birds and burrowing seabirds, which are keystone species in the Auckland Island ecosystem. Mice can have extensive detrimental impacts on islands (e.g. Marion Island, Gough Island (South Atlantic), Antipodes Island, Midway Atoll (North Pacific)), including the local extinction of some invertebrates, severe suppression of land birds and, in some cases, preying on large seabirds (resulting in zero recruitment). Removing cats and mice alongside pigs would allow bird, plant and invertebrate populations to re-establish and grow, maximising ecosystem recovery and resilience.

Can it be done?

The eradication of pigs, mice and cats from Auckland Island has been assessed against five principles of eradication and found to be feasible. Methods and capabilities are available or can be developed within specified timeframes with appropriate resourcing and sequencing. The project and the associated challenges are large. The site itself presents significant challenges relating to the scale of the island, remoteness, isolation, steep terrain affecting accessibility, poor weather, lack of infrastructure, difficulty in servicing and the immense quantities of gear and personnel required to be transported.

The project's implementation encompasses an extensive infrastructure programme followed by eradication of pigs, mice then cats (in that order) and each programme timed according to the seasons to maximise assistance from the environmental conditions. Pigs must be eradicated first to make the attempts on mice and cats possible (pigs will create gaps in bait coverage for mice and interfere with traps and baits for cats). The mouse eradication method complements that for cats. Too long a delay after the pig eradication risks vegetation regrowth that could make cat hunting unfeasible.

Assessment against the five principals of eradication:

1. ALL INDIVIDUALS OF THE TARGET SPECIES CAN BE PUT AT RISK BY THE PROPOSED ERADICATION TECHNIQUES

Pigs can be eradicated using an intensive and sustained application of a suite of overlapping techniques (trapping, aerial hunting and ground hunting plus Judas pigs to aid validation). Aerial hunting requires the development of capability with high-resolution thermal camera technology and aerial hunting teams. This tool makes the operation feasible by reducing the area to be ground-hunted by half and significantly reducing the risk of leaving animals behind in difficult terrain. The island should be temporarily fenced in two locations to create three management blocks.

Helicopter application of cereal baits containing rodenticide is the only feasible method for eradicating mice. Auckland Island is four times larger than the largest mouse eradication globally to date. Despite mice never having been eradicated at this scale, a large-scale trial over 1000 ha on Auckland Island showed mice can be eradicated in the summer season at a lower bait application rate than typically used (2 × 4 kg/ha compared with best practice of 2 × 8 kg/ha usually in winter). This departure from best practice is required to make the volume of bait and the likelihood of comprehensive bait coverage feasible given the limited number of flyable hours due to inclement weather and the constrained logistics of the remote location. The method requires improvement to the helicopter bucket mechanism for reliable bait application at the proposed sowing rate.

Trials on Auckland Island have greatly informed the feasibility of eradicating cats and reduced uncertainties. The eradication of cats is dependent on developing data processing capability for managing the volume of imagery from an island-wide grid of approximately 1500 trail cameras. This will help optimise the time between a cat being detected on camera and its image being processed, recognised and responded to. The cat eradication should occur soon after baiting to eradicate mice to take advantage of potential knockdown of cats via secondary poisoning and the late autumn/winter conditions. It is also highly desirable to have baits containing a cat-specific vertebrate toxic agent (VTA) available for aerial application following the mice eradication. This is the only tool that can potentially put every cat at risk and would greatly improve the likelihood of success and opportunity for rapid completion. A team of cat detection dogs, skilled handlers and trappers are key to the detection and dispatch of surviving cats. If a cat-specific VTA is not available, targeted trapping and use of lures with the aid of the camera grid would be relied upon to eradicate cats. This would take much longer, cost more and carry a greater risk of failure.

2. PESTS CAN BE DISPATCHED AT A RATE EXCEEDING THEIR RATE OF INCREASE AT ALL DENSITIES

To succeed, all operations require treatment and monitoring methods to be applied at sustained intensity until completion. Each operation can be designed to do this and remove individuals at a higher rate than they can be replaced, but seasonal timing is important. Well-designed monitoring with careful data collection and timely analysis is needed to inform decision making. This will allow operations to adapt as the situation changes (e.g. population density, behaviour, seasonal changes) and contribute to confidence that eradication has been achieved to avoid premature conclusion and failure.

Pig population density can be quickly reduced with lured trapping and aerial hunting before ground hunters are deployed. Mice will be breeding during the summer when baiting is planned. Mouse baiting will target all individuals through the application of two comprehensive treatments of the site in the space of several months. The interval between treatments should exceed 14 days to give young mice emerging from nests access to bait. Baiting should be completed by March to avoid alternative food being available (especially a large tussock seeding event) in any given year. Cat population density can be quickly reduced by primary (cat VTA) and secondary poisoning (eating poisoned mice), allowing ground hunters to mop up surviving cats with the aid of the island-wide network of trail cameras to target trapping effort.

3. THE PROBABILITY OF THE PEST RE-ESTABLISHING IS MANAGEABLE TO NEAR ZERO (SUSTAINABLE)

The isolation of the site and managed visitation mean that once eradication is achieved, the risk of incursion is low and manageable. The nearest populations of pigs, mice and cats are several hundred kilometres away, too far for the possibility of self-introduction. DOC is the authority that governs island access for management purposes and usually allows approximately 800 visitors per annum under tourism concessions with biosecurity provisions in the mandatory landing permits. A deep-sea fishing fleet regularly shelters near the island and should be engaged with to manage incursion risk. The extraordinary amounts of equipment, people and supplies to be taken to and from Auckland Island during the eradication project significantly elevates the biosecurity risk. This has been effectively managed in other subantarctic island eradications and is achievable for Auckland Island given timely investment in planning and additional biosecurity facilities.

4. THE PROJECT IS SOCIALLY ACCEPTABLE TO THE COMMUNITY INVOLVED

The Maukahuka project is strongly supported by Ngāi Tahu, (represented on several occasions by kaumatua Tā Tipene O'Regan) and stakeholders including tourism concessionaires. DOC's project to rid Antipodes Island of mice in 2016 (Million Dollar Mouse) achieved significant recognition and public support and similar public interest is expected for Maukahuka. This project is aligned with the statements of intent in the local Conservation Management Strategy (CMS) and Ngāi Tahu's vision document Te Tangi a Tauira. The use of toxins will draw some negative response, though their use is targeted for a short period in a one-off event on an uninhabited island. Auckland Island pigs have value for specific medical research because of their disease-free status and there is interest from at least one venture in recovering some pigs before eradication.

5. THE BENEFITS OUTWEIGH THE COSTS

The proposed pest eradication requires large but one-off investment for permanent and internationally significant biodiversity benefits with low to zero ongoing cost to sustain.

Eradication of pigs, mice and cats will immediately halt the destruction of indigenous fauna and flora to enable recovery and protection of over 500 native species. It would increase the total pest-free area in the NZSIA by over 250%, from 30 000 ha to 76 000 ha. This will secure the region as predator-free and reduce the extinction risk for more than 100 endemic species. The isolated landmass of the Auckland Islands makes them important breeding grounds for 25 seabird species (albatrosses, petrels, penguins, cormorants, terns and gulls) that forage the surrounding seas. Removing pigs, mice and cats will complement by-catch reduction work and improve the health of the Southern Ocean ecosystem, boosting resilience against projected climate change threats. Twenty-five native bird species that currently only breed in significant numbers on pest-free offshore islands in the Auckland Islands archipelago will be able to naturally repopulate Auckland Island. Rapid recovery of invertebrate populations will provide food for returning land birds and nutrient cycling and pollination for plants. Iconic subantarctic megaherbs will again flourish in the largest habitat available to them.

The Maukahuka project will deliver improved predator control tools and expertise to support PF2050 and is a tangible and necessary precursor to other ambitious PF2050 projects. Disbenefits, such as by-kill of native species and disturbance to vegetation from the infrastructure programme are expected to be minor and expected to rapidly reverse over 5–20 years (as demonstrated on Enderby Island). Per hectare costs are comparable with other island eradication projects and annualised costs over 10 years are comparable with other landscape-scale conservation projects. Project failure could jeopardise political and public goodwill towards future operations, but challenges are known and can be planned for and success will inspire people to undertake even more ambitious work.

Maukahuka will continue the progress of conservation in the global subantarctic area and enhance New Zealand's reputation for conservation leadership. For Ngāi Tahu, the project is another vital step in restoring the mana and mauri (energy, power and life force) of the whenua (land) they are kaitiaki (guardians) of and hold stewardship over. Tangibly, it will provide employment opportunities, opportunities to exercise customary rights of mahinga kai (food gathering), mātauranga (knowledge), tikanga (customary values and practices) and kawa (protocols) and to demonstrate an exemplar relationship with iwi, hapū and whānau (tribes, subtribes and families). Operated from a regional centre in Invercargill, Southland, this project will provide significant economic stimulus locally and support development of supplier capability for conservation regionally and nationally.

INFRASTRUCTURE AND LOGISTICS

Establishing appropriate infrastructure and reliable logistics are essential precursors to facilitate operations. The pig programme will take approximately 1 year to deliver, mice up to 6 months and cats between 1 year and 3 years depending on tools and efficacy. The infrastructure and logistics programme is the largest single component of the project, bigger than any of the individual eradications. It will take two to three summers to establish prior to the eradications and one to two summers to demobilise afterwards. The remote location and scale of infrastructure required greatly enhance the project costs, complexity and timeframes. Operational delivery will be land-based, as ship-based operations would be prohibitively expensive (several tens of thousands of dollars per day for ship charter) for the length of time involved and the size of a ship needed. Additionally, significant island-based infrastructure would also still be needed to manage helicopters (hangars, fuel and crews).

Facilities are needed to support year-round island occupancy for several years and facilitate regular access to all parts of the island by ground hunting. A main central base is needed to accommodate approximately 24 people, in addition to two smaller subsidiary bases (one north and one south), three boat sheds, 17 field huts, four helicopter hangars and fuel stores to manage up to 150 000 L of Jet A1 at a time. Maintenance and compliance requirements run throughout the life of the project.

A supplier is needed for shipping large volumes of cargo (approximately six voyages over the project), e.g. buildings and materials for infrastructure installation and extraction, helicopter fuel for each phase and mouse bait. Over 1200 tonnes (t) of supplies and materials are expected to be shifted to the island over the life of the project. Operational preparations include several large expedition-style tasks such as placement of 500 t of mouse bait (approximately 35 × 20-foot shipping containers in volume) plus fuel at nine load sites several months before baiting; and installation of 1500 trail cameras across a rugged island 50 km long with a team of 20 people. Delivery of each operation will occur concurrently with planning and preparation for the next. Dedicated project and contract management capacity is an important function for each stage and should not be underestimated.

Each eradication is dependent on helicopter support, ranging from two helicopters for the pig programme and up to six for baiting mice, totalling approximately 80 months of helicopter support, in addition to 20 helicopter transits between the mainland and Auckland Island. Multiple single-engine helicopters will need to be positioned to/from the mainland several times. Certain suitable helicopter models can fly the 465 km directly to the island from Invercargill under current rules. This simplifies the logistics, as the helicopters don't have to be shipped. The helicopter tasks and pilot skills are specialised and different for each eradication. Additionally, pilots with expert long-lining skills are required to unload and load ships for the infrastructure programme and regular resupplies. For example, the 500 t of bait and 150 000 L of fuel for the mouse eradication alone equates to over 800 helicopter movements from ship to shore.

The vast amounts of gear and supplies will require a dedicated mainland biosecurity facility in excess of current local DOC capacity, as well as island facilities to receive and handle them. The logistics and biosecurity of several large supply items (e.g. mice bait produced in Whanganui; flat-packed buildings; large volumes of jet fuel) will need to be managed at storage facilities near to the eventual port of departure. The supply chain steps include: procurement, containerisation, transport to port of departure, handling and storage in a bio-secure facility, quarantine, transport to port, shipping to island, offload by helicopter or small vessel, biosecurity check, storage on island and return of items/waste to the mainland. Logistics will need to be coordinated by dedicated roles with a fit-for-purpose inventory system.

Regular passenger transport services are required to resupply the island and carry out island team changeovers, with monthly voyages expected during the pig programme and 6-monthly during the cat programme. Aviation options (helicopters, floatplanes) can't provide a complete solution due to payload limitations and cost respectively, so marine transport will be necessary. However, few suppliers exist, and the frequency of work doesn't warrant the permanent allocation of a supply vessel in Bluff. Securing certainty of supply will be important.

What will it take?

A multi-species eradication using all preferred eradication tools will take up to 10 years from commencement of the infrastructure operation. This could be reduced if operations go well but is ambitious and requires a high level of resourcing and support at all stages. There will be a lag time from the decision to proceed until momentum and readiness to implement are achieved, this can be minimised by progressing some tasks in the interim.

This will be the largest eradication project that DOC has undertaken. The operational cost of the full project is estimated at $84m over 10 years, based on conservative estimates of operational duration due to weather constraints and modelled based on short staffing rotations. Longer staff deployments than proposed here are achieved in other programmes, which would be significantly cheaper and simplify logistics.

Likely funding options focus on joint Government and philanthropic sources. Personnel and helicopter costs stand out as the largest cost components of the project. Operational teams of 25–30 people will be needed for each programme, with a support team of 15–20 people on the mainland to service island work and prepare operations to run sequentially as well as undertaking the full range of project management tasks.

Two helicopters are required on-site for a large part of the operating period. It is estimated that the option of purchase/lease of two helicopters to remain on island could save between $4 and $5 million in standby fees. This option was successfully modelled during the rodent eradication project on South Georgia Island in the southern Atlantic Ocean.

Declaring each stage complete and stopping work on it needs to be evidence-based, as stopping without adequate validation of success risks project extension and presents the greatest danger to budget over-runs. Conversely, opportunities to complete the project early (whilst retaining confidence in the result) will offer the most savings.

Each successive pest control operation provides an obvious stage-gate decision point for continuation of the project. Once infrastructure is in place, it can be maintained (at an ongoing cost) until operations are funded and/or ready to start.

The project is pushing the boundaries of what DOC can achieve, so a partnerships approach is the preferred model, though such a model is yet to be tested or delivered by DOC at this scale. A workable partnership agreement and an operating model to control funds, govern, manage and deliver the project would be needed in such a case. Several options are available, the final structure will be dependent on the identity and preferences of the parties involved.

Key risks

1. INCLEMENT WEATHER MAY DELAY OR INHIBIT COMPLETION OF OPERATIONS, RESULTING IN OVERRUNS IN COST AND TIME OR PROGRAMME FAILURE.

The subantarctic provides the most challenging weather conditions in New Zealand for operations dependent on helicopters and shipping. Conditions are changeable, can be extreme and potentially damaging for equipment and could deter, delay or prevent supply and/or operational activity. Frequent low cloud and high winds about mountain passes essentially split the island into several parts and prohibit feasibly operating from a single location. The frequency and duration of suitable operating conditions have a direct impact on each pest control programme's duration, particularly aerial baiting of mice where sustained poor conditions risk failure to achieve comprehensive bait coverage.

Mitigation:

- Budget for operational duration with enough contingencies to realistically account for all potential operating conditions.
- Resource well to achieve objectives within the required timeframes (e.g. base at least six helicopters on Auckland Island for the mouse eradication, to allow rapid progress to be made with baiting when conditions are suitable).
- Locate accommodation and helicopter infrastructure in each third of the island to provide localised access, enabling operations to use short weather windows and make methodical progress when travel to distant locations from one base would be inhibited.
- Use satellite internet capability and internet-based weather forecasting to predicate operating opportunities in advance.
- Prioritise work in places where access is most limited (the western coast and areas above 400 m altitude) when conditions are suitable.

2. IF PROCUREMENT IS NOT FIT FOR PURPOSE IT COULD DELAY THE PROJECT BY YEARS AT SEVERAL STAGES, CREATE UNCERTAINTY FOR INTER-DEPENDANT MULTI-MILLION-DOLLAR CONTRACTS AND REQUIRE REPETITION OF COSTLY AND TIME-CONSUMING PROCESSES FOR EVERY ENGAGEMENT.

Procurement for the project involves at least 10 one-off procurements over $100 000 and many more repeat procurements above this threshold for helicopters, shipping, and passenger transport. Government procurement processes aim to test suppliers and provide best outcomes for DOC through competitive tendering but are not geared well for extraordinary activities with few potential suppliers such as for this project.

Mitigation:

- Investigate custom procurement options and reduce risk to attract suppliers.
- Engage openly with suppliers and seek industry advice early during planning to understand capacity and find solutions.
- Delegate financial authority, supported by Governance, to a level that provides efficient approval processes and connection with the project team.
- Understand how Government procurement rules will be affected if the project is managed and governed via an external entity.

3. INABILITY TO SECURE THE RELIABLE SUPPLY OF SHIPPING AND HELICOPTER RESOURCES TO SERVICE THE COMPLEX LOGISTICS MAY DELAY OR INHIBIT COMPLETION OF OPERATIONS, RESULTING IN OVERRUNS IN COST AND TIME OR PROGRAMME FAILURE.

Feasibility and project timeframes depend on securing transport and helicopter support services to establish an effective supply chain to Auckland Island. Significant dependencies exist, such as the timing of core operations, staff rotation rosters and specifications of support infrastructure. Requirements for helicopters and shipping services involve extraordinary and infrequent activities with few potential suppliers. Capacity for the specialist helicopter piloting skills (such as for aerial baiting and aerial hunting with thermal cameras) and helicopter engineers will be difficult to secure for deployment to the remote site. Coordination with other programmes (such as Tiakina Ngā Manu) for baiting pilots and helicopters will be required.

Mitigation:

- Develop simple, flexible and bespoke procurement options to avoid lengthy processes.
- Define specific needs early in the planning phase and engage with suppliers and industry expertise to build trust, understand capacity and find solutions.
- Consult with other programmes and explore opportunities to co-develop capacity.
- Contract key logistics for the life of the project to provide certainty.
- Embed industry expertise within the team to design procurement and manage complex compliance and contract scenarios. Ensure contract management capacity is resourced appropriately.
- Contract helicopter supplier for pig programme early and perhaps separately from other helicopter services so development of thermal camera capability is ready in time.

4. THE IMPACT OF A SERIOUS INCIDENT AT ANY STAGE COULD HAVE FATAL CONSEQUENCES AND/OR RISK THE VIABILITY OF THE PROJECT.

The operations involve extensive work with helicopters, boats, firearms and chainsaws, plus construction and remote fieldwork in an isolated place. These activities are all in the eight critical risk categories identified by DOC and will be predominantly delivered by contractors. An injured or ill team member may require intensive management on island for several days before medical evacuation is possible. The presence of helicopters on the island vastly improves the ability to retrieve an injured person to a base facility or conduct search and rescue operations.

Mitigation:

- Run a risk assessment process to identify potentially fatal hazards and plan for them.
- Ensure good team leadership, skilled and valued staff, and engage suppliers early to involve them in planning, treat them as team members and develop a shared safety culture.
- Use an effective communications network (satellite internet, VHF radio, inReach devices, helicopter tracking) to provide accurate local forecasting, enable early warning of an incident and access to off-island professional support for managing an incident/patient.

- Include a dedicated, on-island safety role to help with planning of day-to-day operations, reporting and debriefing to ensure details of operations and incidents are recorded for ongoing safety management assessments and improvements.
- Incorporate search and rescue capability and paramedic-level medical skills in the island teams.

5. IF IMPROVED ERADICATION TOOLS AND NECESSARY CAPABILITIES ARE NOT AVAILABLE, THE PROJECT WILL BE DELAYED OR NO LONGER VIABLE.

Operations for each target species are pushing current limits of scale for available technology and skills. Technical feasibility is dependent on capability development for both personnel and eradication tools. Required developments will optimise the likelihood of success for each eradication (reduce risk, complexity, duration, cost, while increasing confidence and likelihood of success).

Mitigation:

- Prioritisation of the project's research and development objectives throughout DOC with strategic alignment and management support of development programmes.
- Allocate seed funding so development programmes can be started as early as possible. New technologies must be tested and proven to be reliable and operationalised as far as practicable before rolling out at the scale of Auckland Island.
- Identify stage gates for feasibility to be reviewed if any critical elements change or fail to be realised.
- Ensure comprehensive training plans are in place before staff selection, with adequate lead-in time planned to train staff.
- Plan for succession and contingency throughout all team levels (field team, team leaders, programme leaders, project and contract management, training and supplier capacity).
- Use relationship vision document in development with Ngāi Tahu to contribute to project design for capability development.

6. IF DOC CAN'T PROVIDE AND SUSTAIN THE NECESSARY SUPPORT FOR A PROJECT OF THIS SIZE, THEN THE PROJECT MAY FAIL OR BE TERMINATED EARLY.

The Feasibility Phase has shown that the project is too large and complex for DOC to undertake using business-as-usual management. A project review in July 2019 highlighted the limited capacity of DOC Tier 3 management levels in Operations to properly support the scale of the additional work, the inhibitory delegations given to the Project Manager and the need for empowered governance. Large landscape-scale projects are relatively new to DOC, existing corporate systems and support resources are designed to support smaller scale, annual work-plans. The scale of this project requires organisational coordination and enhanced project management.

Mitigation:

- Articulate prioritisation throughout DOC and ensure resourcing is planned and targeted.
- Establish a reporting line with direct access to decision makers, as well as an empowering mandate for the team and appropriate delegation and authority to meet timeframes and manage risk.
- Sustained organisation-wide commitment, attention and action are required, along with new ways of working and a willingness to look for solutions.
- Act on recognised limitations of high-level management capacity.
- Explore the substantial opportunity for in-kind support.
- Ensure flexibility to move funds between financial years to enable the timely management of a complex operational programme.

7. THE PARTNERSHIPS APPROACH AND NEED FOR COLLABORATION MAY INCREASE COMPLEXITY AND AFFECT THE ABILITY TO DELIVER ON TIME AND WITHIN BUDGET.

There is need for large-scale collaboration with partners to help fund and facilitate the project. Having multiple significant stakeholders requires the utmost care in managing expectations and facilitating governance teamwork to avoid complicating the project instead of enabling it.

Mitigation:

- Seek excellence in project design and leadership.
- Develop a workable partnership approach that reflects the unique needs of the project.
- Carefully consider the implications of partnership commitments and ensure agreements and Governance reflect expectations, mutual benefits and accountabilities, including safety.
- Ensure processes allow for timely decision making, management of scope and good communication.
- Apply lessons from review of past and present landscape-scale projects in project design. A review of this Feasibility Phase should also be undertaken to complement the recommendations in this report.

8. AS PROTOCOLS AND LEGISLATION CHANGE, THE REQUIREMENTS FOR OPERATIONS AT AUCKLAND ISLAND MAY BECOME UNTENABLE.

Changes to protocols, permissions and legislation will occur over the life of the project and if not anticipated and managed well have the potential to cause significant delay, increase complexity and cost and affect feasibility. Current examples include: review of the DOC helicopter operating protocols (potentially restricting passenger transfer over water and reviewing direct flights of single-engine machines to Auckland Island), a Regional Coastal Plan review (proposing seasonal boat access restrictions at Port Ross due to the presence of breeding southern right whales / tohorā (*Eubalaena australis*) in winter) and the Conservation Management Strategy (CMS), which advises against new fuel storage that will be required for Maukahuka.

Mitigation:

- Develop strong relationships with external regulatory bodies and internally within DOC to involve them in design to ensure project needs are understood, considered and actively managed.
- Consider potential exemptions or grandfather clauses to mitigate some of the effects of changes introduced during the project.
- Design for anticipated change, where possible.

9. EXTERNAL DISRUPTIONS MAY AFFECT SUPPORT, SIGNIFICANTLY DELAY THE PROJECT OR CAUSE IT TO BE TERMINATED.

Disruptions may come from a range of sources, including changing social or economic context, change in Government or partner interest, national-scale disasters, flow-on effects of a serious incident on-site or from availability of critical transport solutions or suppliers. Delays to the delivery timeline are likely the immediate effect, with associated compounding effects, including impact on subsequent programmes and contracts, limitations of time-bound permissions, downtime for personnel, contract penalties and asset maintenance requirements. Due to the importance of seasonal timing of the work and dependencies between programmes, even short interruptions are likely to cause up to 12 month delays.

Mitigation:

- Use a collaborative approach to ensure Government and partners hold each other to account.
- Model potential scenarios during planning to ensure their implications are understood and minimised.

10. IF BIOSECURITY IS NOT PROPERLY MANAGED, OTHER ORGANISMS COULD BE INTRODUCED TO AUCKLAND ISLAND OR CURRENT PESTS SPREAD TO PEST-FREE ISLANDS IN THE ARCHIPELAGO.

Unprecedented volumes of equipment, supplies and personnel going to/from Auckland Island present significant biosecurity risk for this sensitive site. Supplies could originate from anywhere in New Zealand and provide an incursion pathway for unwanted organisms as varied as plague skinks (*Lampropholis delicata*), Argentine ants (*Linepithema humile*), rats (*Rattus* sp.) and diseases. A deep-sea fishing fleet also regularly shelters in inshore waters at the island.

Mitigation:

- Develop a biosecurity plan for the project ahead of implementation.
- Ensure standards are included in supplier contacts, biosecurity measures are implemented and additional facilities are available before commencement of infrastructure programme.
- Engage with and educate the fishing fleet to reduce the likelihood of a vessel inadvertently transporting pests and to assist DOC to protect the place and report illegal landing activity.
- Include biosecurity observations in monitoring during and beyond the project to ensure no unwanted organisms establish (e.g. weeds around infrastructure sites).

Dependencies

Technical feasibility is dependent on the development and readiness of several new and improved eradication capabilities, including aerial hunting teams aided by high-resolution thermal camera technology; an improved bait bucket for low application rates; and software for automated processing of imagery from trail cameras. A cat VTA, registered for aerial distribution is highly desirable. Capacity is also required for cat detection dogs and handlers and specialist bait-spreading pilots, which are likely to require active development. If any of these cannot be delivered, project feasibility should be reassessed. Delivery of all three operations is also dependent on the ability to fly single-engine helicopters to Auckland Island by direct flight from the mainland and to reliably secure cargo and passenger shipping services.

Recommendations

A full set of recommendations to address issues, reduce risk and increase the likelihood of success of the project appear in Appendix 8. In Table 1 we present the 10 most critical recommendations, many of which are actions that can be taken now, ahead of project initiation, to reduce uncertainty and progress towards optimal readiness whilst simultaneously providing benefits to other conservation work.

Conclusion

Eradication of pigs, mice and cats from Auckland Island is worthwhile, achievable and sustainable. Maukahuka is a priority eradication project because of its special protection status and the severity of damage from mammalian pests to this taonga. The project is complex with a long timeframe and the scale is significantly increased by the lack of pre-existing infrastructure and remoteness. However, the challenges can be planned for and overcome. The large investment is spread over the life of the project and well protected by the isolation of the site as the risk of pests returning is low. It is the largest island eradication objective for PF2050 that is well defined and ready to progress. It offers an attractive opportunity for partnerships and for tangible large-scale outcomes in the medium term to create momentum and advance New Zealand's PF2050 goal.

Several risks require high-level attention during project design and are critical to success. Consideration of these can start early in anticipation of project initiation. Steps that can be taken immediately include initiating/continuing development of required capabilities, progressing permissions, completion of site management plans, securing funding and completing project design. These actions will aid in minimising the lag between a decision being made to proceed and achieving the readiness required to commence implementation. To make progress, a decision to proceed and a committed investment strategy are the highest priority next steps, which would allow critical path tasks to commence.

Maukahuka is a wonderful example of the ambitious approach that DOC has demonstrated in its history of acting to protect and undo damage in our most treasured but challenging places. The feasibility of this project carefully builds on the lessons from the past; we stand on the shoulders of giants. Armed with this knowledge, the wero of kaitiakitanga has been laid down to restore the mana of Auckland Island.

Table 1. Priority recommendations to address issues, reduce risk and increase the likelihood of success of the Maukahuka Pest Free Auckland Island project

PRIORITY	RECOMMENDATIONS
1.	The scope of the project should encompass eradication of all three pest species delivered in sequential operations in short succession.
2.	DOC should provide a lead commitment to the project by securing the Crown investment and articulating an investment strategy for the life of the project, thereby providing investor confidence and enabling the required third-party contributions.
3.	Investment in capability developments to optimise technical feasibility is required for: • Thermal camera technology and experienced aerial hunting teams. • Improved helicopter bait bucket for reliable low sow rate application. • Automated image processing software to label and triage imagery from trail cameras. • An effective toxic bait registered for cats that can be aerially applied. • Cat detection dogs and handlers.
4.	The following project design tasks should be completed as soon as possible and incorporated into the project plan: finalising the relationship vision document between Ngāi Tahu and DOC, finalising the governance model and finalising the team structure; defining delegations, defining decision-making accountabilities and defining financial management.
5.	The project operating model must include dedicated high-level management support from within DOC, so decision-makers are engaged in the project and connected to project management.
6.	Overarching site management plans, including the NZSIA Biosecurity Plan, a Subantarctic Research Strategy and a Subantarctic Strategy should be updated/completed by DOC's relevant district and national teams to guide project design and ensure strategic alignment.
7.	The project infrastructure plan should be shared to initiate consultation with relevant DOC teams and external authorities to progress any interim actions identified.
8.	Shipping and helicopter industry expertise should be embedded into the project team designing procurement and managing complex compliance and contract scenarios. Management capacity must be resourced appropriately.
9.	Biosecurity planning and the infrastructure programme must be funded early in the process to ensure they are ready to go when the project gets underway.
10.	Engagement with potential funding partners and stakeholders must continue to facilitate better understanding of relative costs, wider benefits, stopping points, complexities and opportunities.

1. Introduction

New Zealand's Department of Conservation / Te Papa Atawhai (DOC) has undertaken a study investigating the feasibility of eradicating pigs (*Sus scrofa*), mice (*Mus musculus*) and cats (*Felis catus*) from Auckland Island, in the Auckland Islands (also known as Motu Maha) in the New Zealand subantarctic islands area (NZSIA; comprising Campbell Island/Motu Ihupuku, Antipodes, Bounty, Snares and Auckland Islands; 76 000 ha; Figure 1). The area is recognised globally for its unique biological and cultural values. Auckland Island is the main island of the Auckland Island group, the largest and biologically richest of the New Zealand subantarctic islands. Within the Auckland Island archipelago, Adams and Disappointment islands are globally significant as some of the largest islands in the world unmodified by people or introduced pests.

Figure 1. Location of the New Zealand subantarctic islands.

Pigs, mice and cats have inflicted severe ecological damage over the past 200 years[1]*. Eradication of pigs was proposed as early as 1982 and again in 1993, and eradication of cats since 2002[1]. In 2016 the Government announced the Predator Free 2050 (PF2050) initiative, including the interim goal of eradicating all invasive predators from offshore island nature reserves by 2025. Auckland Island is by far the largest island nature reserve and now the only site in the NZSIA where mammalian pests remain. It is New Zealand's fifth largest island and the largest uninhabited island.

A project to eradicate the remaining mammalian pests from Auckland Island would build on previous eradication successes in the NZSIA: Auckland Island (goats *Capra hircus*)[2]; Enderby Island and Rose Island in the Auckland Island group (rabbits *Oryctolagus cuniculus* and mice)[3]; Campbell Island/Motu Ihupuku (sheep *Ovis aries*, cattle *Bos taurus* and Norway rats *Rattus norvegicus*) – cats also disappeared following the removal of sheep and cattle)[4] and Antipodes Island (mice)[5]. No mammalian pests exist on the Snares and Bounty Island groups. Nearby Macquarie Island is a large Australian subantarctic island that has had all invasive vertebrate pests (weka *Gallirallus australis*), cats, rabbits, ship rats *Rattus rattus* and mice) eradicated from it[6]. A mandate for the feasibility study was approved by DOC's Deputy Director-General Operations (DOC-3009605). This document reports on the feasibility study's findings. It provides a reference and justification for stakeholders and provides an understanding of the scale and complexity of the problem. This study has used an evidence-based approach and expert elicitation to assess the technical feasibility of eradicating each of the three target species. It addresses three key questions: why do it; can it be done and what will it take? This report outlines the preferred methodology, highlights the risks, identifies challenges and dependencies and defines the subsequent steps needed for quality project design. Appendix 1 provides a glossary of terms used in this feasibility study report.

* Superscript numbers refer to references. These are listed at the end of the report.

A summary feasibility report (DOC-6085426; see Appendix 2) was presented to the Governance Group in November 2019. If an eradication project is initiated, the technical feasibility study (this report) will guide components of operational planning. A project plan will be written as an overarching document to guide the management of the project. This will address next steps required for quality project design identified in the feasibility study and set out responsibilities, timelines, decision making processes and project reporting.

This feasibility study is based on the resource kit for rodent and cat eradications from the Pacific Invasives Initiative (Version 1.0.2 October 2011; Figure 2). It references feasibility studies from previous DOC eradication projects including 'Cat and rat eradication on Ahuahu – Great Mercury Island'[7] and the 'Rangitoto and Motutapu pest eradication'[8]. This version was built following review by DOC's Island Eradication Advisory Group (IEAG), which advises on planning and implementation of island eradication projects undertaken by DOC and international groups. In 2018, the IEAG recommended to reduce uncertainties through further investigation before feasibility could be finalised (advice note DOC-5465177). Findings from extensive field trials in summer 2018/19 (DOC-5911275) and winter 2019 (DOC-6099361) have greatly informed this assessment of feasibility. In answering the questions 'can it be done?' and 'what will it take?', this study has also drawn on the lessons from previous eradication projects. The study has been carried out with expert support from IEAG and many others from within and external to DOC, including Alastair Fairweather (Waikato Regional Council), Elaine Murphy (DOC), James Russell (University of Auckland), Grant Harper (Biodiversity Restoration Specialists), Nick Cave (Massey University), Al Glen (Manaaki Whenua - Landcare Research) and Richard Griffiths (Island Conservation).

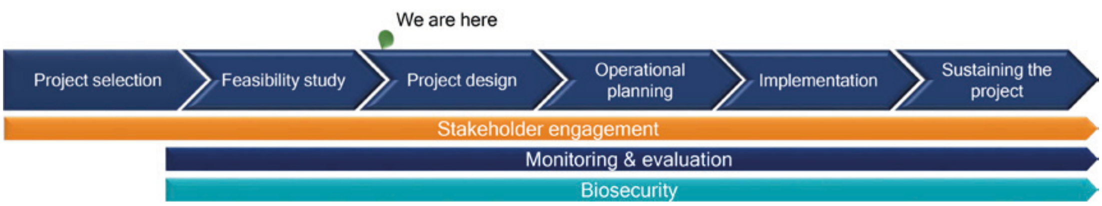

Figure 2. Eradication best practice project development process.

Plate 2. The Auckland Islands are a true maritime haven, with 25 species of seabirds breeding there. More than 99% of the declining global population of white-capped albatross / toroa (*Thalassarche cauta steadi*) nest there (A). A small colony persists on main Auckland Island, though breeding success in areas accessible to pigs is zero (B). Eradication of mammalian pests from Auckland Island would increase the available safe breeding habitat for seabirds in the archipelago by 420%. *Photo credits: Tui de Roy (A) and Paul Sagar (B)*.

2. Project goals, objectives and outcomes

2.1 Goal

The goal of the Maukahuka project is the eradication of all mammalian pests from the Auckland Islands.

Maukahuka contributes to the national Predator Free 2050 interim 2025 goal of we will have eradicated all mammalian predators from New Zealand's uninhabited offshore islands, supporting the New Zealand Biodiversity Strategy (Figure 3).

This work would also complete the vision of a New Zealand subantarctic islands area free from mammalian pests, contributing to two of DOC's stretch goals (Figure 3):

- 90% of our threatened species across New Zealand's ecosystems are managed to enhance their populations
- 50% of New Zealand's natural ecosystems are benefiting from pest management

These goals focus effort and help us move towards DOC's vision documented as Intermediate Outcomes.

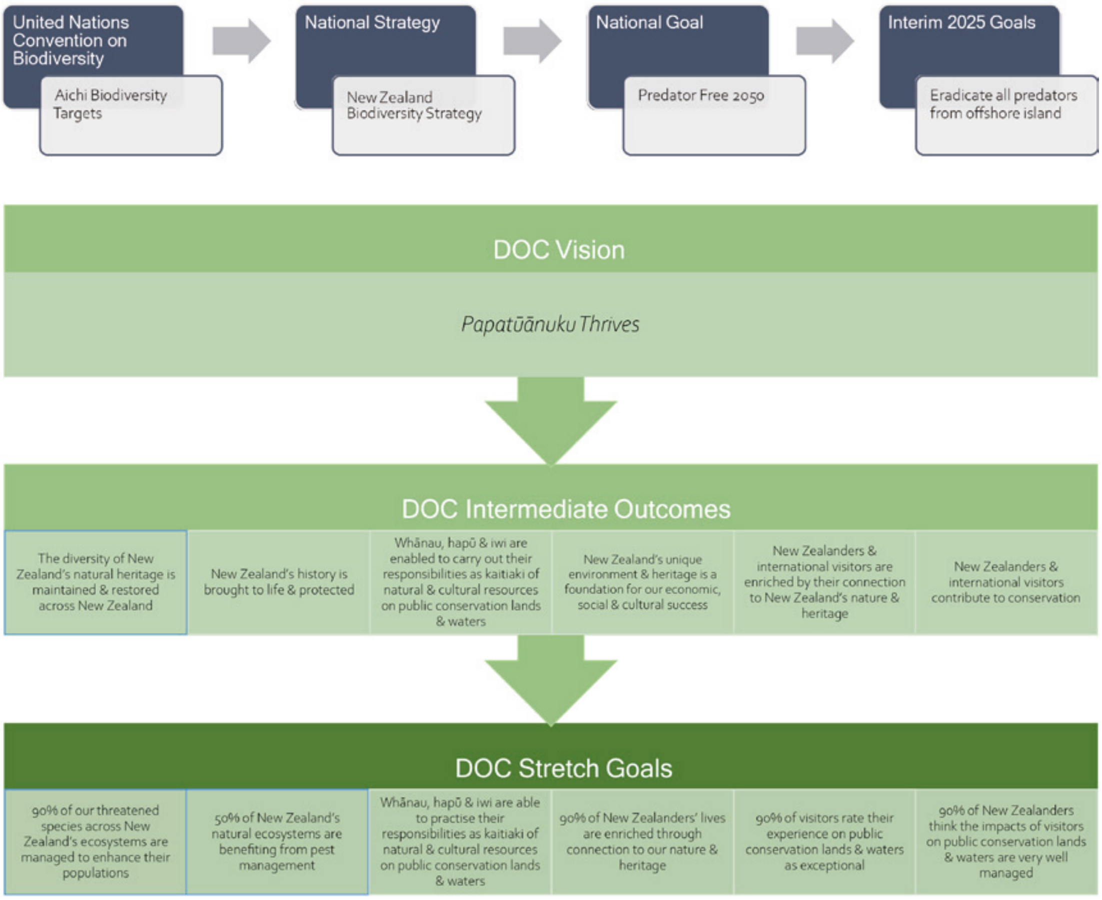

Figure 3. Relevant (blue boxes) New Zealand Government (grey) and Department of Conservation (green) strategy and goals that the Maukahuka project outcomes will enable.

2.2 Objectives and outcomes

The key objectives of Maukahuka are to eradicate pigs, mice and cats respectively, from Auckland Island (Figure 4). Auxiliary objectives include development of capability, role modelling a true relationship with iwi, hapū and whānau, successful collaboration with partners and sharing knowledge (Figure 4). Eradicating remaining mammalian pests from Auckland Island is a necessary step to even more ambitious PF2050 goals.

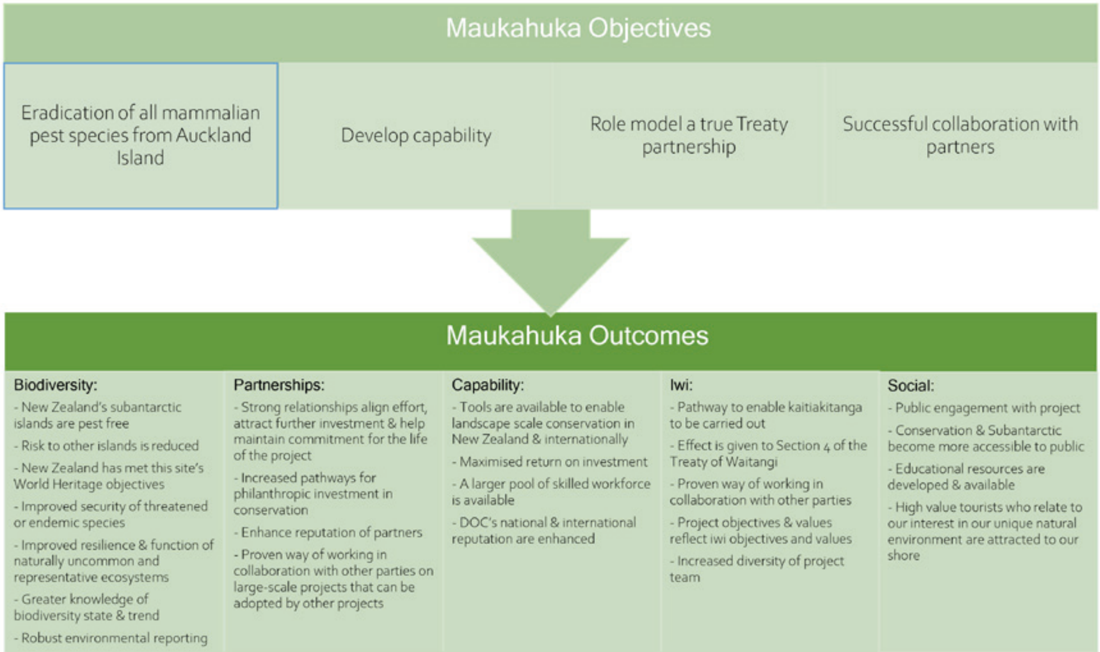

Figure 4. Objectives and outcomes of Maukahuka – Pest Free Auckland Island project. Key objective highlighted in blue.

Plate 3. Auckland Island has a distinctive character. The ravaged remains of a land mass formed from volcanic activity 25–10 million years ago has been shaped by an extended period of glaciation and prevailing westerly seas. Formidable cliffs rising over 400 m high run the length of the long western coast (A) and give way to deeply incised cirques and fiords on the eastern side (B). The dense peat soil layer averages 2 m deep, though it can be up to 8 m. Vegetation forms distinct bands, from eastern coastal swaths of the southern-most forest in the New Zealand region to (with increasing altitude) dense scrub, tumbling tussock-fields and stunted fellfield meadows of megaherbs. *Photo credits: Finlay Cox/DOC (A) and Stephen Horn/DOC (B).*

3. The site

3.1 Location

The remote Auckland Islands (50.69°S, 166.08°E) are located 465 km south of Bluff in the Southern Ocean (Figure 1). They are part of the New Zealand subantarctic islands, five island groups totalling 76 458 ha: Snares Islands/Tini Heke, Bounty Islands, Antipodes Islands, Auckland Islands and Campbell Island/Motu Ihupuku (Figure 1). Their associated marine reserves extend 12 nautical miles from the land and collectively cover approximately 1 400 000 ha. All the island groups lie within 47° and 53° south between the Antarctic and Subtropical convergences, where the marine environment is highly productive. The islands have rich biodiversity, high wildlife population densities and levels of endemism because of their geographical isolation from mainland New Zealand, and from each other.

Auckland Island (45 889 ha) is the largest island in the Auckland Islands archipelago (56 186 ha), which comprises seven large islands (>10 ha) and many additional smaller islands, islets and rock stacks, totalling 217 sites above mean high water spring (MHWS Table 2; Figure 5).

Table 2. Islands of the Auckland Islands archipelago and current mammalian pest status.

NAME	SIZE (ha)	MINIMUM DISTANCE TO AUCKLAND ISLAND (m)	MAMMALIAN PESTS
Auckland Island	45 889	N/A	Pigs, mice and cats
Adams Island	9693	548	None
Enderby Island	695	2340	None
Disappointment Island	284	5730	None
Rose Island	79.8	480	None
Ewing Island	58.2	1150	None
Ocean Island	11.9	268	None
Masked Island	5.7	118	Cats and mice
Figure of Eight Island	5.3	576	Unknown
16 other islands (10 named)	1 – 5	7 – 5400	Unknown
90 other islands and stacks (14 named)	0.1 – 1	7 – 5600	Unknown
102 other stacks (3 named)	<0.1	6 – 5500	Unknown
In total there are 217 sites in the archipelago with a combined area of 56 816 ha			

Figure 5. Map of Auckland Islands, key sites and pest status of islands.

3.2 Physical landscape

The Auckland Islands have a distinctive and rugged character. They are remnant land masses formed from volcanic activity 25–10 million years ago and shaped by an extended period of glaciation and prevailing westerly seas. The islands comprise mainly volcanic lava and scoria blanketed in a peat layer averaging 2 m deep on lowland hillsides and more in lowland flat areas[9].

Auckland Island is 43 km long and 27 km wide at its extremes and has a coastal perimeter of approximately 374 km at MHWS (Figure 5). The terrain is typically mountainous with peaks up to 650 m in altitude. The western side is an almost unbroken reach of formidable cliffs up to 400 m high. The eastern side is much more sheltered, comprising a series of deeply incised cirques and fiords formed by glaciation. Two large harbours (Port Ross in the north and Carnley Harbour in the south) and some of the ten narrow inlets on the eastern side usually offer sheltered anchorage. There are hundreds of permanent small streams and a few small inland lakes.

3.3 Weather

The climate of the Auckland Islands is the result of interaction between a persistent low-pressure zone at 55–65°S and a broad subtropical high-pressure zone around 10–35°S. The islands therefore receive a constant bombardment of weather fronts moving from west to east across the Southern Ocean. The daily weather is characterised by long periods of wind and frequent rainfalls. It is typically cold and cloudy but there are times when the island's hills become free of cloud, winds ease and visibility is good. The seasonal and daily variations in temperature are small due to the consistent strong westerly flow and maritime environment. Hail can fall in any month and snow will fall on the tops in winter, more frequently at the southern end of the island.

3.4 Biodiversity

The geographical isolation of the Auckland Islands and their situation in the highly productive Southern Ocean have shaped a remarkable and unique biodiversity (Table 3), including distinctive plants, birds, invertebrates, marine mammals, fish and marine algae assemblages. Extraordinary examples of adaption and numerous rare and/or endemic biota are present in the island group, which is the most biologically diverse of all the islands in the NZSIA. Strong links between the marine and terrestrial environments are facilitated by seabird and marine mammal fauna. The high nutrient input they provide drives ecosystem processes and supports a high level of species richness. The islands are a stronghold for taonga, including several species of toroa (albatrosses, family Diomedeidae), tītī (petrels, family Procellariidae), hoiho (yellow-eyed penguin, *Megadyptes antipodes*), whakahao/rāpoka (sealion, *Phocarctos hookeri*) and many more. Adams and Disappointment islands are globally significant wildlife refugia and are recognised as containing some of the least modified ecosystems in the world.

New Zealand is considered the world capital of seabird diversity. Ninety-six seabird taxa breed in New Zealand, half on which are endemic (breed nowhere else). Seabirds dominate the Auckland Islands (Table 3), a globally significant site for many species, as acknowledged by the islands' designation as an Important Bird Area by Birdlife International. Of the 38 indigenous bird taxa on Auckland Island, 25 are seabirds, including three endemic species. The entire global population of Gibson's albatross/toroa (*Diomedea antipodensis gibsoni*) breed on Adams and Disappointment islands, while 99% of the global population of white-capped albatross/toroa (*Thalassarche cauta steadi*) breed on Auckland, Adams and Disappointment Islands[10].

There are 13 native terrestrial bird species on the Auckland Islands, six of which are endemic, the highest count for any of the NZSIA islands[10]. The global population of the enigmatic Auckland Island rail (*Lewinia muelleri*) resides on Adams and Disappointment Islands. Adams and Enderby Islands are home to kārearea (New Zealand falcon, *Falco novaeseelandiae*), Oceania's southern-most raptor population[10]. Hunting by humans and predation by pigs and cats contributed to the extinction of at least one species – the Auckland Island merganser (*Mergus australis*) – last recorded in the early 20th century[1, 10]. The invertebrate life is relatively well reported, with more than 280 identified species, of which at least 90 are endemic (Table 3). Larger-bodied and flightless invertebrates are well represented on the island group. No reptile or amphibian fauna are present. Freshwater fauna comprises 10 known invertebrates and one fish species (kōaro; *Galaxias brevipinnis*). Two species of seal, New Zealand fur seal (kekeno; *Arctocephalus forsteri*) and the New Zealand sealion (rāpoka/whakahao) breed in moderate and large numbers respectively around the coast of the islands. The largest global population of the formerly endangered southern right whale (tohorā; *Eubalaena australis*) breeds in the waters surrounding the Auckland Islands.

Table 3. Composition of known terrestrial lifeforms of the Auckland Island group.

LIFE FORM	NUMBER OF KNOWN NATIVE SPECIES	LEVEL OF ENDEMISM (% of known species)
Vascular plants	196	3
Invertebrates	280	30
Land birds	13	32
Seabirds	25	12

The flora of the Auckland Islands is strikingly varied, from the coastal swaths of the southern-most forest in New Zealand to dense scrub, tumbling tussock-fields and topped by stunted fellfield and meadows of megaherbs. There are at least five endemic vascular plants. In recognition of the richness, special forms and unique associations of the plant life, the International Union for Conservation of Nature (IUCN) has designated the NZSIA a World Centre of Floristic Diversity. The macroalgae and intertidal communities are notably dominated by brown and red algae, though remain understudied.

Vegetation cover is predominantly native with some notable exotic species cover including *Olearia lyallii* (olearia), *Sagina procumbens*, *Stellaria media* and fine grasses in sheltered passages between tussock pedestals[11]. Olearia is a New Zealand native thought to have been introduced from mainland New Zealand. It prospers in canopy gaps in rātā (*Metrosideros umbellata*) forest and can outcompete megaherbs to dominate low-stature coastal communities[11].

3.5 Land use tenure

The NZSIA is a World Heritage site, representing some of the world's most extraordinary natural heritage. The World Heritage status of the islands was conveyed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1998 under two criteria:

> Criterion (ix): "...outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals..."
>
> Criterion (x): "Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation".

Managed by DOC, the comprehensive legal, administrative and management systems in place ensure that the islands of the NZSIA have the highest level of protection under New Zealand legislation. All the island groups in the NZSIA, including their foreshores, are Nature Reserves under the Reserves Act 1977. Adams Island was protected as a Nature Reserve in 1910, followed by the remaining Auckland Islands in 1934. In addition, each has been identified as a National Reserve, which acknowledges "values of national or international significance" (Section 13, Reserves Act 1977). The Auckland Islands group is surrounded by an overlapping no-take Marine Reserve (established 2003) and Marine Mammal Sanctuary (established 1993) out to 12 nautical miles, complementing the protection afforded to the islands themselves.

3.6 Visitation

There are no permanent inhabitants anywhere in the NZSIA and access is by permit only, administered by DOC. Five companies currently hold concessions for guiding tourists in the NZSIA. Visitation has averaged 824 tourists annually over the last 10 years. Concessionaires can land visitors on Enderby Island and at 10 sites on Auckland Island[12]. Guidelines are provided in the Conservation Management Strategy (CMS) for Southland Murihiku[12] that limit the maximum number of visitors per day for most of the sites to 50 people. Two hundred visitors per day can land on Enderby Island and the former European settlement at Hardwicke and Terror Cove on Auckland Island. Tourist vessels currently depart from, or may land at, several places before landing at the Auckland Islands. These departure/landing sites include Campbell Island/Motu Ihupuku, Macquarie Island (administered by Australia), the New Zealand mainland, Chatham Islands, Ushuaia (Argentina) and Hobart (Australia). Other reasons for landing on the island are restricted to authorised research, maintenance purposes and Ngāi Tahu kaitiaki responsibilities or cultural activities.

3.7 Human history

The Auckland Islands have a history which dates to the great Polynesian voyages of the eastern and southern Pacific during the 13th to late 14th centuries AD. On Enderby Island there is evidence of Polynesian occupation in Sandy Bay occurring sometime in the late 13th to late 14th centuries AD[13] and today this evidence can be seen as exposed ovens. The Pākehā history begins on 18 August 1806 when the islands were first encountered by Europeans. Since this time Pākehā have occupied and used the island for a number of reasons including sealing and whaling, planned settlement, farming, scientific and astronomical surveys, military outposts, establishing castaway depots (with the islands also being the location of a number of historically significant shipwrecks)[13]. Māori also occupied the islands early in their written history with Ngāti Mutanga and their Morori slaves arriving in 1842 and finally leaving in 1856.

3.8 Existing infrastructure

There are eight small field huts in the archipelago (Table 4). Only the field huts on Auckland Island are proposed for use during eradication operations because of the geographical isolation, biosecurity risk, and the potential for frequent wildlife disturbance on pest-free islands[12] (Table 4). There are several remnant historical structures on Auckland Island but none, other than the Coastwatcher's hut at Ranui Cove, could be made fit for use.

There are several short access routes to visitor sites on Auckland Island[12] (Figure 5). There is a route from Dea's Head hut to the Hooker Hills, a circuit on the southern side of Laurie Harbour, and some routes from the field camp at Smith Harbour (see Figure 21, p. 83). Historically, several tracks were cut and sites cleared and levelled for the establishment of settlements as well as for other purposes, including sealing, extraction of tonnes of rātā wood (Erlangen Clearing) by a German steam ship at the start of World War II, several occupations by castaways, mineral surveys, scientific research and multiple attempts to locate the wreck of the General Grant and retrieve the gold supposedly within.

Table 4. Existing infrastructure on the Auckland Islands.

SITE	EXISTING INFRASTRUCTURE	PROPOSED USE
Auckland Island	• 1 × 6-person field hut at Dea's Head • 1 × storage shelter at Dea's Head • 1 × 5-person field hut at Smith Harbour • 1 × 2-person field hut at Smith Harbour • 1 × storage shelter at Smith Harbour	Support field team with minor modifications Support field teams, supplement main base facility at this site
	• 1 × historic Coastwatcher's hut at Ranui Cove	Mess (kitchen/dining) for a temporary field camp with moderate modification
	• Several dilapidated historic structures (boat sheds, shelters, etc.)	No functional value
	• 3 × basic grassland helipads (Smith Harbour and Dea's Head)	Support helicopter use and medivac capability
	• 1 × storage shelter camp + camp sites Camp Cove	Temporary field camp to support field teams
Adams Island	• 1 × 6-person hut at Maclaren Bay • 1 × 2-person bivvy at high altitude	Not proposed for use
Enderby Island	• 1 × field hut + 10-person accommodation block + lab. • 1 × basic helipad and a small fuel store • Several additional storage sheds	Infrastructure on Enderby Island not proposed for use, except the helipad and fuel depot (maintained by helicopter operators) for emergency purposes
Dundas Island	• 1 × 2-person fibreglass bivvy 'apple hut'	Not proposed for use

3.9 Target species

3.9.1 Feral pig (*Sus scrofa*)

Arrival

Pigs were first introduced to Auckland Island at Port Ross in 1807 and further liberations occurred in the 19th century[1]. They were well established in the north of the island by 1840 and throughout the island by 1886[1].

Population density

There is limited knowledge of population size and habitat ecology. Data suggests that the population is at a low density. Extrapolating data from the summer 2018/19 trials on Falla Peninsula gives a population estimate of 917 pigs (0.02 pigs/ha[14]). However, it is likely that population densities are uneven across the island. Observations during winter 2007[15] and summer 2018/19 suggest that density is higher in the north[14]. Pig populations can respond quickly to changes in habitat quality/resource availability and to variation in weather. It is likely that the pig population on Auckland Island fluctuates in size and distribution[16].

Distribution

Pigs have been recorded (through observations and pigs fitted with global position system (GPS) collars) across the whole of Auckland Island, except in inaccessible sections of the western cliffs[17]. There are no observed distribution patterns by sex or age, or seasonal movements[17]. Individual variation in habitat preference is likely. Distribution may also change with habitat quality, population size and resource abundance.

Home Range

GPS collaring of pigs in 2007 gave home range sizes of 137–3280 ha, with males having larger ranges than females. Home range size increased with percent cover of tussock[17]. This variability is consistent with pigs inhabiting other highly variable environments[17]. Home ranges are likely affected by food availability, seasonal factors and individual preferences. Importantly, sows can reduce their normal range by up to 94% when farrowing[18].

Diet

Chimera, Colman and Parkes (1995) found pigs on the Auckland Islands relied on a small number of food items, determined by availability. The stomach contents of pigs foraging in the open alpine tops had a high proportion of earthworms and the roots and rhizomes of remaining herbs and tussock (Figure 6). Pigs foraging in the coastal zone had a more varied diet. Scavenged dead fish, birds, sealions, whales, penguins and invertebrates are a significant part of their coastal diet, along with ferns, fungi and seaweeds.

Behaviour

Most pigs encountered on Auckland Island are solitary, although mobs of up to 18 have been seen (A. Cox 2018, pers. comm.). Summer trials during 2018/19 revealed that pigs were not as naïve to hunting as assumed[14, 18]. Pigs appear to use set routes when travelling within their home range. Harper (2007) noted pigs travelling 2–3 km while foraging along the coast. Interactions at bait stations demonstrated hierarchical behaviour, with adult males and their mates being dominant over associated females and their offspring. Apparent subdominant males were seen to be evicted from groups of females and/or bait dumps by the dominant male[15].

Figure 6. Pig (*Sus scrofa*) rooting has almost denuded Auckland Island of native megaherb species (A) as exemplified by comparison with similar habitat on pest-free Enderby Island (B). At the single remaining colony of the declining white-capped albatross (*Thalassarche cauta steadi*) species on Auckland Island a cat feeds on a freshly killed chick (C) and a pig (D) forages amongst nesting albatrosses. Pigs have been observed toppling albatross nests and preying on both adults and chicks at this site and breeding success in pig-accesible areas is zero. The impacts of cats on albatross breeding success remains unknown, though cats can access areas of the colony that pigs cannot. *Photos: R. Sagar (A), F. Cox/DOC (B), S. Bradley (C), P. Sagar (D).*

Lifecycle

Most feral pig populations breed all year round. Variation in the timing of breeding is likely to depend on location, habitat and resource availability[16]. High proportions of females were observed breeding between December and February 1972/73[9] and sows with litters or near farrowing in November and December 1989[18]. The portion of subadults is lower than in mainland populations, possibly because of lower survival due to climatic and dietary pressures.

3.9.2 Mouse (*Mus musculus*)

Arrival

Mice were first recorded on Auckland Island in 1840 but were likely to have arrived in the two decades prior[1]. Mice were first recorded on nearby Masked Island in 1907 and are presumed to persist there[1]. They were eradicated from Enderby Island and Rose Island in 1993 (Table 2)[1].

Population density

There are large seasonal and annual variations in mouse population densities that likely reflect patterns in food availability[1]. Forest and scrub habitat on Auckland Island supply a more stable food supply and mouse population densities are more stable in these habitats than in tussock, which is subject to boom-bust population dynamics associated with seed mast events[19]. Mouse population sampling has occurred in years prior to, during and post mast events, providing a range of population density estimates. The minimum of < 1 mouse/ha in forest was recorded during a non-mast summer[20], including mice. The highest density of 42 mice/ha was recorded in tussock in the winter following heavy tussock mast[19].

Distribution

Mice on Auckland Island have been detected at similar densities in all habitats across the latitudinal and altitudinal gradients[14]. Distribution is likely affected by seasonal fluctuations in food availability. Further south, on Macquarie Island, mice lived on the alpine tops, suggesting that mice on Auckland Island are probably not limited by climate.

Home range

Capture-mark-recapture sampling of mice on Auckland Island showed that home range size varied inversely with population density and food availability but not by age and sex[14]. Average home range sizes [mean (95% CI)] were higher in forest [0.51 (0.33–0.77) ha] and scrub [0.46 (0.29–0.74) ha] were higher than in tussock [0.18 (0.13–0.25) ha][22].

Diet

Mice feed on invertebrates, seeds, other plant material and are occasionally predators of native fish eggs and the eggs and chicks of small bird species[23]. At extreme latitudes, invertebrates are the most consistent and dominant component of mouse diets, though seeds and fruit are important seasonal sources of food[24]. Mice have also been known to extensively prey on seabirds on islands in isolated situations where they are the only invasive mammal present (Figure 7). This behaviour has had catastrophic consequences for juvenile recruitment of affected species[25].

Figure 7. Figure 6. Juvenile grey-headed albatross (*Thalassarche chrysostoma*) with fatal injuries from being preyed upon by mice (*Mus musculus*) on subantarctic Marion Island. *Photo: Ben Dilley.*

Behaviour

Mouse behaviour will be influenced by predation by cats on Auckland Island[1]. Mice are mostly nocturnal and generally feed at dusk and dawn, but will feed less intensively at other times[26]. Wild mice are generally non-territorial though strong territorial structure has been found in low-to-medium density populations[26]. Home ranges and social hierarchy are influenced by body size.

Lifecycle

Commensal mice in New Zealand reach sexual maturity at 8 weeks. Gestation is 19–21 days and average litter sizes range between 5 and 7 pups[26]. The lifecycle of mice on Auckland Island is unknown. Breeding is thought to almost, if not completely, cease on other subantarctic islands in winter[27]. In winter 2019, female mice were in good condition but not breeding following a significant mast event and male mice were beginning to show signs of coming into breeding condition (enlarged testes)[19].

3.9.3 Feral cat (*Felis catus*)

Arrival

Cats were first recorded on Auckland Island in 1840 at Terror Cove and were presumably introduced by sealers[1]. Cats and their impacts have been regularly observed on Auckland Island[1].

Population density

Extrapolating data from a camera grid run in the Dea's Head area during both summer and winter in 2019, the Auckland Island population is estimated to be 550–690 cats (1.1–1.5 cats/km^2). This is lower than the density inferred through trapping by Harper (2007) of 2.75 cats/km^2. Both studies give cat densities following tussock mast events and associated mouse population spikes[28]. It is likely that population density is dictated by resource availability.

Distribution

Cats are found on Auckland Island and nearby Masked Island and possibly on other islets in the archipelago (Table 2)[1]. Trapping and tracking of cats during winter 2007 and throughout trials in 2018/19 show that cats are using all habitats on Auckland Island, including steep terrain along the western cliffs[14, 15] that is inaccessible to people.

Home range

Female availability may primarily determine home ranges of male cats, whereas female distribution is determined by food resources[29]. GPS tracking of cats on Auckland Island revealed mean ±SEM (range) home range estimates for males of 1772 ±515 (176–6860) ha and females of 354 ±101 (116–654) ha[30]. Home ranges overlap between and within sexes. Home range sizes to date are large and comparable with cats on Rakiura/Stewart Island[31].

Ranging behaviour in mainland New Zealand is strongly influenced by changes in prey abundance[31]. Preliminary evidence from Auckland Island shows that some individuals appear to be cued into seasonal prey sources and will abruptly move away from their core home range to presumably access these prey types[14].

Diet

Three dietary studies of cats have been undertaken on Auckland Island. Their diet mainly comprises small passerines, small seabirds and mice[32]. They also eat larger passerines, other seabirds (e.g. shags) and opportunistically forage on marine-derived food (e.g. squat lobsters *Munida gregaria*), squid, shellfish and seaweed. A cat was observed eating a deceased white-capped albatross fledgling at the South-West Cape colony during August 2019; it is unknown whether this bird was scavenged or preyed upon by the cat[19] (Figure 6). Cats on Auckland Island would likely eat the many extirpated seabird species now only breeding on pest-free islands in the archipelago, but diet studies are unlikely to show this. Observations suggest mice form a larger proportion of cat diet in winter following mast events when mice are abundant, than in non-mast years[32].

Behaviour

Daily patterns of feral cat activity vary widely with site and prey type[15, 33]. The majority (80%) of cat detections during the camera trial in summer 2018/19 occurred at night or during twilight hours[14]. Preliminary observations from tracking data collected since summer 2018/19 suggest that cat activity doesn't differ strongly between seasons or sexes[19, 30].

Lifecycle

Feral cats have litters of up to five kittens and can breed several times a year when resources are not limiting[34]. Spatial analysis of tracked breeding females may provide insight into timing, duration and frequency of kitten rearing on Auckland Island. Juvenile mortality is a significant restraint on population growth when prey is limited. Only one cat of the twenty caught during summer 2018/19 was a juvenile[14]. In winter 2019, two out of nine cats caught were juvenile[19]. The eruption of mice following the tussock mast is thought to be driving higher juvenile cat survival.

Plate 4. The Auckland Islands' human history dates to the great Polynesian voyages of the eastern and southern Pacific during the 13th to late 14th centuries AD. Pākehā history begins in the early 19th century. Since this time Pākehā and Māori have occupied and used the main (Auckland) island for a number of reasons including sealing and whaling, planned settlement, farming, scientific and astronomical surveys, military outposts, establishing castaway depots with fingerpost signs, with the islands also being the location of a number of historically significant shipwrecks. *Photo credits: Canterbury Museum (no known copyright) (A) and Rachael Sagar, DOC (B)*.

4. Why do it?

4.1 Mandate

DOC is the lead central government agency responsible for the conservation of New Zealand's natural and historic heritage and for administering the Auckland Islands Nature Reserve (the highest level of protection under New Zealand legislation). The statutory provisions of the Conservation Act 1987 and the Reserves Act 1977 give the Minister of Conservation (MOC) and DOC the mandate to manage the Auckland Islands for the purposes set out in Section 6 of the Conservation Act 1987 and Section 20 of the Reserves Act 1977.

One of DOC's primary functions is to preserve and protect plants, animals and ecosystems. Section 20 of the Reserves Act 1977 requires the indigenous flora and fauna, ecological associations, and natural environment shall as far as possible be preserved and the exotic flora and fauna as far as possible be exterminated. Eradication of pigs, mice and cats will immediately halt the depletion of native wildlife and enhance and protect the internationally significant conservation values of the site, consistent with its status as a Nature Reserve, World Heritage area (UNESCO), Important Bird Area (Birdlife International) and World Centre of Floristic Diversity (IUCN).

The Auckland Island group is a priority ecosystem for DOC, ranked number 50 out of 850 ecosystems ranked to date (DOC Business Planning data 2015–2019; DOC-5421433 and DOC-5629301). This project contributes directly to DOC's key intermediate outcome for natural heritage and two stretch goals (Figure 3). Eradicating pigs, mice and cats from Auckland Island completes the vision of a pest free NZSIA and is aligned with the PF2050 initiative, supporting the New Zealand Biodiversity Strategy (Figure 3). These objectives are reflected in the Southland/Murihiku Conservation Management Strategy (CMS) 2016[12]. The vision under section 2.10 of the CMS states: *The islands within this place support thriving indigenous ecosystems that are free of pest mammals and wild animals and are havens for an abundance of endemic species*[12].

Under Section 4 of the Conservation Act 1987 the Department of Conservation Te Papa Atawhai is required to give effect to the principles of the Treaty of Waitangi. Ngāi Tahu ki Murihiku are tāngata whenua and kaitiaki of the Murihiku region, including the subantarctic islands. They have prepared a management plan: Te Tangi a Tauira – the Cry of the People (Ngāi Tahu ki Murihiku 2008), which consolidates Ngāi Tahu ki Murihiku values, knowledge and perspectives on natural resource and environmental management issues. Section 3.7.3 of the document states: *These islands represent the most untouched and unexploited areas of New Zealand. Ngāi Tahu ki Murihiku support the protection and enhancement of all Offshore Islands to ensure ecosystems remain intact and where appropriate eradication of pests and reintroduction of indigenous species are advocated...* . Section 3.7.3 Nga Take – Issues and Kaupapa – Policies advocate for participation and *capacity building with respect to local rūnanga papatipu involvement with eradication and research programmes* administered by DOC.

4.2 Impacts of pests

Introduced pigs, mice and cats have inflicted severe damage on Auckland Island over the past 200 years[1]. The impact over this short timeframe compares with the millions of years of isolated evolution which has shaped the Auckland Islands' unique native wildlife. It is difficult to accurately quantify the impact of pigs, mice and cats on Auckland Island, as the majority of the devastation occurred before ecological observations began[1]. The islands within the Auckland Island group that have remained free of pests provide an invaluable reference for comparison. The impacts of pests on native species assemblages on Auckland Island may be inferred by contrasting analogous habitat on adjacent pest-free Adams, Disappointment and Enderby islands[1]. The presence of these pests continues to erode the ecological and cultural values of the island and exposes other globally significant pest-free islands to increased biosecurity risks. Arrival of pigs, mice or cats on Adams or Disappointment islands would have catastrophic consequences for native and endemic species.

4.2.1 Biodiversity

- Predation pressures, habitat loss, disturbance and competition from all three mammalian pest species have lowered the abundance and diversity of native bird species found on Auckland Island. Only 13 of 38 native species are known to breed on the island in the current state. The presence of pests has increased the wariness of the few remaining terrestrial bird species, which show a reluctance to forage on the ground[1]. Insectivorous birds are further limited by increased competition for prey with mice, as indicated by a near absence of macroinvertebrate fauna and the altered invertebrate community structure.
- Pig rooting and mouse predation of seeds and seedlings has resulted in grossly lowered vegetation biomass, altered community structure and succession regimes. The striking and unique megaherb group has suffered strong impacts and has been suppressed to near zero density, except on inaccessible, rocky cliffs (Figure A4.1, p. 112)[1]. It is likely that mice further suppress megaherb recruitment by consuming their highly palatable seeds and seedlings.
- Invertebrate abundance and diversity have been drastically reduced by predation from all three pest species, and the loss of invertebrates further impacts ecosystem health through the loss of their pollination and nutrient cycling services.
- The loss of millions of burrowing seabirds, the key ecosystem engineers in this environment through their importation of marine-derived nutrients and soil-turnover, has reduced primary productivity, disrupted nutrient cycling and ecosystem functionality[1]. Through continued predation, this is a self-perpetuating cycle and has resulted in a dramatic loss of biodiversity. There are numerous records of cats and pigs efficiently extirpating colonies of seabirds over the course of a century, indicating that populations of seabirds on Auckland Island must have once been very large[1].
- Diminished populations of native and endemic species have very likely resulted in a loss of genetic diversity, which supports the resilience of a population to change[36]. Many species native to the Auckland Islands are impacted by threats in and away from their terrestrial habitat, including climate change, interactions with fisheries, disease and pollution. Additive impacts on their populations at their breeding sites through the presence of pests further reduces the resilience of these threatened populations[37].

4.2.2 Cultural heritage

- Degradation of archaeological sites caused by pig rooting and altered vegetation structure is a great loss because of the cultural heritage value and the enormous potential to reveal information about the past for which little written history exists. Many of the sites are particularly significant in a national context because of the relatively undisturbed nature of the islands and the historical themes represented, such as early Polynesian settlement and the sealing and castaway eras[13].
- The loss of biodiversity and the inability of the island to support species that evolved there, including taonga species, has weakened the mauri (energy, power, life force) and mana (prestige) of the place.

4.3 Maintaining the status quo

If the status quo is maintained, then the ecological value of the site will continue to degrade. The risk of a pest incursion to Adams Island remains significant. There is recent evidence of cats swimming over 120 m from the main Auckland Island to Masked Island to prey on burrowing seabirds[19]. There is increasing evidence to suggest that mice can swim distances of over 500 m in cold waters[23]. The shortest direct distance between Adams and Auckland islands (548 m) is swimmable by pigs but often affected by strong tidal currents. Additionally, some small islets in Victoria Passage are less than 200 m apart, providing stepping stones to Adams Island (Figure 5). Floating debris could act as rafts, providing incursion pathways for smaller pests[23]. An event such as occurred in Perseverance Harbour, Campbell Island/Motu Ihupuku, where flooding caused the harbour to fill with tussocks shows how precarious the situation is (G. Taylor 2019, pers. comm.). The biodiversity impacts of any pest species establishing on Adams or Disappointment islands would be hugely significant and negative – the islands are the strongholds for numerous endemic species and are recognised as some of the largest unmodified ecosystems in the world.

Mice can have extensive detrimental impacts on islands (Marion Island, Gough Island, Antipodes Island, Midway Atoll), including the local extinction of some invertebrates and severe suppression of land birds (snipe, pipits)[23–25]. Worryingly, there are several examples where mice are the sole introduced predator on an island and have learnt to prey on seabirds, with the behaviour rapidly spreading through the mouse populations (Figure 6)[25, 38–40]. An example of this is on subantarctic Gough Island, where it is estimated that 2 million seabirds per year are lost to predation by mice, resulting in zero recruitment for some species (e.g. Tristan's albatross)[38]. This is of particular concern for the pest-free islands of the Auckland Islands, which are a stronghold for Gibson's albatross/toroa (100% global population), white-capped albatross/toroa (99% global population), light-mantled sooty albatross/koputu (*Phoebetria palpebrata*; > 25% global population), lesser fulmar prion (*Pachyptila crassirostris flemingi*; 100% global population) and Auckland Island shag (*Leucocarbo colensoi*; 100% global population).

In addition to the obvious impacts on biodiversity, an incursion on Adams, Enderby or any other pest-free island in the NZSIA would adversely impact economic, political, reputational, environmental and compliance factors. The cost of the required rapid response to an incursion on Adams Island would likely be tens of millions of dollars, if it could be enacted. Reputational impact would be international and likely detract from the PF2050 initiative. DOC would have failed its obligations under UNESCO and Nature Reserve legislation. Status quo would deprive the PF2050 initiative of an opportunity to create momentum, build capability and leverage large-scale conservation investment.

The ongoing presence of predators on Auckland Island limits the gains from the Crown's investment in seabird bycatch reduction, through negative impacts on the breeding success of already threatened species[1]. Accidental bycatch is highest in the subantarctic region[41] and Gibson's albatross/toroa, white-capped albatross and white-chinned petrel (*Procellaria aequinoctialis*) in particular have been significantly impacted through bycatch[42]. The presence of pests on Auckland Island reduces the safe breeding habitat for these vulnerable species by 420%. The removal of pests from breeding sites has been shown to have the largest positive impact for threatened seabird population trends, followed by bycatch reduction[37, 43].

4.4 Benefits

Despite covering only 5% of the world's surface, islands are home to 20% of the world's bird, plant and reptile species, and 40% of all critically endangered animals. Island-dwelling species are disproportionately vulnerable to being wiped out; 80% of extinctions happen on islands. Of the animals that have become extinct since the 16th Century, 54% of the amphibians and mammals, 81% of the reptiles and 95% of the birds lived on islands[44].

In an ever-changing world where species face threats posed by competition with humans for food and habitat, by climate change, by pollution and by accidental or over-harvest, pest-free islands offer refuge and a source of resiliency to those that depend on them. In terms of conservation gain per dollar spent, islands are worth their weight in gold. Eradicating pigs, mice and cats from Auckland Island will achieve ongoing nationally and globally significant benefits, including gains in conservation, large-scale DOC – Ngāi Tahu collaboration, capability development, leverage for landscape-scale conservation, increased public wellbeing, economic stimulus and fulfilment of statutory obligations. The proposed pest eradication requires a large upfront investment for permanent and internationally significant biodiversity benefits with low to zero ongoing costs to sustain.

Disbenefits, such as by-kill of native species and disturbance to vegetation from the infrastructure programme are expected to be minor and the latter expected to rapidly reverse over 5–20 years (as demonstrated on Enderby Island). A complex benefits inventory captures the detailed measurable benefits that Maukahuka Pest Free Auckland Island will achieve (DOC-6035780).

4.4.1 Biodiversity

Successful eradication will remove the predatory threat of mammalian pests and enable recovery of native species. This will help protect over 100 endemic species from extinction. It will expand the pest-free area available for native species to safely occupy by 420% (45 889 ha) in the Auckland Island group and by more than 250% in the NZSIA (76 000 ha). The eradication of all three pest species will enable:

- Recovery of more than 500 native species: 280+ species of native invertebrates (90+ endemic), 196+ species of native plants (6 endemic) and 38 native species of bird (9 endemic).
- Natural repopulation by 26 native bird species that currently only breed in significant numbers on pest-free offshore islands in the archipelago.
- Rapid recovery of invertebrate populations, providing food for returning forest and ground birds, nutrient cycling and pollination services for plants.
- Importation of marine-derived nutrients from returning seabirds and invertebrate activity, allowing recovery of nutrient cycling, increasing vegetation biomass and shelter for nesting birds.
- The expansion of native species populations in number and size, increasing ecosystem health and resilience to change (climate change, arrival of disease, etc.).

4.4.2 Reduce biosecurity risk

Large and globally significant unmodified, pest-free islands exist adjacent to Auckland Island. Adams Island is recognised as one of the largest pristine islands in the world, but it is within swimming distance of Auckland Island for mice, pigs and, potentially, cats (see section 4.3 – *Maintaining the status quo*). Eradication of pests could be viewed as a proactive insurance policy. It will reduce the risk of incursion and its catastrophic consequences: large-scale biodiversity loss, reputational damage and the associated rescue response.

4.4.3 Socio-economic

- Operated from a regional centre in Invercargill, Southland over a period of 10 years, this project will provide significant economic stimulus to both the region and nationally both via direct project investment and flow-on activity.
- Government funding is expected to leverage 1:1 investment from third parties (c. $40–50m) that will be spent nationally, providing opportunities for participation by New Zealand businesses. Investment in research and development has high return on investment, estimated as 3:1 in efficiencies saving for the project alone (c. $10m). This will also deliver improvements in efficacy and feasibility that are needed by other biodiversity projects, particularly PF2050 objectives.

- Maukahuka would enhance the visitor experience for up to 800 high-value tourists who visit the NZSIA each year and promote opportunities for support of other conservation objectives.
- Increased transport to and from Auckland Island during the project and installation of infrastructure will provide ongoing opportunities to support other conservation work. Examples include improved heritage preservation and research opportunities.

4.4.4 Development of capability

- The investment will increase operational skills and capability across DOC, Ngāi Tahu and associated industries. A big pool of skilled conservation workers and future leaders will emerge with experience in large-scale pest management and complex operations in a remote place.
- Improved and new, proven tools and techniques for landscape-scale pest management (e.g. cat toxin, detection dogs, aerial hunting with thermal camera, trail camera data processing). This contributes to the achievability of New Zealand's PF2050 goal and other ambitious pest eradications nationally (e.g. Stewart Island/Rakiura) and internationally (e.g. Niau (French Polynesia), Floreana (Galápagos Islands), Socorro (Mexico) and Alejandro Selkirk (Chile))[37].

4.4.5 Ngāi Tahu

For Ngāi Tahu, the project is another vital step in restoring the mana and mauri of the whenua (land) they are kaitiaki (guardians) of and hold stewardship over. The commitment and mana Ngāi Tahu have brought to this project have had significant influence on decision makers to date. The project will:

- Enable engagement in the project and increased access to the whenua, enabling Ngāi Tahu to exercise their customary rights of mahinga kai, mātauranga or traditional knowledge, tikanga and kawa.
- Enhance the mana of Ngāi Tahu and enhance DOC's relationship with Ngāi Tahu through participation and inclusion in the project governance, design and delivery and knowledge sharing to enable pest eradication at other sites (Rakiura, Tītī Islands) and future iwi-lead projects.
- Provide opportunities for Ngāi Tahu employment in a range of project and support roles as well as research opportunities.
- Enable role modelling of a true relationship and collaboration with Ngāi Tahu and partners (DOC-6262719).

4.4.6 Partner collaboration

- Working with partners at this scale will provide important momentum for the PF2050 initiative.
- It will help leverage other large national and international conservation gains (inspire and inform further pest control projects); for example, the concept of a global Subantarctic Alliance[45].
- Partner networks will extend outreach to promote the work and improve engagement with the NZSIA World Heritage site, the conservation story of the region and the skills of the Department.

4.5 All or nothing: multi-species eradication reasoning

This project is three successive eradication operations delivered in sequence to complement each other in operational efficiency, risk management and benefit realisation. The outcomes are more than the sum of their parts and cost less than if done separately and are more likely to succeed. To maximise benefits and reduce risk, we strongly recommend eradicating all three mammalian pest species in one project. Importantly, a three-species approach also extracts the most value from the large investment in infrastructure and establishing logistics and a project team. Eradication of pigs alone, or pigs and mice are the only other scenarios that could be achieved, but neither scenario is advised.

Removing only pigs or pigs and mice would drastically reduce the benefits due to the species-specific and site-specific predator release dynamics and differing vulnerability of native species and habitats to these effects. For example, following the eradication of feral cats from subantarctic Marion Island, the anticipated recovery of native species has been significantly impaired by mice. In the absence of competition and suppression by other mammals, mice have attained higher population densities, limiting vegetation, invertebrate and bird recovery, and risks to species and ecosystems remain high[39, 40, 46]. It is generally accepted that cats died out naturally on Campbell Island/Motu Ihupuku following the removal of sheep, likely as a result of regeneration of vegetation and marginal habitat availability[4]. Natural attrition of cat populations on Auckland Island following the eradication of pigs and mice would be very unlikely to occur. Large swaths of coastal forest provide ample shelter and higher terrestrial bird species populations provide more stable food sources than on Campbell Island/Motu Ihupuku. The continued presence of cats on Auckland Island would limit the recovery of the island; in particular, preventing the return of key endemic terrestrial birds and burrowing seabirds, which are integral to ecosystem recovery through nutrient importation (see section 4.2.1 – *Biodiversity*).

There is a risk to feasibility if there are unplanned pauses between pest programmes. The large job of establishing a specialist project team, an island supply chain and ensuring continuity of knowledge and capability will be at high risk of being lost if one species only was targeted or there was a pause of years between successive operations targeting different species. Several years would be needed to rebuild capability. Maintenance of infrastructure is also demanding and expensive in remote locations and efficiencies are gained by continuous use for the successive target species. The cat and mice and programmes should be initiated within 3 years of eradicating pigs, as vegetation recovery will constrain travel for personnel ground-hunting cats, particularly in forest and short tussock habitats (c. 30% of the island; Figure A4.1, p. 112) and make observing the signs of target species difficult in these places[6].

Key risk:

- *Not including all three eradications in the scope of a single project drastically reduces biodiversity benefits and risks disbenefits to native species; additionally, it will cost more, take longer due to the effort and investment required to build and retain the required capacity and capability and the inability to benefit from efficiencies and interdependencies.*

Plate 5. On Auckland Island, a dense, woody scrub band extends from near the coast to approximately 300 m above sea level and significantly impedes travel. Tracks will be required for personnel to safely and efficiently carry out work during an eradication project. The width/grade of a track will vary depending on purpose and location. Tracks were cut to facilitate field trials on Auckland Island during 2018–19, and to understand the effort involved to cut tracks in this environment. *Photos: Stephen Bradley*.

5. Can it be done?

In this section we assess the Maukahuka Pest Free Auckland Island Project objectives against current evidence and proposed methods.

The eradication of each of pigs, mice and cats from Auckland Island have each been assessed against the five principals of eradication and found to be feasible. The step-change in capability required to eradicate all three species from Auckland Island is significant, but not unprecedented (Figure 8). Each island eradication success has refined the approach and allowed development of tools and technology that support efficiency and confidence in eradication success.

More than 1200 invasive mammal eradications have been attempted on islands around the world, with an average success rate of 85%[37]. In recent years, the success rate of eradications has increased and larger, more remote and technically challenging islands are being cleared of pests[37]. There are precedents for the successful eradication of pigs, mice and cats from large (>10 000 ha) islands both globally and within the Subantarctic region (e.g. Santa Cruz, Marion Island, South Georgia, Antipodes Island; Table 5).

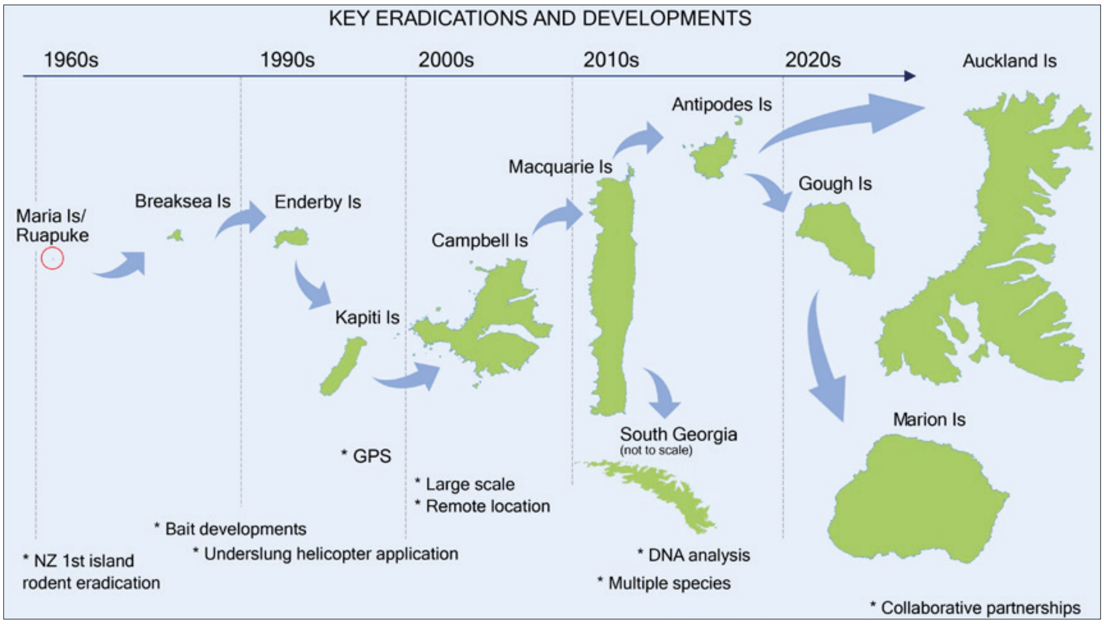

Figure 8. Islands that have been or are in the planning stages of eradicating mammalian pests and were considered a step-change in capability during planning for the Auckland Island project. *Indicates key technological and methodological developments that have improved eradication operations.

Table 5. Island eradications with global and regional relevance to Maukahuka. Data extracted from the Database of Island Invasive Species Eradications (DIISE 2018). TBC = to be confirmed (waiting for validation of results).

TARGET SPECIES	ISLANDS SUCCESSFULLY ERADICATED GLOBALLY (ATTEMPTS)	SUBANTARCTIC ISLANDS SUCCESSFULLY ERADICATED (ATTEMPTS)	LARGEST ISLAND SUCCESSFULLY ERADICATED*
Pig *Sus scrofa*	52 (69)	4 (4)	57 515 ha Santiago Island
Mouse *Mus musculus*	104 (148)	4 (10 incl. 2 TBC)	12 900 ha Macquarie Island
Cat *Felis catus*	58 (104)	4 (8)	29 541 ha Marion Island

*Whole island eradication, as opposed to range-restricted species eradications on larger islands.

5.1 Technical approach

Eradication projects have a binary outcome: succeed or fail. Success demands the permanent removal of every individual of a target species; failure eliminates almost all benefits and can risk disbenefits. Usually, money and resources are fully committed before failure is apparent. To minimise the risk of failure, eradication projects demand excellence throughout at all levels.

Eradications require that every individual pest be put at risk by an eradication tool. Accordingly, eradications must account for individual behaviours amongst the target species. It is difficult to detect animals in low densities, thereby confirming the removal of all targeted individuals. To increase the likelihood of success, and to ascertain when that has occurred, eradication projects should be designed to be strategic, systematic, intensive, skilled, disciplined, measured and analysed, and adaptive to the situational information.

Specifically, five principles of eradication have been identified that must be met in order to achieve eradication success:

1. All individuals can be put at risk by the eradication technique(s).
2. They can be dispatched at a rate exceeding their rate of increase at all densities.
3. The probability of the pest re-establishing is manageable to near zero (sustainability).
4. The project is socially acceptable to the community involved.
5. The benefits outweigh the costs.

The eradications of pigs, mice and cats on Auckland Island are discussed in this chapter, with assessment against the first and second principles of eradication (above) for each target species. The methods presented are based on evidence from previous eradications and trials on Auckland Island in summer 2018/19[14] and winter 2019[19]. An assessment against principles 3 (section 5.5.4 – *Outcome is sustainable*), 4 (section 5.5.1 – *Socially acceptable*) and 5 (sections 4 – *Why do it?* and 5.5.3 – *Environmentally acceptable*) are made elsewhere in the document. Key gaps in capability have been identified and required developments will be addressed through development of a Research and Development Plan and training plans for each eradication.

The eradication methods presented hereafter use current thinking and available tools and technologies. These methods are intended to inform the decision of feasibility and the detail provides useful reference for initial operational planning. For such an isolated site, every visit is important to advance operational planning. Actual methodology will likely change as we learn and adapt based on site-specific knowledge, allowing us to refine our thinking, and as new technologies become available. Where identified, next steps for quality project design have been stated for individual methods to guide operational planning.

5.1.1 Eradication strategy

Strategic eradication programmes involve application of a sequence of techniques that are often described as phases: knock down, mop up and validation. These phases are artificial constructs and, depending on the target species, they may overlap or follow sequentially at the completion of each phase. Depending on the target species, a phase may be achieved using successive deployment of tools that put all individuals at risk, or from the highly prescribed use of a single tool. For example, rodent eradications require precise planning prior to the operation commencing, and typically involve the one-off use of a single tool (aerial toxic bait spread) that exposes every individual over a short period (knock down phase), followed by a stand down period that allows any survivors to increase to detectable levels (validation phase). As rodents have small home ranges there is no efficient means of detecting and eliminating survivors, and therefore no mop up phase.

In contrast, the phases during other mammal eradication programmes often run as a continuum, using a suite of overlapping tools and techniques over a longer period to put all individuals at risk. Other mammal eradication programmes require flexibility to be able to adapt/develop as the idiosyncrasies of operating in each environment in different seasons are understood. As the eradication progresses, an understanding of change in spatial and temporal abundance of the target species and effort to detect survivors will inform when and what technique to deploy, as well as informing the probability of eradication once individuals of the target species are no longer being detected.

In both rodent and other mammal eradications, the inability to detect all target animals may mean either absence or that those still present were not detected. Animals can be hard to detect for two reasons:

1. The probability of detecting animals varies between individuals and techniques. No one technique will detect all individuals.
2. Compounding this, ineffective implementation can result in selection and/or learning within the population.

Care should be taken not to prematurely conclude that the eradication has been successful. Past eradications have shown that these challenges may be reduced by strategic delivery of techniques. Planning should follow these guidelines to increase the likelihood of success:

- Conservatively design the eradication methodology so that individual behaviours are accounted for, thereby increasing the likelihood that every individual is dispatched or detected,
- Design programmes using proven monitoring tools that provide confidence that zero detections indicate absence,
- Target the last individuals efficiently,
- Ensure data collection during eradication operations is of high-enough quality to reliably inform decision making,
- Carry out regular evidence-based reviews and updates of plans,
- Build team morale to ensure a strong eradication mind-set is maintained,
- Use communications to articulate purpose and progress to internal and external audiences.

The size of Auckland Island combined with the other constraints (remoteness, poor weather, areas of difficult terrain, lack of pre-existing infrastructure) mean innovative improvements of current tools and developing new capability for detection and dispatch will save money and time.

5.1.2 Eradication timing and sequence

Pigs must be eradicated first, as they would compromise any attempt to eradicate mice and cats by consuming baits, leading to gaps in coverage and failure to put every mouse and cat at risk. They would also likely interfere with traps targeting cats. Mice should be eradicated second, as baiting for mice will benefit the operation to eradicate cats via secondary poisoning and removing mice as a food source for cats. Figure 9 provides an overview of eradication timing for the Maukahuka Pest Free Auckland Island Project.

Pig operations should start in winter, when pigs on Auckland Island are more likely to be food limited and therefore interact with feeders[19]. The programme to remove mice should only start the summer after the pig programme is completed to allow time for shipping bait and setting up bait load sites in the winter between the pig and mouse operations, and avoid a clash in case the

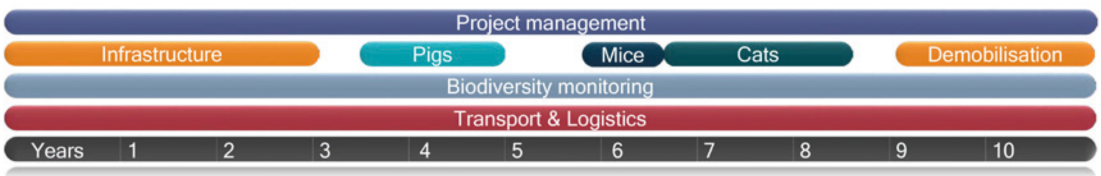

Figure 9. An overview of the timing and sequence of programmes to eradicate pigs, mice and cats from Auckland Island.

pig eradication takes longer than expected. The cat programme should begin 8 weeks after the initial mouse baiting operation to maximise the knockdown of cats through secondary poisoning and increase the likelihood of cats consuming toxic meat baits due to the removal of mice as a food source. The mouse and cat programmes should be initiated to keep the project running continuously but preferably within 3 years of pigs being eradicated.

The relative timing of operations targeting each species will be subject to seasonal considerations and final eradication methodology and is discussed in more detail below. The timing and duration of techniques is indicative only as it is based on estimates from previous operations and current understanding. Ultimately, knowledge of some of the variables (including animal behaviour and the idiosyncrasies of operating at Auckland Island) will only be gained as each programme is delivered. Each programme will refine the planning for the subsequent operations. For example, extensive hunting for pigs will identify caves for baiting during the mouse eradication and improve knowledge of cat activity and detectability with thermal camera technology.

Methodologies that were considered and discounted for the eradication of pigs, mice and cats on Auckland Island can be found in Appendix 3.

5.1.3 Weather and operating conditions

The weather patterns at Auckland Island are typical of the Southern Ocean around 50°S, with a consistent westerly flow. Weather data from the Auckland Islands are limited, with most data collected from a Metservice New Zealand automatic weather station installed on Enderby Island or geo-referenced time-lapse photo sequences[48].

Based on knowledge from previous eradications and site-specific information gathered during summer 2018/19, flyable conditions for baiting and aerial hunting are defined as a maximum daily wind gust of <33 kt and cloud base >600 m. Flyable conditions for passenger transport on island are defined as a maximum daily wind gust of <33 kt and cloud base >400 m. The proportion of time flyable by helicopters for baiting, aerial hunting and passenger transport were estimated from the Enderby data (Table 6)[48]. Approximately one in five days is suitable for aerial baiting or hunting. Findings highlight that helicopter operations should be ready to take advantage of more frequent shorter weather windows to make progress.

Daylight hours and weather have been factored into estimates of duration for each operation. The assumption was made that small boat operations will be possible 40% of the time. Understanding the influence of weather constraints on helicopter operations will be refined with more time spent on the island and collection of weather data during the planning phase and each eradication.

Next steps for quality project design:

- ***Measure swell data over time to inform planning and future go/no-go decisions for safe and efficient boating operations.***
- ***Monitor visibility conditions at key locations to better estimate the impact of low cloud on helicopter operations.***

Table 6. Proportion of time (95% confidence intervals) estimated to be flyable to support eradication operations on/around or passenger transport to/from Auckland Island, based on weather records from Enderby Island and known operating conditions for these activities.

OPERATIONS REQUIRING FLYABLE TIME	UPPER (%)	MID (%)	LOWER (%)
Baiting and aerial hunting	24	20	16
Passenger transport	38	32	27

5.2 Pigs

5.2.1 Overview

Pigs can be eradicated with current technology. To put all pigs at risk, a suite of overlapping techniques is proposed (Figure 10). Independently, each technique will not remove the whole population but collectively the sequence will put every individual at risk, and simultaneously allow validation of success across temporal and spatial scales.

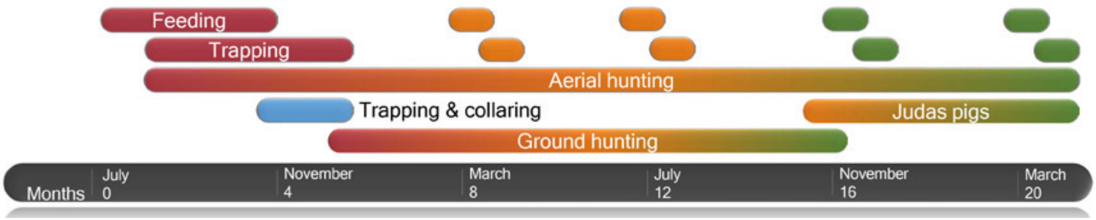

Figure 10. Proposed sequence of techniques to eradicate pigs from Auckland Island. Red = knockdown; orange = mop-up; green = validation

The proposed methodology commences with automated pre-feeding then trapping selected sites where multiple pigs are visiting. Aerial hunting aided by thermal camera technology would start as traps are rolled out to reduce pig population to low density. Ground hunting will then be used to identify and dispatch remaining individuals during a full island sweep and validate eradication with a second full island sweep. The release of Judas pigs and continued aerial hunting throughout the programme will provide additional confidence during the validation phase.

The island will be divided into three smaller management units (Figure 21, p. 83). Eradication techniques will be methodically applied through these independent blocks from south to north – working from the most difficult terrain and vegetation to the easiest. Working south to north also reduces the risk of pigs attempting to swim to Adams Island (or other islets) during pursuit.

An important theme for the sequence of techniques is that every engagement with a pig must be lethal. Not every encounter is an engagement. For example, if an aerial shooter is not confident that all the pigs in a group can be dispatched because of group size and distance from cover; the helicopter crew will waypoint the location and not engage until there is a high probability of dispatching all the animals in the group. This may mean targeting them with a less aggressive tool such as traps. Attention to detail and eradication mentality will be an important component of successful delivery.

The proposed method was successfully trialed (excluding trapping) on Falla Peninsula, Auckland Island (c. 1000 ha) in summer 2018/19[14]. Aerial hunting using thermal cameras effectively reduced the pig population before intensive ground hunting was used. All remaining pigs were efficiently dispatched in a single ground hunting sweep. The result was validated by a second ground hunting sweep.

The effectiveness of aerial hunting using thermal cameras applied island-wide reduces the area to be ground hunted by c. 12 000 ha per sweep (Figure A4.1, p. 112). Without thermal camera capability, three ground hunting sweeps of a greater area would be needed (3 × 38 000 ha = 114 000 ha without thermal cf. 2 × 26 000 ha = 52 000 ha with thermal). Lack of thermal camera technology increases the risk of failure via increased risk of leaving individual animals in difficult terrain and the programme having to run longer.

Field trials had better success with automated feeders in winter than summer, although the automated feeders were less effective on exposed tussock sites regardless of season. Beginning the pig operation in winter and using this tool in selected sites, which are logistically sensible, will maximise the efficacy of this tool.

5.2.2 Proposed methodology and supporting evidence

Fences

Two fences will be installed that will split the island into three management blocks (Figure 21, p. 83) and will facilitate other eradication techniques, such as a holding Judas pigs (see *Judas pigs* later in this section). The fences are not intended to be impervious to pigs and will enable monitoring of migration between blocks. Fences will improve operational efficiency by increasing security of treated blocks by minimising migration into them from adjacent blocks undergoing treatment. Fences will be visually inspected for evidence of migration when required and game cameras may be used to monitor possible pressure points.

Feeders

Feeders that attract pigs to an area where they can be targeted with trapping or shooting have been successfully used for initial knockdown and ongoing surveillance in previous large-scale pig eradication programmes (e.g. Santa Cruz[49]). Feeders and trapping have been important tools for putting family groups and nocturnally active pigs at risk on other eradications with high pig population densities[49]

Feeders holding a large supply of kibbled corn that release some on an automated timetable will be utilised on Auckland Island. All feeder sites should be large and flat, with vegetation cleared enough to install a trap and enable shooting and resupply from the air. Feeders will be monitored with game cameras to refine their use and guide how detected animals will be dispatched or trapped. Multi-catch traps should be installed at sites visited by several pigs, (see *Traps* later in this section). For sites with only individual pigs visiting it will be more efficient to dispatch pigs with aerial or ground shooting when they come to feed.

Trials on Auckland Island showed that feeders were more effective in winter when installed in sheltered sites where fresh pig sign was present and the pig population density was higher[19]. Although helpful for trapping, habituating pigs to visit at 'mealtimes' by regular feeding will also be critical for attracting and dispatching individual pigs.

Anderson et al. (2010) suggested that to put all animals at risk, the distance between devices should approach the radius of the smallest home range. Home ranges measured for pigs on Auckland Island are 1.37–32.8 km^2 (see section 3.9.1 – *Feral pigs*), which suggests the spacing of devices could be as tight as at 700 m s. Given that this is the first technique to be applied in the eradication sequence, the proposed spacing for pig auto-feeders in the tussock grasslands is 2 km apart and 1 km apart along the perimeter of the forest and scrub vegetation strata. These locations are based on coarse analysis of a digital elevation model and will be further refined with on-ground investigations by skilled operators. Flexibility of placement for location of feeders will improve efficacy, allowing installation of additional feeders where pig sign is observed. Deciding on the number of feeders and their distribution across the island will need to balance effort (installation, management and extraction) with expected returns and the use of more aggressive eradication tools.

Next steps for quality project design:

- *Assess the biosecurity risks and non-target impacts associated with large-scale use of kibbled corn (as part of the Assessment of Environmental Effects during operational planning) to ensure benefits outweigh costs and to consider other contingency options.*

Traps

Live-capture traps will be targeted at feeder sites that are regularly used by multiple pigs, pigs at night and/or to facilitate the capture of Judas pigs (see *Judas pigs* later in this section). Live traps are essential for targeting mobs of pigs to ensure the engagement is lethal for all members of the mob. They can also target piglets, which can be more difficult for aerial shooting and dogs to detect. Other advantages are that traps work 24 hours a day, 7 days a week and can target pigs at night.

To enable the capture of multiple pigs, traps will likely be installed in a walk-in corral, utilising a one-way gate system. The frequency of trap-checks will comply with legislative requirements (e.g. within 12 hours after sunrise, the day after they are set unless all necessities are provided). Traps can remain open until pigs are comfortably using them then set live when a suitable weather window is forecast to allow helicopter/boat access to check traps. Keeping the trapping strategy simple will be important, given the scale. Up to 30 traps may be utilised in a rolling front and will be kept in place until no longer effective at each site.

Results from a trapping study in Australia suggests an efficiency of 62% of pigs exposed to traps being captured[50]; and in another study an 83% reduction of a population was achieved using this method[51].

Next steps for quality project design:

- *Refine trap design to suit the Auckland Island conditions, to reduce the risk of pigs escaping and to improve portability and ease of set up.*

Aerial hunting

Aerial hunting assisted by thermal camera technology is considered an effective tool for achieving eradication of pigs on Auckland Island. This tool would reduce the risk of non-lethal engagement and increase confidence in eradication success. Aerial hunting is particularly effective in tussock, low scrub and other low-density vegetation. Aerial hunting will proceed in a rolling front through the three fenced management blocks (Figure 21, p. 83; Figure A4.1, p. 112) to minimise ground hunting effort.

A trial of thermal camera assisted aerial hunting on Auckland Island during summer 2018/19 showed that detection probabilities differed between habitat strata (Table 7) and that non-target species could be reliably identified in all[14, 52]. Pigs could be driven from one habitat to another to increase confidence in detection and subsequent dispatch. Table 7 presents detection data from trials on Falla Peninsula, showing how many passes in each habitat type would be required to be confident no pigs were present in the area. Based on relative vegetation composition, we estimate the minimum total distance needed to be flown to achieve coverage of Auckland Island at 2750 km. Conservative flight times that consider all variables (non-target interactions, daylight hours, chase time and number of passes by vegetation type)[14] indicate that it will take approximately 500 hours to complete this coverage, which could require up to 344 days to achieve (Table 8), depending on weather (see section 5.1.3 – *Weather and operating conditions*). Spatial data and field observations are integral to an assessment of confidence in aerial hunting as a detection tool.

Table 7. Detection probabilities by vegetation type using a thermal camera on Auckland Island during summer trials 2018/19, which informed the number of passes needed to ensure confidence all pigs in the area have been detected. The number of passes to ensure confidence is the total number of times an area needs to be covered with the thermal camera to have confidence that all animals in an area could and/or have been detected by this tool.

VEGETATION TYPE	APPROX. AREA (ha)	DETECTION PROBABILITY THERMAL CAMERA (%)	NUMBER OF PASSES TO ENSURE CONFIDENCE
Open tussock	10000	>99	2
Tall tussock with low scrub	12000	~80	3
Tall and/or tight scrub	20000	~60	4
Tall and/or dense forest and coast	6000	<30	6

Table 8. Overall time (days) required to acheive 500 hours of flying time under possible weather scenarios affecting helicopter operations for thermal camera assisted aerial hunting on Auckland Island during spring–summer. Average daylight of 9 hours per day has been assumed.

OPERABLE DAYLIGHT HOURS	24%	20%	16%
Time to achieve 500 hours flying	229 days	275 days	344 days

Effort estimates assume high resolution thermal camera assisted hunting, and this technology is not currently available in New Zealand. Currently available thermal camera technology in New Zealand is one generation behind that tested on Auckland Island during summer 2018/19 and capability is limited to one or two operators. This project has engaged with the research group Zero Invasive Predators (ZIP) and commercial operators with the intention of developing and building a fit for purpose camera for operators to purchase and operate for the project.

Capability to support an eradication operation on the scale of Auckland Island does not currently exist. Two to three cameras and at least two aerial hunting teams experienced with thermal camera capability are needed to support deployment of two teams on the island at any one time. Efficacy of the aerial hunting teams (pilot, shooter and camera operator) is dependent on experience working together. Adequate lead-in time will be required to build this experience (estimated at a minimum of 60 hours operating). Early identification of the helicopter supplier for the pig programme will provide greater opportunity for involvement in camera development and for the aerial hunting teams to work together and hone skills before deployment.

On the island of Santa Cruz (USA), 77% of pigs were dispatched by standard aerial shooting[49], indicating that despite differences in vegetation between Santa Cruz and Auckland Island, aerial shooting unassisted by thermal camera technology could still be an effective tool on the open tops (c. 10 000 ha; Figure A4.1, p. 112). However, the detection probability for aerial hunting of pigs in tight scrub or forest on Auckland Island without thermal camera technology is near zero. The detection probability without a thermal camera in tussock is low enough to warrant double the number of passes in this habitat compared to hunting with one[14, 52]. Thermal camera technology currently available would greatly improve the feasibility of pig eradication compared with aerial hunting without any thermal capability. It would also reduce costs through reduced effort and increases potential for early completion. Significantly increased ground hunter effort would be needed to ensure confidence of eradication without thermal camera technology and is not considered feasible (see later in section).

The utility of any aerial hunting will be informed by how long it continues to be effective, i.e. until it is not detecting pigs anymore due to low population density. Environmental changes will need to be considered when assessing whether to use the tool as they may result in changes in animal behaviour. For example, a rare sunny day will encourage more animal activity on the tops, increasing detectability.

Key risk:

- *The pig eradication is dependent on timely development of thermal camera technology and experienced aerial hunting teams.*

Next steps for quality project design:

- *Ensure the tactics used to eradicate pigs minimise the risk of pigs swimming to Adams Island when land adjacent to Adams Island is being hunted.*

Ground hunting

Aerial hunting in tussock grasslands has a high detection probability, so the main ground hunting effort will focus on scrub and forest strata (c. 26 000 ha; Figure A4.1, p. 112). Ground hunting is the most aggressive technique proposed. A 'detection line' team hunting approach[14] will be used to ensure that coverage is comprehensive. A detection line approach increases the likelihood that piglets, which have less scent and make less sign, will be detected[14]. It will use a team methodology, with teams of hunters each working one dog. Skilled operators and a well-coordinated, systematic delivery with good communications are essential to maintain the team approach and give confidence that if pigs are present, they will be detected. Every engagement must be lethal. The number of pigs that ground hunters detect and dispatch will depend on the efficacy of aerial hunting. Ground hunting will progress through blocks south to north to reduce the risk of pigs swimming to Adams Island (or nearby islets) when pursued.

Field trials on Auckland Island show that if thermal camera technology is available for aerial hunting then ground hunters would only need to cover the island twice to be confident that pigs are absent. A proposed hunting team of 12 personnel (two teams of six) optimises the logistics of two helicopters of AS350 Squirrel size or equivalent being based on the island. Summer trials in 2018/19 showed one hunter (and dog) covers 40 ha per 6 hour hunting period (Table 9). Based on these assumptions and including weather contingencies, it would take a minimum of 119 days for 12 hunters to cover the island twice (Table 10).

Collecting data on hunter and dog coverage, pig sign, interactions, kills and effort will help build confidence in detection sensitivity and guide decisions on adapting effort and technique. On-the-ground knowledge of terrain, conditions and dog and hunter performance will support these decisions[6].

Table 9. Mean effort (±SEM) to cover Falla Peninsula (956 ha) twice by a ground hunting team of five plus dogs during summer trials 2018/19.

	EFFORT (ha per hunter per hour)
Sweep 1	6.6
Sweep 2	7.9
Scrub	6.9 ± 4.9
Forest	6.5 ± 3.6
Tall tussock with low scrub	10.2 ± 2.6

Table 10. The minimum number of days for a 12-person hunting team, each covering 6 ha per hour for 6 hours, to complete two or three sweeps of the forest and scrub areas of Auckland Island, under scenarios that may affect operating conditions.

OPERABLE DAYS*	100%	70%	50%	33%
Time for two sweeps 26 000 ha (days)#	119	170	238	360
Time for three sweeps 38 000 ha (days)†	353	629	830	1193

* Assumes that hunters can be transported via helicopter or small boat, or on foot to hunting locations.

\# Total area for two sweeps is 26 000 ha and excludes tall tussock/scrub habitat under the assumption thermal camera assisted aerial hunting would cover 20 000 ha of tussock habitat.

† Standard aerial hunting without high resolution thermal camera aid would only cover 10 000 ha of short tussock and total ground hunting area would increase to 38 000 ha.

Helicopters are essential to support ground hunting. Helicopters will allow positioning hunters to the scrub line from where they will hunt down to the coast and will be able to respond to pig pursuits if required, reducing the risk of non-lethal engagement. Small boats will complement helicopters to limit the impact of weather on operations. Boats can be used for hunter drop offs and pickups at the coast and must have capacity to relocate each hunting team in one trip. Approximately 80 km of proposed tracks would provide contingency access for ground hunting teams to get to trap sites and hunting areas when conditions are not suitable for helicopter or boat operations (see Figure 21, p. 83). Additional tracks for cat eradication will also benefit pig hunting if cut in advance for this programme.

Individual pigs may be pressured to the coast, and aerial or boat shooters may be used to complement ground hunting teams. On two occasions during summer trials, dogs nearly went over coastal bluffs while holding/bailing pigs. Minimising the number of dogs in pursuit avoids over-exciting the dogs, reducing this risk[14]. Ground hunting should only commence when the pig population is low, to avoid having to engage multiple pigs at once with a higher risk of failure or scattering dogs. Small boat support along the eastern coast will help reduce the risk of losing dogs if a dog chases a pig into the water.

If aerial hunting with thermal camera technology is not available and standard aerial hunting is used, it is anticipated that ground hunters would need to complete a minimum of three sweeps of the island to have confidence pig eradication was achieved. The area to be ground hunted for each sweep would increase to 38 000 ha to include tall tussock/scrub habitat (12 000 ha; Table 7). Based on the effort recorded during the field trials[14] (Table 9) and excluding weather contingencies, it would take a minimum of 353 days to cover the island three times (Table 10), compared with 119 days for two sweeps with thermally aided aerial hunting. Attracting hunters and maintaining the motivation of hunters and dogs for three full sweeps over a minimum of 12 months is unlikely and could jeopardise the programme through insufficient people or poor quality of applicants. Productivity and attention would also reduce, increasing the risk of failure. This option is not considered feasible.

Next steps for quality project design:

- *Identify how small boats and helicopters can best support ground hunting safely.*
- *Define rules of engagement in vicinity of cliffs.*

Judas pigs

The use of Judas pigs is proposed to complement aerial hunting by confirming pigs are absent from areas following hunting. This technique capitalises on the social nature of pigs by releasing radio-collared pigs back into an area that has been hunted and using them to seek out surviving pigs. After a period of time, hunters can track the Judas pig and dispatch any other individuals associated with them[49].

Judas pigs will be live-captured progressively through the three fenced blocks in traps or through aerial hunting[49]. Captured pigs will be de-sexed and fitted with VHF-GPS transmitters so they can be found. Judas pigs are then relocated into a different block not being hunted so they are less likely to be dispatched when eradication techniques are implemented in their 'home' blocks. Once a block has been covered by aerial and/or ground hunting, Judas pigs previously caught in the area are recaptured and returned to their home block. Here they are monitored to find surviving pigs, indicate locations for resurvey and provide insights into pig behaviour at the time. Judas pigs are more effective in areas where there have been more pigs (such as the northern end of the island) due to the greater likelihood of undetected individuals remaining[53]. Pig capture and releases will be coordinated to ensure there are enough taken from and returned to each block and area.

Two fences create three independent operational areas and negate the need to manage large numbers of pigs in a pen or offshore island for the Judas programme. The integrity of fences will need to be regularly checked with the additional pressure put on fences by Judas pigs. It is possible pigs may return to their original home range unassisted. This is acceptable provided the means of locating and identifying Judas pigs is reliable.

Next steps for quality project design:

- *Define and test procedure, permissions, ethics approval and handling requirements for a Judas pig programme.*

Validation

Confidence in pig eradication will compound as each tool is sequentially deployed and reaches near-zero detections for the more passive tools (fences, feeders, trapping) then zero detections for the more aggressive tools (aerial and ground hunting, Judas pigs). It is not proposed to set up and use the camera grid, proposed for cat eradication, during the pig eradication due to servicing costs and the efficacy of other tools available. Confidence that pig eradication has been successful will be achieved when there have been no new detections across multiple overlapping tools. Additional confidence will be achieved by subsequent years of occupation, helicopter activity for mice and extensive hunting (including cameras) activity for cats. A decision to stop should be made with the aid of technical advice, which is a function of DOC's IEAG. The combination of overlapping tools increases confidence in pig eradication success during the final phases of ground hunting.

5.3 Mice

5.3.1 Overview

Aerial spread of cereal baits containing rodenticide is currently the only technique capable of putting all mice at risk and eradicating them from Auckland Island. Trials have shown that the proposed method can eradicate mice from the island[54], despite some deviation from current best practice[55] required to make the logistics feasible. It is imperative that pigs are eradicated before the mouse baiting begins, as pigs will eat bait, creating gaps in bait distribution and increasing the risk of failure.

The logistics of eradicating mice at the scale of Auckland Island are challenging. The proposed prescription is for two comprehensive treatments using a minimum of 4 kg/ha of rodent baits (cf. existing best practice of two treatments at 8 kg/ha; Table 11). The only bait registered for targeting mice with aerial bait spread in New Zealand is Pestoff Rodent Bait 20R® (pelletised 2 g cereal baits). It contains 20 ppm of the toxin brodifacoum, a second-generation anticoagulant and is a proven product for eradicating mice from islands[23].

For logistical reasons, baiting should be timed for summer instead of the usual winter timing for rodent eradications in temperate climates (Figure 11). Results from the bait uptake trial on Falla Peninsula, Auckland Island conducted in summer 2018/19 provide confidence the method can put all mice at risk, despite mice breeding in summer[54]. Critically, comprehensive bait coverage must be achieved over the entire treatment area to succeed. Summer timing (100% more daylight hours than winter) and two bait applications provide the best chance of achieving this.

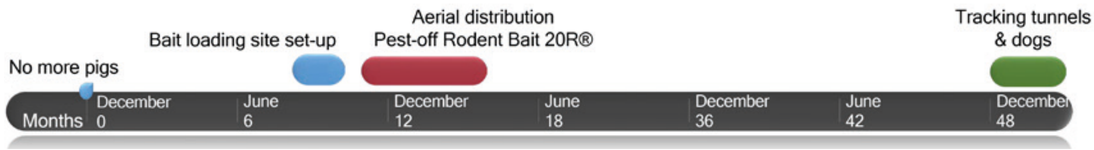

Figure 11. Proposed sequence of actions to eradicate mice from Auckland Island. Red = knockdown; green = validation.

5.3.2 Proposed methodology and supporting evidence

Baiting prescription

Bait is applied using helicopters guided by Global Positioning Systems (GPS). Helicopters will carry specialised under-slung bait buckets with motorised spinners that throw bait in a wide arc below the helicopter. Standard buckets used for across island bait spreading throw bait in an arc of 360°. Directional buckets limit throw to 180° and will be preferred for baiting coastal perimeter and cliff areas. Bait will be applied in two comprehensive treatments, a preferred minimum of 14 days apart. The minimum bait application rate for a single treatment is 4 kg/ha over a treatment area of approximately 46 000 ha. Additional bait will be applied to steep slopes and other special areas to increase certainty (c. 10 900 ha; Figure 12, Figure 13, section 5.3.2 – *Bait availability*). For example, the coastal boundary where pilots manually open and close the bucket at the start and end of flight lines during across island baiting requires additional baiting to ensure adequate coverage. Accordingly, the total area for bait spread is approximately 56 760 ha per treatment. Each treatment requires 225 t of bait, plus contingency bait to be applied if available (total 504 t including 12% contingency; Appendix 5; Table A5.1, p. 113).

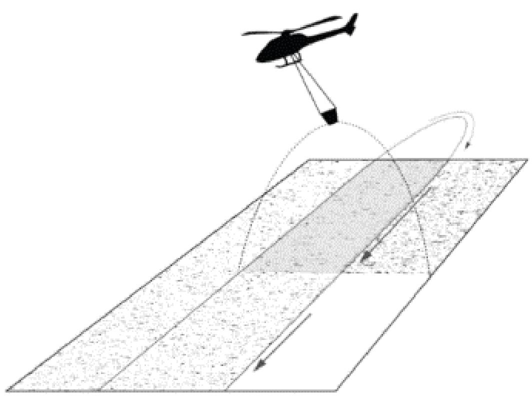

Figure 12. Bait-spreading pattern illustrating 50% overlap of bait swaths (Broome et al. 2017)

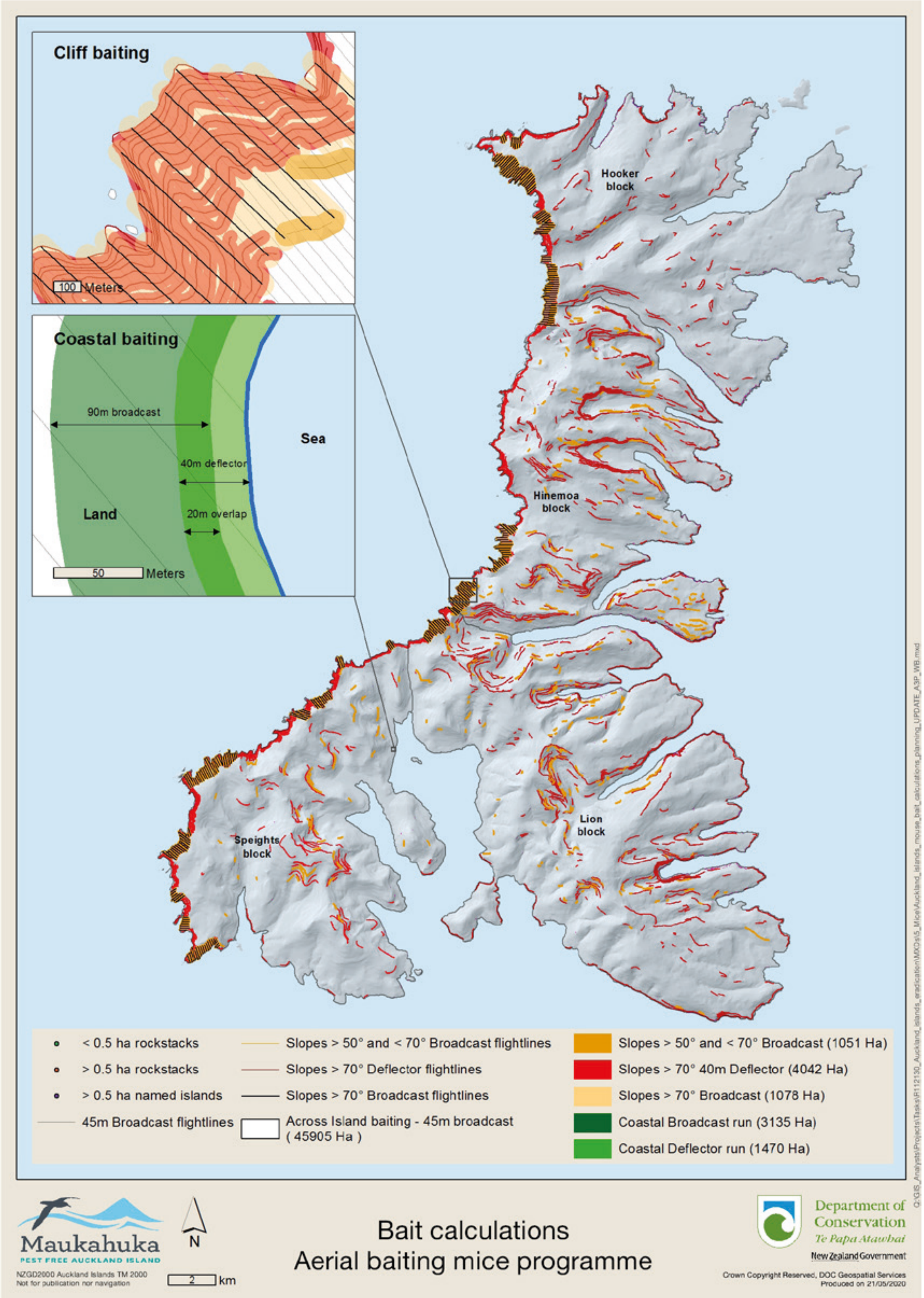

Figure 13. Proposed bait application method for the eradication of mice on Auckland Island

Aerial bait spread will be supplemented by bait stations and hand spreading of bait in and around operational infrastructure, existing historic structures (e.g. Tagua, Ranui, Waterfall Inlet, etc.) and accessible caves above mean high water spring.

Bait treatment should commence by November to be completed by March (c. 120 days; Figure 11; see *Bait availability* later in this section).

The proposed method was tested using a single minimum application of 4 kg/ha on a 953 ha trial site (Falla Peninsula) at Auckland Island in summer 2018/19. Productivity of 0.8 t/hr was recorded for standard broadcast and 0.5 t/hr for coastal deflector bucket work[54]. Smaller volumes of bait were loaded into each bucket than is normal, resulting in lower productivity than could be expected. Using these conservative rates, distributing 504 t of bait for the minimum proposed treatment is estimated to take 668 hours of helicopter flight time (Table 11).

Bait and fuel should be positioned on the island prior to the initiation of the mouse programme, so baiting operations are not delayed or helicopter resources diverted to unloading ships. Approximately 181 hours are estimated to be required for the site set up and 121 hours for demobilisation, depending on final bait storage and transport options (Table 11). The proposed bait application rates result in a very large but feasibly manageable quantity of bait, considering manufacture (see *Bait production* later in this section), transport (section 6.4.2 – *Mouse bait*), storage (sections 6.3.8 – *Bait storage* and 6.4.2 – *Mouse bait*), handling and aerial bait spread using six helicopters (section 5.3.1 – *Seasonal timing*).

Baiting swaths will overlap by 50%, in line with best practice[55] (Figure 12). This effectively doubles the flight distance or area to be covered for bait spread (e.g. 46 000 ha treatment area becomes 92 000 ha for each treatment; Figure 12). In this way, bait is applied everywhere twice during each treatment to reduce the risk of gaps. This means the nominal or target bait application rate on the ground (4 kg/ha) is achieved with a flow rate of bait out of the bucket that is half the target rate (2 kg/ha). Overlapping bait swaths is a critical part of the prescription design to minimise the risk of gaps in coverage to ensure all mice are put at risk. The importance is particularly significant for completing baiting on a very large subantarctic island where bait application will be disrupted by inclement weather. The generally poor weather conditions will adversely affect the continuity and accuracy of bait spread, so bait should be incrementally spread whenever short weather windows make it possible.

There is increasing risk of interruption to bait flow out of the bucket at lower flow rates due to the bucket mechanism[23]. This is currently a limiting issue for the proposed flow rate of 2 kg/ha. Bait flow was interrupted four times from 17 bucket loads during trials in summer 2018/19[14]. With current helicopter GPS an interruption to bait flow caused by a blockage would not be detected or recorded as a gap in coverage, which is a potentially fatal point of failure for eradication[23]. Improved bucket design to facilitate reliable low flow rate of bait is considered integral to mice eradication success and is a key development dependency to be pursued (section 6.1.2 – *Better bait bucket*). Consistency of bait size and weight also becomes increasingly important at lower flow rates to ensure bucket flow is not interrupted.

Mice have been eradicated from 104 islands globally[47]. Six mice eradications have occurred on islands at high latitudes and with cold climates, including the eradication of mice from New Zealand's subantarctic Antipodes Island (2045 ha) in winter 2016[56]. The largest successful eradication of mice to date was from Macquarie Island (12 800 ha) in 2011 (Figure 8), in the presence of ship rats and rabbits. Auckland Island is nearly four times larger than Macquarie Island. Other nations are planning to eradicate mice from large islands at this latitudinal range and feasibility studies have progressed to operational planning for Gough Island (6500 ha; in 2021) and Marion Island (29 000 ha; date unconfirmed). In New Zealand, 28 islands >1 ha have been cleared of mice from 36 attempts[23]. Success has been greater than 90% where current agreed best practice used in New Zealand has been applied[23].

Mice have been eradicated from other islands using bait application rates lower than 8 kg/ha. In 1993, mice were eradicated from Enderby Island in the presence of rabbits using two applications of bait at 5 kg/ha[57] and from Adele Island (87 ha) in New Zealand's Abel Tasman Park in 2017 with one application at 3 kg/ha (C. Golding 2019, pers. comm.). Recently, mice have also been eradicated from Maud Island (Marlborough Sounds; 309 ha) using two applications of 4 kg/ha in winter 2019[58].

Key risks:

- *The proposed bait prescription is dependent on improved bucket technology to sow bait at 4 kg/ha (2 kg/ha flow rate and 50% overlap) with 100% reliability. Investment in this development is required to ensure it is proven and ready in time.*

Next steps for quality project design:

- *Confirm size of treatment area with a boundary flight early in planning phase – the treatment boundary should be the coastal edge of continuous rodent habitat (see helicopter recommendations – Antipodes After Action Review DOC-2928572).*
- *Review bait application rate once a ship, cargo and helicopter capacity are known, and increase sowing rate if logistics allow.*
- *Understand reliability and points of failure for any new bucket design.*
- *Plan contingency options with shipping capacity if 4 kg/ha cannot be achieved.*

Bait availability

COVERAGE

Evidence supports that the proposed minimum application rate (4 kg/ha) will put all mice at risk on Auckland Island[54]. Applying bait in two treatments with a minimum interval of 14 days between treatments (best practice)[55] is designed to extend the period of bait availability so every mouse can access bait. Eradication relies on every mouse encountering bait and consuming a lethal dose. An extended period of bait availability is important because mice can be light and erratic feeders[59]. Most die about 5 days after bait application, although some survive for long periods before succumbing and some require significantly higher doses than others[23]. The second treatment is also designed to mitigate the risk of juvenile mice emerging from the nest after bait from the first treatment is no longer available. For a smaller site, baiting would normally cease between treatments to achieve a minimum interval of 14 days between treatments. Baiting will be continuous at Auckland Island because it will take more than 14 days to complete each treatment (approx. 335 hr flight time per treatment; Table 11).

Table 11. Comparison of New Zealand current best pratice bait application rates[55] for mouse eradication and proposed minimum bait application rate for mice on Auckland Island (46 000 ha) and the effects on logistics. Assumes flight lines at 45 m to achieve 50% overlap of bait swaths and additional baiting around higher risk areas to increase certainty (total treatment area for single application = 56 760 ha).

	BEST PRACTICE	PROPOSED
Season	Winter (general preference)	Summer
Treatment 1 (kg/ha)	8	4
Treatment 2 (kg/ha)	8	4
Bait (t)	900	450
12% contingency (t)	108	54
Total bait (t)	1008	504
Bait pods	1440	720
Fuel drums	2000	1000
Flight time set up (hr)*	362	181
Flight time baiting (hr)*	1336	668
Flight time demobilisation (hr)*	242	121
Total flight time (hr)*	1940	970
Total flight distance (km)	10200	10200

* Figures are based on a conservative estimate that good visibility, rain and wind conditions occur 15% of the time (upper value for days with wind gusts >24 kt) and 75% of daylight hours are productive flying (allowing for daily set up, preparations and pack-up procedures).

Mice have small home ranges and a potentially smaller foraging area while bait is available[23]. Female mice range less when breeding and young mice have a very small range[24], suggesting less tolerance for gaps in bait spread in summer when mice are breeding than in winter when there is no breeding. The smallest home range (0.13 ha; lower 95% confidence interval[22]) measured in tussock habitat on Auckland Island would theoretically receive 260 baits per 4 kg/ha application, more than enough for every mouse to encounter a lethal dose (approx. 0.5 bait). This assessment is supported by positive results from the bait uptake trial of a single application of 4 kg/ha at Auckland Island in summer 2019[54]. Only two mice of 232 sampled in the treatment area had not consumed bait. Both were small juveniles (<10 g) and it is believed they would have been vulnerable to a second application of bait a few weeks later, once mature[54].

Bait spread to cover the whole of Auckland Island is expected to be sporadic, completed over weeks as weather allows. Each period of baiting activity will build on previous work to progress bait coverage along the treatment area in a 'rolling front'[55]. Some baits will inevitably be exposed to degrading conditions a short time after application. The durability of Pestoff 20R® during bait uptake trials on Auckland Island in summer 2018/19 is encouraging. Bait remained available to mice and in generally palatable condition after 9 nights despite significant rainfall (138 mm) during that period. Availability reduced from 4 kg/ha to a minimum of 0.6 kg/ha after 9 nights[14]. This lower estimate equates to availability of 39 baits within the lower 95% confidence estimated home range of 0.13 hectares[22].

STEEP SLOPES

There are c. 4042 ha of slopes greater than 70° (cliffs) where additional bait is to be applied using directional buckets (Figure 13; section 5.3.1 – *Baiting prescription*). Altitude gains of approximately 40 m (approximate swath width of directional bucket) should be used per flight line until the area is covered with confidence that baits have reached all vegetated areas. Photo analysis of coastal cliffs reveals several places where flying parallel with cliffs may not be possible (e.g. deep gullies and tight turns involved). This should be confirmed by a boundary flight. Additional bait application with the helicopter flying inland towards and over the top of such areas should be considered. This has been estimated at 1078 ha and accounted for in bait volume calculations.

NON-TARGET SPECIES

The pig eradication must be completed before the mouse eradication can commence. Pigs were temporarily eradicated from the mouse bait uptake trial treatment site on Falla Peninsula on the assumption they would consume cereal baits and create holes in the bait distribution[14]. One pig was known to have broken through the exclusion fence and faeces with tracer dye were found (away from the mice trapping grids[8]), indicating consumption of baits. Bait uptake trial results indicate that cats did not create gaps in bait availability[14]. Some level of population reduction of cats from secondary poisoning is expected and will aid the subsequent cat eradication (section 5.4.1 – *Brodifacoum poisoning*).

No other showstoppers have been identified for mouse baiting relating to non-target species. No native species that may widely consume and/or significantly impact bait availability have been identified (section 5.5.3 – *Environmentally acceptable*). An assessment of environmental effects of island-wide bait distribution will be investigated in the planning phase (section 5.5.3 – *Environmentally acceptable*).

Next steps for quality project design:

- *Plan for a 1-year gap between pig and mouse programmes to allow the pig eradication to run longer if necessary and avoid preparing for mouse programme while pig hunting is ongoing.*
- *Work out details of what needs extra baiting and how it can be achieved during operational planning.*

Seasonal timing

COVERAGE

Bait application on Auckland Island is planned to occur between November and March (austral summer) and trials support that this timing will allow all mice to be put at risk. Baiting could start earlier but should be completed by the end of February before tussock seed matures and becomes available in March. An attempted eradication will fail if bait spread cannot be completed across the whole island at least once. Summer timing instead of the usual winter timing will improve the probability of completing the broadcast of a minimum 504 t of bait in the generally inclement weather (section 5.1.3 – *Weather and operating conditions*). A summer operation is recommended as there are around twice the number of daylight hours (max. 16.5 hr) available than in winter (max. 8 hr) for helicopter operations (Table 12). The proposed timing is a balance between the risk of not completing bait coverage in the winter due to operational constraints (Table 11; Table 12), helicopter availability, increased risks in summer of alternative food sources and the presence of juvenile mice, which may not immediately eat bait.

Table 12. Comparison of helicopter baiting between winter and summer on Auckland Island, assuming the same weather conditions apply to each season.

	WINTER	SUMMER
Months	May – Aug	Nov – Feb
Approx. daylight hours	1058	1864
Estimated productive flight time needed (hours)	668	668
Helicopters needed to complete baiting in 120 days*	7	4
Helicopters needed to complete baiting in 90 days*	9	6

* Figures are based on a conservative estimate that good visibility, rain and wind conditions occur 15% of the time (upper value for days with wind gusts >24 kt) and 75% of daylight hours are productive flying (allowing for daily set up preparations and pack-up procedures).

A logistical comparison between winter and summer timing (Table 12) shows that nine helicopters would be required to complete two bait treatments in 90 days in winter for the assumed conditions, compared with six helicopters in summer. Sourcing and supporting up to nine helicopters for a winter operation (Table 12) and remote deployment is not feasible. The pool of baiting pilots with the required skills is small and unlikely to meet the needs for remote deployment to service nine helicopters for several months. Sourcing up to six helicopters is feasible but challenging, requiring the right incentives, personnel and personal motivation.

The total area for bait spread over the two treatments has not yet been achieved in a single season for any rodent eradication to date. Considering the average weather at the site and its unpredictability in any given season or year, the uncertainty is too great to confidently predict completion of bait spread in the winter season at this scale. Therefore, it is recommended that an operation is timed for summer. Six helicopters could advance baiting progress rapidly (4–5 t of bait per operating hour) when conditions are good.

The weather for baiting is expected to be generally poor (section 5.1.3 – *Weather and operating conditions*), increasing the risk of long interruptions or washouts of bait. Experience on Auckland Island in summer 2018/1914 and baiting on Antipodes Island in winter 2016[23, 60] support the notion that bait spread on Auckland Island will be sporadic. It will require utilisation of short weather windows (productive time of >1 hr depending on the situation). To increase efficiency, multiple bait loading sites should be used to reduce helicopter transit time for reloading (Figure 14). A total of nine load sites are proposed based on a 5 km radius for transit, and approximate location based on topography to improve likely access in low cloud conditions (Figure 14). Final locations of bait loading sites will be informed by site knowledge during the infrastructure and pig programmes. 'Pop-up' loading sites could support pre-established loadsites where required.

Figure 14. Proposed bait application method for the eradication of mice on Auckland Island.

Interruptions to baiting of more than 3 days will require application of additional bait at boundaries between treated/untreated areas, depending on the duration of the interruption and condition of bait. This is to mitigate the risk of mice migrating to areas where viable bait is not available and is an important use of contingency bait.

Poor weather can inhibit the completion of bait spread on large islands. For example, in 2010 on Macquarie Island (12 800 ha), only 8% of the island could be baited in 2 months due to low cloud and high wind[6]. A second attempt the following winter in better conditions completed application of 330 t of bait over 12 800 ha (2 full + 1 part treatments) in less than 3 months using four single engine squirrel helicopters (BA and B2 models[6]). If extremely poor weather restricts baiting on Auckland Island to one treatment rather than the planned two, the programme would still have a chance of success (e.g. mice phase South Georgia Eradication[61] and summer trials Auckland Island[14]). Planning should allow for flexible decision making.

Mechanised bait loading using conveyors transportable by helicopter should be considered at the main base sites. These won't speed up bait loading but will decrease the time bait loading personnel spend working near a hovering helicopter. High-speed refuelling will be important to reduce downtime. Pilot downtime due to weather counts as duty time unless the pilot had pre-rostered time off. Pilot fatigue is a priority risk to manage. Logistics management software such as 'Air Maestro' (Adelaide, Australia) is available to help manage duty and flight time for operations involving multiple pilots. Helicopter operations at Auckland Island during summer 2018/19 identified difficulties in balancing pilot availability with rapidly changing weather forecasts. With only one pilot doing passenger flights and baiting, several additional days off were needed to reset the 7-day duty period every 3–4 days to avoid missing a weather opportunity for baiting in the longer-range forecast (7 days ahead). It is recommended that two pilots only are rostered on at a time to conduct passenger transfers.

Next steps for quality project design:

- *Understand how flight and duty hour regulations will structure pilot rosters for baiting work (Part 137 operations – CAA regulations). Monitor changes to the regulations during operational planning.*
- *Consider how to react in case the first treatment is delayed beyond the time where a second treatment could be attempted.*

ERADICATING BREEDING MICE

Results from the bait uptake trial in summer 2018/19 show all mice can be put at risk on Auckland Island from bait application in summer when mice are breeding, especially if a second treatment is completed several weeks after the first[54].

Expanding populations of mice have been eradicated from islands previously. Mice were eradicated from Maud Island in winter 2014 using best practice (2 × 8 kg/ha)[23], and again in winter 2019 (2 × 4 kg/ha) after an incursion event led to a population of mice re-establishing[58]. In winter 2017 mice were eradicated from Adele Island (87 ha) in the Abel Tasman National Park, in the presence of abundant natural food and using a single application of 3 kg/ha of Pestoff Rodent Bait 20R® (C. Golding 2019, pers. comm.). The mice eradication on subantarctic South Georgia occurred with bait spread during the autumn (March to May), when mice numbers were highest, but the breeding rate was beginning to decline[61].

Apart from weather and daylight conditions, summer timing with completion by March is recommended instead of autumn or winter to avoid tussock grasses in mast years potentially providing a large alternative food source, widely available across c. 10 000 ha of habitat. Mice can breed all year round if high quality food is available, but generally have distinct breeding seasons on cool climate islands and stop breeding in winter[56]. Mice were recorded breeding on Auckland Island in winter 2007 following a large tussock seeding event (mast) in 2006/07[62]. Population density and abundance were significantly higher in winter 2019 than summer 2018/19 due to a tussock mast in autumn; however, no breeding was detected in winter despite mice being in excellent condition[19].

Results from the bait uptake trials in summer 2018/19 show that mice eradication timed for summer can occur in a masting season if baiting can be completed before seed ripens in autumn[54]. The population density of mice on Auckland Island was elevated in the summer following the large tussock mast (2019/20) relative to results from the masting summer (18/19) when bait uptake trials occurred[63]. Bait availability at 2 × 4 kg/ha would still provide enough bait for the highest population density recorded. Timing an eradication for the summer following a large tussock mast warrants further consideration. In this event, possible actions would be to proceed as planned; increase bait quantity to match the logistical capacity once a ship has been identified; or delay mice baiting and subsequent cat eradication by a year.

BAIT PRODUCTION

The quantity of bait required to eradicate mice from Auckland Island can easily be produced. Pestoff Rodent Bait 20R® is the only bait registered in New Zealand for aerial distribution to target mice. Orillion, based in Whanganui, New Zealand, is the only manufacturer of Pestoff Rodent Bait 20R® and can produce the required volume of bait (J. Quigley 2019, pers. comm.). One month of production time should be allowed for production of 500 t using both plants or a maximum of 100 days using only the smaller C-Plant. A lead-in time of 6 months between order and production is required to ensure availability of raw materials. This becomes a decision milestone for the mouse operation as the bait has a shelf life of 12 months according to the label. Working back from baiting starting in November, the island set up should occur no later than September to give time to prepare the arrival of the baiting team. Bait production should be completed, and bait delivered to port of departure in July to allow re-manufacture of part or whole order in case of problems. Confirmation of the bait order would be required in December of the year prior to production.

VALIDATION

Validation to determine the success of the mouse eradication would preferably occur a minimum of two mouse breeding seasons following bait application[55]. A limited range of detection devices (largely reliant on only two tools: inked tracking cards in tunnels and rodent detection dogs, to avoid confounding results), will be deployed across the island in areas considered to be the most likely refugia for mice.

Result monitoring should be undertaken towards the end of the cat programme when helicopters and field huts are still present. Waiting longer than 2 years would increase confidence for less effort, but monitoring should be completed before removal of base and helicopter facilities in case of failure. Timing the monitoring for when helicopter support was present would facilitate efficient island-wide monitoring to increase confidence of validation. Intensive monitoring for survivors during the 2 years post baiting is not recommended with current knowledge, due to the scale of the island and the low likelihood of detection or ability to respond. A well-timed sampling approach is achievable.

The island-wide network of cameras deployed to detect cats could give early indication of failure to eradicate mice. Absence of mice detection on cameras would not be definitive as the camera network will not be targeting mice, which move much faster than cats and may be undetectable at low numbers. If mice are detected, then physical evidence is required to compare DNA with voucher samples to rule out incursion, as opposed to eradication failure[64]. Nuclear DNA samples from Auckland Island mice show the mouse population originates from America and is genetically distinct from mice on mainland New Zealand[65]. Verification of whether a mouse caught after the baiting operation is a survivor or from an incursion should therefore be easily determined. Voucher samples of Auckland Island mice for reference are held by Te Papa Tongarewa (Dr Colin Miskelly) and University of Auckland (Dr James Russell).

Next steps for quality project design:

- *Use site knowledge gained throughout programmes to inform surveillance sites for mouse eradication validation.*

5.4 Cats

5.4.1 Overview

Trials on Auckland Island in summer 2018/19 and winter 2019 have greatly informed the feasibility of eradicating cats and reduced uncertainties. We are confident cats can be eradicated with the proposed method (Figure 15). No single tool is available that can put all cats at risk, but a suite of tools has been identified that can target every individual. Tools will be implemented from the most passive to the most aggressive over time (Figure 15). Combined with intensive monitoring, this approach gives the best chance to conclude eradication.

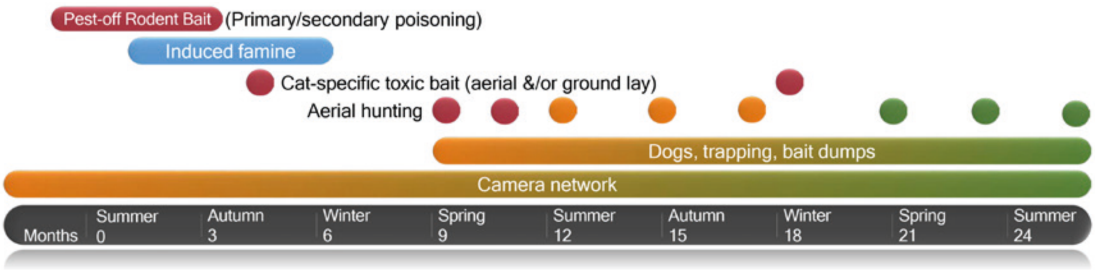

Figure 15. Proposed sequence of methods to eradicate cats from Auckland Island. Red = knockdown; orange = mop-up; green = validation. Blue indicates state induced by eradication tools.

Knockdown will be achieved primarily through both primary and secondary poisoning. Secondary poisoning of cats from mouse baiting operations is considered critical for cat population knockdown. The cat-specific toxic bait currently being developed by the DOC Biodiversity Threats team, supported by the Maukahuka team (DOC-6214883), will greatly increase efficiency and the likelihood of eradication success. Aerial hunting assisted by thermal camera technology (see section 5.2.2 – *Aerial hunting*) will be used for knockdown in light vegetation and inaccessible areas.

The operation will be continually assessed, and the approach adjusted based on information from multiple monitoring tools. An island-wide camera grid installed before baiting begins, targeted trapping, trained cat dogs and bait dumps will provide means of detecting and targeting individuals while simultaneously providing a means of validating eradication across temporal and spatial scales once known individuals are (presumed) dispatched. Multiple detection tools will increase confidence in success.

Island-wide surveillance using trail cameras is logistically achievable with installation of tracks, and helicopter and boat support. Automated image processing software (see section 6.1 – *Research & Development*) is needed to make data management feasible and a rechargeable battery pack would greatly improve camera maintenance.

5.4.2 Proposed methodology and supporting evidence

Brodifacoum poisoning

The cat operation should be timed to follow immediately on from the aerial distribution of Pest-off Rodent Bait 20R® to eradicate mice on Auckland Island. Cats are not the target species of this toxic bait but previous projects have reported knockdown of cats following rodent eradications using brodifacoum ranging from < 50% to 100% of the population[34]. Achieving 100% knockdown of cats on large islands from aerial baiting for rodents is unlikely. We therefore assume that there will be some, but not total, population reduction of cats following a mouse eradication operation through primary and/or secondary poisoning.

It would be beneficial for the camera network (see section 5.4.1 – *Camera detection network*) to be operational prior to commencing the mouse baiting programme. This would allow the trend in distribution and abundance of cats to be followed pre- and post-mouse baiting to ascertain the level of knockdown achieved and to provide a reference for change in behaviour as the population is affected. This additional monitoring adds costs that would be re-cooped if the operation could be concluded earlier as a result.

Cat-specific vertebrate toxic agent (VTA)

Aerially applied toxic baits for cats is preferred as an additional knockdown tool for this eradication due to the scale and terrain of the island (Table 13). Aerial application would allow bait to be efficiently broadcast across the island and delivered to steep slopes (>70°), where people can't access (c. 4042 ha). Additionally, bait could be hand laid to target known individuals during the mop-up phase (see *Targeted hand-laid toxin* later in this section).

Table 13. Advantatges and disadvantages of the use of an aerially applied vertebrate toxic agent (VTA) to target cats for eradication on Auckland Island. PAPP = para-aminopropiophenone.

ADVANTAGES	DISADVANTAGES
• Passive technique • Accessibility – aerially applied VTA can be efficiently delivered to all habitats and terrain, including the scrub zone and the western cliffs. Ground-applied VTA requires less effort than ground-based trapping. • Bait spread logistics and resources are feasible, easily repeatable in any season and minor compared with ground-based trapping or hunting. • Registration of PAPP encapsulation in meat bait for aerial distribution is underway. • Beneficial for projects across New Zealand.	• Costly and time consuming to develop and to register with many uncertain steps and timeframes. • Unproven – needs to be tested to ensure that bait is palatable to cats and show that most cats will consume a toxic dose. • Developing a cat-specific VTA may have a low level of social acceptability, especially if 1080 is used.

All successful cat eradications on islands >2500 ha, bar one, have used primary poisoning for knockdown[34]. The use of toxic bait may be more efficient than trapping for knockdown and mop-up, though the use of both methods should be considered to account for individual behaviours[34, 66]. The likelihood of bait uptake by cats is increased by bait being palatable (preferably fresh, not dried), one bait being a lethal dose and bait being delivered when natural prey sources are low[66].

The eradication of mice on Auckland Island may impact the cat population through the removal of a food source. Prey diversity appears to be fundamental to cat survival on Auckland Island and evidence shows that cats there are adaptable, opportunistic hunters[32]. The impact of losing mice as a prey source is dependent on the availability of alternative food sources. There is uncertainty on Auckland Island about how the bird populations will respond to the removal of mice and the distribution of marine-derived food. The absence of mice is expected to change the distribution of cats by pushing some remaining cats into the coastal areas where they can access marine-derived food and/or increase their consumption of alternative food sources, including poison baits.

To increase the likelihood of cats on Auckland Island encountering fresh bait on this complex landscape, we propose to apply one sausage bait every 40 m with flight lines 500 m apart (1 kg/km^2) in winter. Each cat would have access to between 77 and 3561 baits, based on current home range data from Auckland Island cats[30]. An additional application around the perimeter of the island would concentrate bait in the area where cat population density is highest (rātā forest and steeper coastal habitat where seabirds reside), based on GPS tracking data to date[30]. Total helicopter flight lines for this bait application rate are 1219 km, taking approximately 45 hours of flying. This is at least double the prescription previously used during the successful eradication of cats from Dirk Hartog Island in Australia, a simple, arid landscape[66].

Second and third applications of bait should be resourced and applied as required. This would be considered if detection methods show that cat distribution changes following knockdown and/or if some cats were unlikely to have encountered bait because of poor bait availability (rapid degredation) or alternate prey source availability. For example, a few collared cats appear to access Antarctic prion/totorore (*Pachyptila desolata*) fledglings in the western cliffs during late summer but move back into their eastern coastal territories over winter[14, 19, 30].

There are currently no cat-targeted toxic baits registered for aerial application in New Zealand (Table 14). Registered ground-laid baits are based on sodium fluoroacetate (1080) and unencapsulated para-aminopropiophenone (PAPP). DOC's Biodiversity Threats team is developing an encapsulated PAPP-based toxic bait for aerial distribution to target stoats and cats (Table 14). Sausage and 'meat glue' blocks from Connovation (Auckland-based provider of pest animal control products) have been developed. A non-toxic field trial of these meat baits showed they were highly palatable to cats on Auckland Island[19]. Toxic bait development is at the pen trial stage, but trials of toxic versions have to date proven unsuccessful and much work remains to realise this tool.

Table 14. Potential options for a cat-specific vertebrate toxic agent (VTA) to facilitate the eradication of cats from Auckland Island. PAPP = para-aminopropiophenone.

VTA	CURRENT STATUS	DEVELOPMENT AND REGISTRATION REQUIREMENTS FOR AERIAL APPLICATION	COST (NZD) AND TIMEFRAME
Feral cat polymer bait[1]	Registered for bait station and hand laying	• Field efficacy trial • Specific bait breakdown data • Registration variation	$250K – 300K 3 years
1080 solution in bait	Not registered	• Bait development • Bait palatability • Pen and field trials • Specific bait breakdown data • New registration	$400K – 500k 5 years
PAPP PredaStop in bait	Registered for bait stations	• Bait development • Bait palatability • Pen and field trials • Specific bait breakdown data • New registration	$400K – 500k 6 years
1080 encapsulated in bait	Not registered	• Bait development • Bait palatability • Encapsulation development • Pen and field trials • Specific bait breakdown data • New registration	$400K – 500k 5 years
PAPP[2] encapsulation in bait	Not registered	• Bait development • Bait palatability • Encapsulation development • Pen and field trials • Specific bait breakdown data • New registration	$400K – 500k 6 years

1 ACP 1080 Fishmeal polymer feral cat bait is perceived as inefficient. The palatability of a non-toxic fishmeal polymer bait was trialed during winter 2019 and found to be significantly less palatable than sausage or meat glue baits[19]. Field trials showed the toxin quickly degraded in the damp environmental conditions on Auckland Island[19].

2 Non-toxic field and pen trials showed these baits to be highly palatable. Toxic baits are in the pen and field-based trial stage.

Registration of a new toxic application in New Zealand is hugely complex and time consuming. It follows a prescription regulated by the Environmental Protection Agency and the Ministry for Primary Industries. The steps for toxic bait development are:

- develop a bait matrix that is palatable and logistically suitable
- select a toxin and determine the most appropriate toxin concentration and formulation
- test efficacy and degradation properties
- assess environmental impacts and degradation
- develop appropriate baiting procedure

- consultation
- registration.

Failure at any of these steps could halt the process, requiring redesign and associated delays, or abandonment. For example, the recent registration of Cholecalciferol for rodent bait application in New Zealand took 10 years[67]. Operational planning will proceed with decision points and contingencies in place. Should an aerially applied VTA for cats not be available, trapping would be relied upon as a knockdown tool for cats on Auckland Island and greater hunting resource would be required. A registered and proven bait would need to be available by the end of the pig programme to secure supply in time and train additional cat hunters if the bait in this case. This is still considered feasible, though with a lower confidence in the result due to the increased time scales involved, and potentially a much greater effort to achieve success.

Key risk:

- *An attempt to eradicate cats from Auckland Island using currently available tools, whilst feasible, carries a significant risk of failure as well as higher costs and longer duration to complete. Development and registration of an effective toxic bait registered for cats that can be aerially applied would greatly enhance confidence and reduce eradication timeframes.*

Next steps for quality project design:

- *Ensure decision points for contingency planning are integrated into operational planning, in case a bait is not available.*

Camera detection network

Eradicating cats on this scale and in a logistically feasible way relies on high confidence in the ability to detect cats. Following advances in quality, affordability and longevity, camera traps are becoming an increasingly common tool for large-scale, remote wildlife monitoring[66]. Trials showed that currently available game cameras with a meat lure are an effective tool for detecting cats on Auckland Island in all seasons and a camera grid can provide data to enable targeting of individuals[14, 19]. Moreover, a camera detection network negates the need to collar and follow individual cats through the mice baiting to monitor knockdown. This is particularly important, as trapping cats to collar them introduces a risk of educating individuals immediately prior to the implementation of eradication tools.

Spacing of devices should be based on the smallest known home range across the year (currently 154 ha)[30]. Using a camera grid that is as tightly spaced as logistically feasible will increase detection probability and likely reduce the duration of an eradication. Camera spacing of 500 m × 500 m (or one camera per 30 ha) was effective in detecting the cat with the smallest known home range twice during the summer 2018/19 trial (c. 27 days)[14]. One camera per 30 ha equates to a grid of approximately 1530 cameras across the island.

An on-island cat detection team of 20 is proposed, with the whole team installing the camera grid, then half the team servicing the cameras and the other half being mostly dog handlers and some ground hunters without dogs who will monitor and respond to cat detections obtained from all tools (see section 5.4.1 – *Dogs*). Installation is estimated to take 24 days using a team of 20 people and servicing the grid should take 20 days with a team of 10 people (with boat and helicopter support; Table 15). Additional cameras could be deployed in areas where cat density may be higher, e.g. in areas of high prey availability.

Servicing cameras will progress along the island, with field teams systematically visiting each camera in an area before moving on. A range of lures (food, visual, social or audible) pulsed through the camera network can be useful to increase interest of individuals[14, 66] but are not essential, as cameras on active game trails can detect cats without a lure[14]. It is generally acknowledged that careful placement of cameras at each site and within a landscape is of primary importance to the successful use of these tools[66]. Building capacity and capability of a skilled team with an

Table 15. Effort required to install and service a camera network on Auckland Island based on findings from on-site summer trials 2018/19[14].

ACTIVITY	EFFORT MEASURE
Installation of cameras on 500 m grid, limited tracks	4 cameras per person per day
Maintenance of cameras on 500 m grid, limited tracks	10 cameras per person per day
Installation of whole grid (n = 1530 cameras): 20-person team with 20% redundancy (days off, injury, weather etc.)	24 days
Maintenance of whole grid (n = 1530 cameras): 10-person team with 20% redundancy (days off, some data management, injury, weather, etc.)	20 days

eradication mind-set is also essential to ensure the success of this tool. The preferred frequency of camera checks would be approximately monthly but subject to battery life, lure life (if necessary) and the need to target individuals. Lithium batteries have performed well in the Auckland Island climate and battery life is not considered a limiting factor for the camera network. The cost and logistics associated with large volumes of lithium batteries required for 1500+ trail cameras over several years supports investigation of rechargeable battery packs or an energy supply.

Camera detection trials on Auckland Island highlighted that processing photos and data from landscape-scale camera networks is prohibitively labour intensive[14] and thus at the proposed scale for this project is not feasible, nor would it allow rapid detection and response to target individuals. To feasibly manage data from the proposed surveillance, automated processing of image data is required to triage falsely triggered images (no animal present) as a minimum and preferably identify images where cats are present. Software and coding to support the initial sorting/triage of images are available and becoming increasingly reliable (DOC-6127504). The Maukahuka team has engaged with various organisations that are working on developing Artificial Intelligence (AI) systems for automated recognition of species from camera footage and thermal detection cameras (DOC-6127504).

Automated detection of cats using a camera that can capture imagery and identify a cat through thermal sensing technology would again reduce data management. If such a detection device could be coupled with a remote camera network that instantly reports detections to a base computer, these technologies could save an enormous amount of labour. More importantly, they could enable rapid response, potentially shortening the time to conclude eradication. Small-scale nodal remote camera networks are currently in use in New Zealand for various conservation programmes (e.g. Glenfern Sanctuary, Great Barrier Island (Aotea)). Trials of thermal cameras built by the Cacophony Project were initiated on Auckland Island in August 2019[19]. Thermal cameras are currently 10× the cost of trail cameras but have the potential to save money by minimising data processing and enabling rapid response to a detection. While these technologies are not essential to eradication success, the Maukahuka team has engaged with groups leading these developments (DOC-6214883) to understand their potential and present status.

Key risk:

- *Utilisation of trail cameras at this scale is not feasible unless automated image processing software to label and triage imagery from the camera network is available and reliable. This must be manageable and aimed at optimising the time between a cat being caught on camera and then responded to.*

Next steps for quality project design:

- *Complete analyses of detection probabilities with different camera spacing, cat home range data and maintenance effort to inform the prescription.*
- *Development of a reliable long-life lure to complement remote camera network.*
- *Seek improved battery pack options for cameras.*
- *Investigate advances in remote sensing technology during project planning and perform a cost benefit analysis for their use on Auckland Island.*

Dogs

Dog teams are proposed as a complementary detection technique to run alongside cameras throughout the mop-up and validation phases. Dogs will help target effort, including the placement of traps or other detection tools and location of dead cats, scats, etc. A systematic grid search is not proposed. Dog handlers and dogs will be used to identify areas of fresh sign and sweep areas where cats are most likely to persist, such as places with localised and/or seasonal prey sources. By virtue of working alongside other detection methods, dog teams may effectively cover the island up to two times during the mop-up and validation phase. Dog team effort will be like the camera team effort, as teams will be working alongside each other to target cats. Detection dogs have been used during previous eradications to search for cats during mop-up and validation phases[66]. Dogs were found to be particularly effective at identifying fresh cat sign and buried scats on Auckland Island during summer 2018/19. Currently there are insufficient dog handler teams for cats to meet the needs of the project. However, with adequate lead-in this can be addressed through a training programme.

Trapping to target individuals

Most successful cat eradications have relied heavily on leg-hold traps during the mop-up phase[66]. Leg-hold traps serve a dual purpose of detecting and capture of remaining individuals. Leg-hold trapping guided by trail camera footage and dogs is proposed as the primary method of targeting cats in the mop-up phase. Leg-hold traps were used successfully during recent trials on Auckland Island and trapping efficiency was greatly increased when cameras were used to target trap placement and design the trap set[14, 19].

Evidence supports the use of a range of lures for trapping, including food, visual, social or audible lures, to increase interest from individuals[66]. The density of traps used in cat eradications varies widely due to a range of factors such as terrain, home range size of cats, ability to cut tracks, and variation in the sequence of techniques etc. Trap spacing will be informed by analysing home range and habitat use data and can also be tailored to individuals based on data from other tools (such as camera footage). A team of 10 people will be responsible for running a trapping programme by responding to detections and targeting effort to catch known individuals, managing a skeleton network of traps in high likelihood areas and assisting with camera network data management. Most of this team should be dog handlers. Currently this capability does not exist, and a training programme will have to be implemented ahead of the eradication programme initiation to meet personnel requirements.

To account for individual behaviours of surviving cats during the mop-up phase, additional trap types are considered for occasional or targeted use. Cage traps are used effectively in cat control operations around New Zealand and have been used in previously successful island eradications (e.g. Tasman Island, where 20 of the last 28 cats were caught in cage traps[68]). At Macraes Flat, cages catch as many cats as leg-holds and all age classes and sizes of animals are caught (P. Liddy 2018, pers. comm.). The literature supports a period of familiarisation with open cage traps and food bait to increase their successful use in feral cat populations. A significant advantage of cage traps over leg-holds is that there is a smaller risk of a cat escaping from a cage trap and becoming trap averse. Cage traps have already been adapted to remote monitoring with remotely monitored networks of cage traps using low-frequency radio technology currently in use at Macraes Flat and on Great Barrier Island (Aotea).

A small number of kill traps could also be used for medium- and longer-term surveillance monitoring in areas thought to be free or almost free of cats and places that are difficult to access. Kill traps have an advantage over both leg-holds and cage traps in that they do not need to be monitored daily so can be 'left behind' in blocks that have been worked through. Important caveats to using kill traps are, firstly, the need to be sure that any kill traps will function perfectly and have low risk of escapes; secondly, that a suitable long-life lure is available that will reliably attract cats over a period of weeks to months; and thirdly, risks to non-target species are understood and agreed to be acceptable.

Again, careful placement of traps at each site and within a landscape are integral to the success of these tools[66]. Traps carry a risk of educating animals if an escape occurs[66]. For example, it took 10 months to re-capture a cat that escaped from leg-hold traps during the Raoul Island cat eradication[69]. The risk of escapes can be mitigated to a large extent by using experienced trappers, care in selecting sites and setting up and maintaining trap sets.

Key risk:

- *Cat detection dog and handler capability, critical to the success of the programme, is not available at the scale required for Auckland Island. A selection and training programme with adequate lead-in time is needed to build the capacity and capability of a skilled trapping team with an eradication mindset.*

Next steps for quality project design:

- *Investigate advances in remotely monitored trapping technologies during the project planning phase and perform a cost benefit analysis for their use on Auckland Island.*

Food dumps to detect and target individuals

Food dumps successfully and repeatedly lured cats on Auckland Island during trials in winter 2019[19]. It is likely that cats on Auckland Island scavenge significantly more in winter than in summer, feeding on coastal detritus such as dead marine mammals. Data from collared cats on Auckland Island[30] and high catch rates in coastal forest in winter 2007[15] suggest that more animals utilise coastal habitat during winter. Strategically placed dumps of food, for instance large amounts of fish or mammal carcasses, can be monitored with trail cameras. If cats are detected at these sites and activity patterns are noted, a shooter stationed at the site can dispatch the animal when it returns or set traps. Animal carcasses (e.g. sheep or pig) are an effective lure and should be placed in covered habitat to limit the ability of non-target species (e.g. giant petrels *Macronectes* sp.) to consume them, increasing their longevity as a lure[19]. Careful placement and/or light vegetation clearance will be required to ensure food dumps will allow shooters a clean shot.

Aerial hunting

Aerial hunting assisted by thermal camera technology has been shown to be an effective tool for detecting cats and kittens in tussock and light scrub on Auckland Island[19]. Applications of this tool in thick scrub and forest appear to be limited for cats. Sporadic searching for cats using aerial thermal imaging in alpine areas and inaccessible terrain would be beneficial through the mop-up phase. Searches along the steep terrain of the west coast could be timed to coincide with petrel fledging as collar data has already shown that some cats make large movements to exploit these resources[14].

Next steps for quality project design:

- *Aerial hunting effort will be informed by lessons on the detectability of cats from extensive aerial work during the pig programme. The information obtained will be used to analyse the costs and benefits of applying this tool for cats on Auckland Island.*

Targeted hand-laid toxin

Hand-baiting is an option as a response to a detection on camera (aerial or trail camera). It provides an opportunity to put an animal at risk over a relatively large area quickly and to rapidly target sites where cats are likely to frequent (habitat boundaries, animal tracks). Baiting cameras with toxic bait will provide data to increase the confidence of targeted individuals encountering and consuming toxic bait. Registration and a good understanding of efficacy will inform the use of this tool.

Seasonal timing

Targeting mice in summer would mean the mop-up phase for cats can commence in early winter (April onward). In winter, temperatures are colder and food is less abundant which will be enhanced by the eradication of mice. For this reason, it is important that the mop-up operation for cats commences as soon as practicable following the mouse operation. Bait uptake by feral cats in Australia was seasonally variable but more consistent in late summer and early autumn as prey availability and minimum overnight temperature decreased[70].

Next steps for quality project design:

- *Retrieve GPS collars from cats on Auckland Island to understand variance in habitat preference and movement to inform spacing and delivery of eradication tools.*

Validation

Validation for the cat eradication will involve a combination of presence/absence data from:

- A network of trail cameras to identify live cats and, in some cases, to match dead ones with previously collected images.
- Cat detection dogs to search for both scent and scats.
- The use of a DNA database to identify individuals and their removal.
- The use of aerial thermal cameras to search inaccessible areas.

Cat DNA will be collected and analysed following the mouse eradication to help confirm cat presence/absence on Auckland Island. DNA will primarily be sourced from scats, which can be collected by field staff who record a date and location for each sample. Detection dogs will be used to facilitate collection. Samples will also be collected from cat carcasses located during eradication operations and compared against the database and camera footage to ascertain the likely number of individuals that remain. The turnaround time will be a constraint, as samples need to get from the island to a lab on mainland New Zealand to be analysed. The turn-around time will relate to resupply runs, approximately every 3–6 months. Ultimately this information will be important at the end of the operation to confirm eradication success and that a decision to stop is appropriately timed.

Presence/absence data collected with the methods described above will be modelled and used to provide a high level of confidence that eradication has been achieved before success is declared.

5.5 Acceptability

There is strong support for the project from a range of stakeholders, including the New Zealand public, Ngāi Tahu, concessionaires, Government, potential suppliers, potential partners and internal DOC whanau. No significant negative issues regarding acceptability that may impede feasibility have been identified to date.

5.5.1 Socially acceptable

There have been high levels of support for the proposed project to date. Ongoing advocacy and engagement are critical to initiating and funding the project (see section 6.6.4 – *Advocacy and engagement*).

Ngāi Tahu support

As tāngata whenua, Ngāi Tahu have a long history and connection with Auckland Island and the NZSIA. Ngāi Tahu hold rangatiratanga in their takiwā, and their Kaitiakitanga rights and responsibilities, customary rights and interests stem from that. They have a shared vision to remove mammalian pests from the island. The strong commitment, leadership and support provided to date has been noted both within and external to DOC. Ngāi Tahu is an active member on the Governance Group to ensure hapū and whanau perspectives are embedded in the decision-making process. Ngā Papatipu Rūnanga ki Murihiku have provided strong support with involvement of leading Ngāi Tahu kaumatua Ta Tipene O'Regan and the Deputy Kaiwhakahaere supporting the mahi. Ngāi Tahu have clearly stated this place and this project are important to their future.

As the project develops, the opportunity for a true partnership with iwi, hapū and whanau is emerging, one that allows iwi aspirations to be incorporated in the project design and delivery. Together, DOC and Ngāi Tahu stand shoulder to shoulder, encouraging potential investment partners to share in the vision and commitment to success. A relationship vision document has been drafted to inform project design (DOC-6262719).

Public support

The Maukahuka project has widespread public support to date, which is expected to continue. DOC's programme to rid Antipodes Island of mice in 2016 (Million Dollar Mouse) achieved significant recognition and public support, which could be emulated and expanded upon. For the Maukahuka project to be well-accepted socially, the hugely significant benefits need to be well communicated locally and internationally. The ethical treatment of cats and pigs is likely to be an emotive issue for some members of the public, especially regarding the use of toxins for cats, but this issue can be addressed through engagement and communications.

An important opportunity exists to better connect people to the NZSIA and socialise the stories of its history, value and the great conservation achievements and ambitions for the place. Technology such as live webcams, interactive web pages, citizen science contributions and crowdfunding (e.g. 'sponsor a hectare' campaign) all hold great potential for this project. The networks of project partners locally and internationally offer an opportunity to maximise outreach and engagement with a range of audiences and leverage larger conservation gains.

Initial external communications include articles targeted at key audiences such as Predator Free New Zealand (PFNZ)[a] and Forest & Bird[b] and presentations were given to interested community and business groups. A hui with key potential partners was jointly hosted by Ngāi Tahu and DOC in May 2019. Newsletters and meetings have been used to keep these organisations up to date. A summary of the major feasibility work undertaken between November 2018 and November 2019 was shared with interested parties[c] at the end of 2019.

There have been challenges with sharing information in a variety of formats through the DOC website[d]. A project website managed in association with a project partner and supplementing the DOC website was a successful strategy for theMillion Dollar Mouse[e] project (website hosted by the Morgan Foundation), which could be used again.

The proposed eradication has had support to date from:

- Budget 2018 funding, International Visitor Levy funding and support from MOC and Ngāi Tahu
- Promotion by Predator Free New Zealand Trust
- General public enquiries from individuals, groups and businesses re. donating, volunteering, in kind support, work opportunities, presentations etc.

Next steps for quality project design:

- *Pursue the development of a project website as an accessible platform to inform and engage the public.*
- *Resource the project team with appropriate skills and capacity to undertake advocacy and engagement work reflective of the project size and complexity.*

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[a] https://predatorfreenz.org/author/rose/

[b] https://www.forestandbird.org.nz/resources/forest-bird-magazine-spring-2019

[c] https://www.arcgis.com/apps/Cascade/index.html?appid=28dd93dd20d04abb97f49ac481e4ac24

[d] https://www.doc.govt.nz/our-work/maukahuka-pest-free-auckland-island/

[e] http://milliondollarmouse.org.nz/

Pig-specific interests

Living Cell Technologies conduct medical research on a privately held herd of Auckland Island pigs and have previously stated that they may wish to harvest approximately 10 more pigs from the island, subject to trial results. They hold a current concession to take pigs from Auckland Island. A second company NZeno, established in 2018, have indicated interest in accessing Auckland Island pigs. They are aiming to establish research into pigs as possible kidney donors for humans. They currently hold no concession. The potential medical value of the pigs is not genetic but due to their long isolation from disease, an important factor for research involving animal tissue being used in humans. The research means that there may be a wider public interest in the project, so further engagement and relationship management will be required. The Rare Breeds Society may also be interested in more pigs, having removed 17 pigs in 1999.

Next steps for quality project design:

- *Maintain communication with medical research company(s) interested in obtaining Auckland Island pigs and address future needs to avoid risking delays. Engage with key contacts during planning phase. Removal of further pigs should be completed as early as possible.*

Tourists and concessionaires

Auckland Island is uninhabited and visitor numbers are carefully controlled by a permitting system managed by DOC's Permissions team. The tourist season runs from mid-November through to mid-March with 750–850 people visiting Auckland Island annually. Several tourist operators hold concessions from DOC to take tourists to the island. The project objectives are aligned with the values of these operators who are supportive of the project.

It will not be possible to suspend tourist activity on the island during the proposed eradication. Good communication with concessionaires is required to manage potentially competing activities on the island (e.g. use of anchorages) and hazards associated with operations. Some infrastructure and, from time to time helicopter and shipping activities, will also be visible, altering the wilderness experience for tourists. If managed well there are also benefits to be gained, including better visitor experiences as a result of improved access, particularly to heritage areas (e.g. installation of boardwalks and vegetation clearance) and opportunities for storytelling and personal connection with the project via staff representatives onboard vessels. Nearby Enderby Island offers a site for visitors to appreciate the natural and historic heritage without compromising eradication efforts. The restoration of native flora and fauna following eradication on Enderby Island provide a tangible taste of the benefits of eradication for visitors to the islands. With good communication, the concessionaires will be valuable advocates and have been strong supporters of the initiative to date.

DOC internal support

Support will be required from across DOC to deliver this ambitious project, regardless of the final operating model established to govern, manage, control finances and deliver it. For the project to be initiated and sustained, buy-in is needed across the Department, from the top down, with local and national service support critical to success. Working with many internal teams to establish feasibility (Table 16) has highlighted the extent of support required and the capacity pressures facing many teams. Internal communications to create awareness and support for the project within the Department, have occurred throughout the Feasibility Phase.

Technical developments required by the project are being worked on in collaboration with other teams (see section 6.1 – *Research and development*). Coordination and integration of the Maukahuka project's objectives into these work streams is needed for efficient use of resources and to ensure timely delivery.

Table 16. Internal DOC teams substantively contributing to Maukahuka Pest Free Auckland Island. See footnotes for abbreviation definitions.

INTERNAL TEAM	WORK STREAM	COLLABORATION/SUPPORT PROVIDED
Biodiversity	• Survey and sample design for monitoring	• Technical advice • Financial contribution
Business Assurance Unit	• Business case development	• Assurance and technical advice
Customer Engagement Unit	• Communications	• Technical advice • Operational support
Finance	• Business case development • BAU	• Technical advice
IEAG	• Project design • Quality assurance	• Technical advice
ISS	• Image recognition for trail cameras • Mass data storage requirements • Connectivity	• Technical advice • Operational support
Operations	• Project delivery	• Operational support • Technical advice
Outcomes Management Office	• GIS	• Operational support • Technical advice
Partnerships	• Philanthropic/third-party funding • Scope and design of governance and partnering model	• Partner relationship development
Planning Support Unit	• Business case development	• Strategic advice
Procurement	• Business case development • Sourcing suppliers • Contracts	• Technical advice
Biodiversity Threats	• Thermal camera development • Cat VTA development	• Technical advice • Co-ordination with other invested projects • Financial contribution

DOC = Department of Conservation; IEAG = Island Eradication Advisory Group; ISS = Information Shared Services; BAU = business as usual; GIS = geospatial information services; VTA = vertebrate toxic agent.

5.5.2 Politically and legally acceptable

The Minister for Conservation (MOC) at the time the feasibility study was undertaken strongly supported the project and acknowledged the strategic alignment between the Maukahuka project and PF2050. This support was exemplified by the award of funding from the International Visitors Levy Fund in 2019 for initial planning, approved by the Minister of Tourism, MOC and Minister of Finance. The strong and visible support from Ngāi Tahu has had a significant positive impact on the MOC's support.

The project must adhere to a variety of legislation, regulations, procedures and codes of practice, overseen by agencies including Maritime NZ, Civil Aviation Authority, Ministry of Primary Industries, WorkSafe and DOC. A compliance register is stored at DOC-6040470 and will evolve with the project. Uncertainties that have been identified and may have an impact on planning are summarised in Appendix 6 – Table A6.1, p. 114.

Applicable legislation is the Wildlife Act 1953; the Wild Animal Control Act 1977; the Resource Management Act 1991 (RMA); the Animal Welfare Act 1999, the Marine and Coastal Area Takutai Moana Act 2011; the Marine Mammals Protection Act 1978; the Fisheries Act 1996 and Heritage New Zealand Pouhere Taonga Act 2014. A Regional Coastal Plan for Kermadec and Subantarctic Islands (Coastal Plan) is a requirement of the RMA and became operative on 15 September 2017. It mainly manages the risks of oil spills and marine biosecurity breaches. The Southland Murihiku Conservation Management Strategy 2016 (CMS) is a statutory document prepared under the Conservation Act 1987 that aims for integrated management of the natural and historic resources and specifies what activities are considered appropriate in specific areas. A Resource Consent will be required for the related infrastructure and these will be covered by the Infrastructure and Logistics Operational Plan. Resource Consent is not required for the application of brodifacoum (Regulation 5, Resource Management (Exemption) Regulations 2017).

Semiautomatic firearms are needed for effective aerial hunting in this eradication situation. The ban on semiautomatic firearms will affect future procurement. Dispensation to purchase and hold will be required, and firearms will likely need to be imported as New Zealand suppliers will no longer stock them. Permission to import restricted firearms will need to be acquired. Secure firearms and ammunition storage on the island and during transit will either need to be inspected by the police or dispensation gained from an in-person inspection and standards considered during infrastructure design.

Key risks:

- *The duration of this project will span several election cycles and may be subject to varying levels of support. Strive to secure Crown investment for the life of the project to minimise impacts of external disruptions. Use a collaborative approach to ensure Government and partners hold each to account.*
- *Changes to protocols, permissions and legislation are likely to occur over the life of the project, with potential to increase complexity and cost, which could impact feasibility. For example, DOC is currently reviewing the helicopter operating protocols and project feasibility is dependent on positioning single engine helicopters onto Auckland Island by direct flight. Good relationships with external regulatory bodies and internally within DOC are vital to proactively manage project risk. Potential exemptions or grandfather clauses may mitigate some of the effects for changes introduced during the project.*

Next steps for quality project design:

- *Understand how changes to the Regional Coastal Plan, CMS and DOC's Helicopter SOP may impact project activities and plan contingencies.*

5.5.3 Environmentally acceptable

No significant negative impacts that may impede feasibility have been identified to date. All infrastructure installed for the project will be removed upon successful completion of the pest programmes, unless district or national Departmental need directs otherwise. No population of non-target native species present on Auckland Island or other islands in the archipelago are considered at risk. Past eradications and recent on-island trials provide an indication of potential environmental effects, including but not limited to non-target species impacts, soil and vegetation clearance and disturbance, increased biosecurity risks, change to weed species distributions or abundance, waste management and transport, storage and use of toxins and fuels. For example, disturbances to vegetation from the infrastructure programme are expected to rapidly reverse over 5–20 years (as demonstrated by vegetation recovery on Antipodes Island after temporary infrastructure set up for the mouse eradication was removed[5]; and Enderby Island after rabbits and cattle were removed[57]). The successful eradication of mammalian pests is likely to generate overwhelmingly positive changes for the Auckland Islands (see section 4.4 – *Benefits*).

Some individual mortality of gulls species (*Larus* sp.), skua/hākoakoa (*Catharacta antarctica lonnbergi*), northern giant petrel/pāngurunguru (*Macronectes halli*), falcon/kārearea (*Falco novaeseelandiae*), Auckland Island pipits/pīhoihoi (*Anthus novaeseelandiae aucklandicus*), Auckland Island dotterels/tūturiwhatu (*Charadrius bicinctus exilis*) and non-native bird species is expected. Secure reservoir populations of native species exist on pest-free islands within the archipelago and could support a low to moderate level of reduction in breeding populations.

Release from browsing by pigs and mice, and soil disturbance associated with the project work may result in an increase in abundance or distribution of weed species. Lessons from Antipodes Island show the value of follow-up weed surveys at infrastructure sites, where introduced weed species have grown and been removed despite the intensive pre-departure quarantine that was in place[60]. The locally exotic New Zealand native olearia (*Olearia lyalli*) was introduced to Auckland Island and has the potential to expand and compete with native plants, particularly in disturbed coastal areas. No other significant weed issues have yet been identified and impacts will likely be manageable with operational biosecurity and a commitment to post-operational surveillance to detect and stop weeds establishing. An updated weeds survey and management plan is required in the short term and falls under the mandate of the Southern Islands team, Murihiku.

Working dogs will be present on the island following toxic bait applications. There is a primary poisoning risk to dogs if they eat baits, and a secondary poisoning risk through scavenging carcasses. Dog handlers and other staff must be vigilant about these risks and apply mitigations as required (e.g. use of muzzles, removal of poisoned carcasses from high risk areas, etc.).

A register of known heritage sites exists (DOC-5588023 & DOC-3199468) and all site works will comply with required permissions (see section 5.5.2 – *Politically and legally acceptable* and Table A6.1, p. 114). As part of operational planning, the Maukahuka project will undertake an assessment of environmental effects (AEE) to assess the actual and potential effects of eradication activities and mitigations in accordance with best practice and meeting legislative requirements (see Table A6.1, p. 114). The monitoring plan will account for the benefits and impacts of the project (see section 6.6.6 – *Monitoring plan*).

Next steps for quality project design:

- *Overarching site management plans including the NZSIA Biosecurity Plan, Subantarctic Research Strategy and a Subantarctic Strategy should be updated/completed by the relevant district and national teams to guide project design and ensure strategic alignment.*
- *Engage with Murihiku team to ensure coordination and alignment of strategy and programmes.*

5.5.4 Outcome is sustainable

If eradication can be achieved, it is highly likely that the island can remain free of introduced pest mammals. The isolation and remoteness of the site offer inherent protection. There are no islands with pest mammals within swimming distance of Auckland Island; following eradication the nearest cats and rodents will be on Rakiura/Stewart Island, nearly 400 km away, and the nearest feral pigs will be 500 km away on mainland New Zealand.

Incursion pathways to the island are largely controlled by DOC through permitting or management of its own activities. However, fishing vessels shelter inshore; and unpermitted visitors probably stop at the island occasionally. Engaging island users through targeted advocacy is recommended to expand surveillance and reduce negligence. An overarching biosecurity plan for the NZSIA is outdated and requires review with consideration of future pest-free status on Auckland Island. Sound local systems are in place, but a biosecurity plan should be created for Maukahuka for all phases of the project including preparations in the planning phase and demobilisation. This will help design the mainland supply chain and manage the large and extraordinary movements of goods and people to a low-impact site. Significant planning and investment are required as soon as the project is initiated to establish fit-for-purpose facilities and manage biosecurity to the standards and capacity required.

Next steps for quality project design:

- *Increase advocacy with concessionaires, permitted visitors and the fishing industry to increase biosecurity awareness and surveillance.*
- *Ensure NZSIA biosecurity plans are reviewed and specified actions can protect the investment.*

6. What will it take?

6.1 Research and development

Several developments for improved tools and capabilities are essential to ensure feasibility of the eradication: the development of high-resolution thermal cameras and operator teams, reliable low-sow-rate bait buckets, sufficient dog handler teams and software to triage imagery from the network of trail cameras. Additionally, the availability of a cat vertebrate toxic agent (VTA) and better batteries for trail cameras are highly desirable and would significantly improve likelihood of success. All new tools must be rigorously tested and proven to be reliable and effective with contingencies available for critical elements (best practice). The Maukahuka project has engaged with relevant DOC teams and suppliers to understand how to and/or drive tool developments and timeframes with respect to project requirements. With seed funding and adequate planning, it is possible to drive and/or support these developments ahead of project initiation. Feasibility will need to be re-assessed if key tools are not available prior to programme initiation. Planning should consider options if preferred tools cannot be made available.

The development of new tools requires support across DOC (see section 5.5.1 – *DOC Internal support*). Outputs will significantly support additional conservation work, including other PF2050 objectives.

6.1.1 High-resolution thermal imagery and operator capability for aerial hunting of pigs

A development programme is required to make high-resolution thermal imagery cameras (n = 3) and operator teams (n = 3; each consisting of camera operator, shooter and pilot) available for the pig eradication. This capability is essential to the feasibility of the pig programme (see section 5.2.2 – *Aerial hunting* and *Ground hunting*) and operational delivery will be delayed until this capability is available. Analysis by ZIP and DOC suggests the market alone won't be able to provide the solution. A development project is proposed to produce cameras fit for purpose that can be made available to operators. Helicopter operators for the pig programme will need to be engaged early to aid development of this capability. DOC plans to undertake an average of 5000 hours hunting pest ungulates annually (DOC Business Planning data 2015–2019; DOC-6060684), and could assist by identifying and providing opportunities to committed suppliers in the lead up to the eradication. However, DOC's Biodiversity Threats team have no current need or intention to invest in this tool for national purposes (P. Jansen 2019, pers. comm.). Therefore, development would need to be led and funded by the Maukahuka project.

6.1.2 Better bait bucket

Current bait bucket technology doesn't reliably deliver bait on the ground at 4 kg/ha as desired. The development of a reliable low-sow-rate bait bucket is critical to the feasibility of eradicating mice from Auckland Island (see section 5.3.2 – *Baiting prescription*). GPS-metered seed-spreading technology from the agricultural industry has been identified as a probable solution to incorporate into bait bucket design. The Maukahuka team has engaged with commercial operators driving this work. Distribution and flow rate trials for new bucket designs are in development. It is recommended to test a final product in several operations (e.g. Tiakina Ngā Manu or similar). If a reliable low-sow bait bucket is not available, an increased sowing rate is possible using current bait bucket technology, but feasibility is subject to shipping logistics. However, more bait equates to increased logistic needs and increasing risk of not completing bait spread.

6.1.3 Detection dog team

Cat detection dog handler teams are required to eradicate cats from Auckland Island (see section 5.4.1 – *Dogs*). Only four cat detection dogs are currently certified as part of the Conservation Dogs programme. Developing the capacity for detection dogs and handlers will need to be planned and instigated early to ensure capacity is available when required e.g. a dog training programme will need a 2-year lead in. It is proposed to start by training two handlers and four dogs in the first 2 years to initiate a programme and determine exactly what dogs would need to be trained for (scent, scats etc.). Handlers could work as part of landscape-scale cat control at the Te Manahuna Aoraki Project (TMA) in the Mackenzie Basin (or at other DOC-led cat control work) and costs shared, benefiting both. Professionally training dogs to provide to selected handlers with training time in the lead up to eradication would be the most efficient means of building capacity. If detection dogs and handlers are not available the eradication will take longer to achieve, which will cost more and increase the risk of failure. Confidence in the result relies on more than one type of detection tool.

6.1.4 Trail cameras

Software that automatically labels and accurately triages imagery/false triggers is required for a camera grid covering the whole island to ensure the feasibility of eradicating cats from Auckland Island (see section 5.4.2 – *Camera detection network*). Delivery of the operation would be delayed until this capability is available. Development of the requirements are staged. As a priority, Maukahuka has engaged with the market to determine what software capability is currently available. Hardware developments that improve maintenance requirements or enable remote data transmission are a secondary priority. For example, a rechargeable battery pack would avoid the use and cost of the vast quantities of AA lithium batteries that would be required to run more than 1500 cameras over 2–3 years; automated alerts sent from cameras is a more uncertain opportunity at this scale but could save the need to physically visit every device to download data and improve response time.

6.1.5 Cat Vertebrate Toxic Agent (VTA)

An aerially distributed cat VTA is the preferred knockdown tool for cat eradication on Auckland Island and would reduce risk to the programme by removing the reliance on trapping as the primary knockdown tool (see section 5.4.2 – *Cat-specific vertebrate toxic agent (VTA)*). DOC's Biodiversity Threats team is developing a VTA for aerial distribution to target mustelids and, potentially, cats. The Maukahuka team is supporting the development and registration of this VTA. In winter 2019 the palatability and degradation of four possible bait matrices were tested on Auckland Island[19]. Subsequent pen trials of toxic versions of the bait have not been effective enough at killing cats. Further testing is being planned and separate cat and mustelid baits are likely to be needed. However, timeframes could be tight to be ready for the cat eradication and contingency options should be explored in case development stalls. Future analysis of GPS data from 31 collared cats on Auckland Island[30] will also improve the understanding of how essential an aerially distributed VTA is for the cat programme. If a cat VTA is not available, trials support the feasibility of using the camera network and targeted trapping as a knockdown tool[14, 19]. However, tracking data show a small number of cats utilise areas that may be inaccessible to people (cliffs) or areas where detection devices have proven problematic (tussock)[14, 19, 30]. Further data are required to understand whether these movements or habitat preferences are seasonal in order to understand what and how much time would be required to target these cats. This means this approach would need to run for much longer to give confidence in eradication and carries greater risk of missing individuals and failing than if a cat VTA was available as well.

Key risk:

- *Lack of strategic alignment across DOC risks prerequisite improvements to tools and technologies not being developed in time. Prioritisation of the project's research and development objectives needs to be articulated throughout DOC and supported by management.*

Next steps for quality project design:

- *Develop a Research and Development Plan that outlines pathways and milestones for tools development.*
- *Understand how to react if a cat VTA is not available. Plan the training programme with enough lead-in time to train a greater number of cat-trappers and dog handlers in this case.*

6.2 Affordability

The proposed pest eradication requires one-off investment for permanent and internationally significant biodiversity benefits with low to zero ongoing costs to sustain. While full investment may not be required upfront, a strategic investment strategy spanning the life of the project is required.

Purchase of a vessel would provide a desirable level of certainty for required transport capability but is considered unfeasible at this time due to cost and the complexity and risks of ownership models, vessel survey and maintenance requirements. This should be reassessed as part of future discussions with project partners in conjunction with expert industry advice. In the interim, engagement with the shipping industry should be undertaken to determine the feasibility of a long-term lease. Viability of both these options is dependent on project initiation and a long-term funding commitment.

Investment in developing better eradication tools enables feasibility and delivers greater benefits (to the project and beyond) and has potential to significantly shorten the delivery timeframe, realising large cost savings.

Estimates of costs (November 2019; DOC-6208649) to deliver the project under the preferred option are $80m for operational costs and $4m for depreciation costs over 10 years (Figure 16). This is based on a nominal 50/50 Crown/Partners investment model and equates to an average $4.2m per annum for each party with significant peaks and troughs over the programme (Figure 16). Budget and financial management implications of different partnering models and investment scenarios need to be understood in greater depth and optimised when developing partnership agreements (e.g. it may be more cost effective for partners rather than DOC to hold capital, as DOC operational costs are subject to corporate overheads). Estimates for inflation, DOC corporate overheads and contingencies may amount to as much as $27m but are likely to be underwritten by DOC national funding pools (Figure 17).

The cost per hectare for Maukahuka is not dissimilar to other subantarctic island eradications, despite the complexities of the remote situation, the logistical requirements and the inclusion of three operations and a large infrastructure programme in the project scope (Figure 18). The Macquarie Island rodent and rabbit eradication was budgeted at and cost $25m (AUD). This was a baiting operation and 3-year hunting programme on an island a quarter of the size of Auckland Island, with infrastructure and pre-existing services and logistics in place.

Opportunities exist for direct cost savings to the project (in the order of millions of dollars) via sponsorship, in-kind support, volunteers and efficiencies from research and development (Table 17). Other DOC programmes would additionally benefit from the capability development.

6.2.1 Budget uncertainties

The costing models are increasing in detail and certainty as planning progresses and should be updated to reflect current thinking once operational plans are drafted. Four clear areas of uncertainty remain: shipping, helicopters, staffing requirements and research and development for new tools. These should be the focus of next steps to refine the project plan and costings. Weather will remain as a variable outside the control of the project that will have a large impact on operational efficiencies and final cost. The level of contingency required is likely to decrease significantly as key costs (such as transport and logistics solutions) become more certain.

Shipping

This is a major uncertainty, complex to model, with a large dollar range heavily influenced by home port location, size and function of the vessel and availability year to year. A clearer understanding of market options is now needed and requires input by industry expertise. The risk imposed by limited availability also needs to be accounted for. Not being able to source or pay for large shipping services would delay or stop the project.

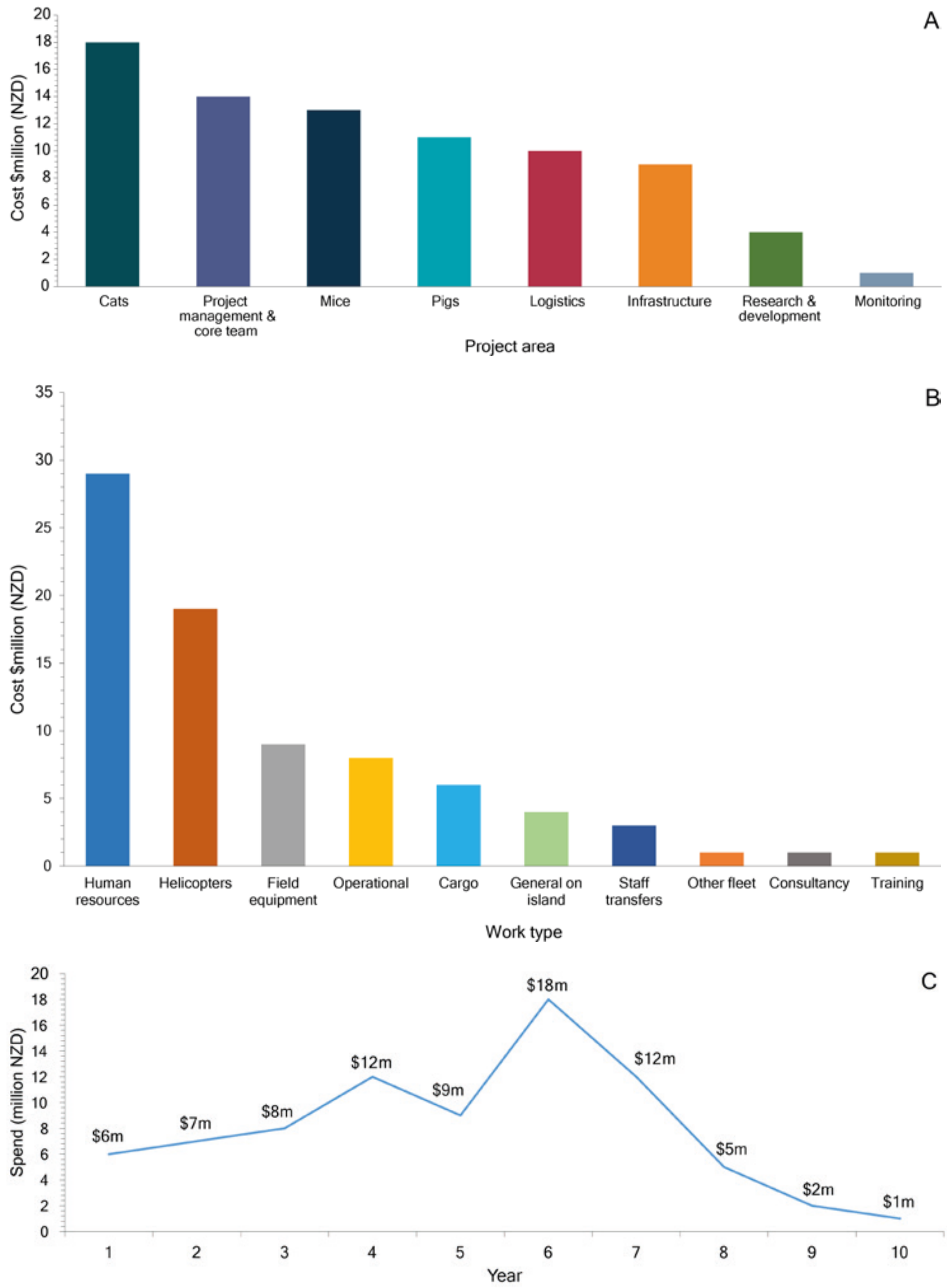

Figure 16. Estimated operating budget (NZD) to deliver Maukahuka by project area (A), work type (B) and year (C). R&D = research and development; NZD = New Zealand dollars

Helicopters

Helicopter options need to be better understood. For example, there are potentially about $8m of standby costs for helicopters for the operation's period, if normal fees are applied. However, bespoke options we cannot yet rely on could result in significant savings (e.g. purchase or lease of two helicopters could save between $4m and $5m in standby fees). Embedding aviation and creative, competent procurement expertise in the project team would enable a new procurement paradigm. Shared financial risk with key suppliers could lead to better pricing and fairer contracts which might attract stronger competition.

Staff

Staff rotation and contract structure will be largely dictated by available transport solutions. There are large effects on budget and logistics of teams rotating on and off the island for different durations (e.g. 6-week cf. 3–6-month rosters and associated contract structures).

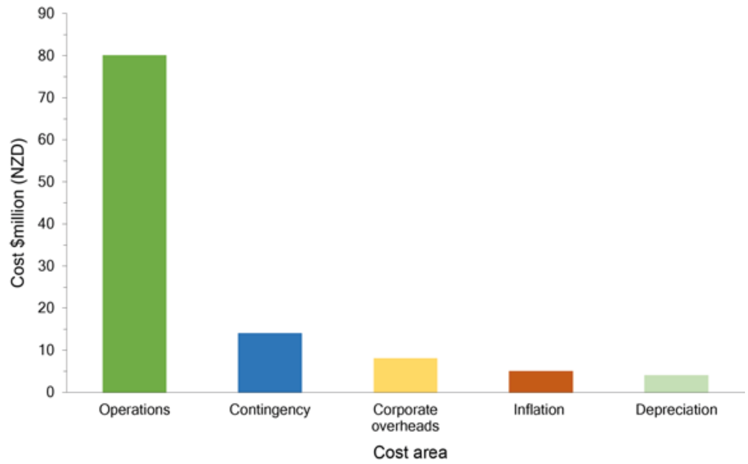

Figure 17. Estimated total budget (New Zealand Dollars) to deliver Maukahuka. These figures are based on a nominal 50/50 Crown/Partners investment model. Contingency averages 15% operational expenditure and 20% capital expenditure and reflects uncertainty in shipping and reliance on good weather conditions. Corporate overheads of 15% are only applicable to the Department of Conservation's 50% contribution. Consumer price index inflation of 1.5% pa from 2021/22 has been applied to operating expenditure and operating contingency.

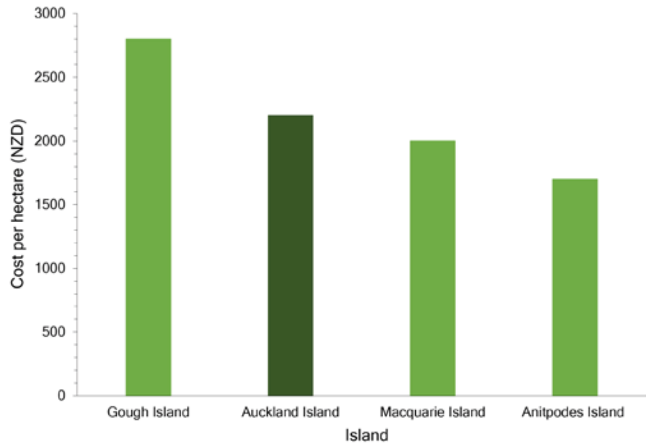

Figure 18. Cost per hectare ($NZ) for eradication projects on similar subantarctic islands.

Table 17. Potential project savings resulting from investment in research and development (NZD) under the preferred funding plan.

DEVELOPMENT	INVESTMENT	SAVING	DESCRIPTION
Thermal camera development and availability of capable operating teams.	$2m	$4.6–6m	Reduce the duration of the pig ground hunting programme by up to 40%.
Mice bait bucket development and purchase of 8 buckets.	$0.4m	$1.4m	Reduced bait volume, associated logistics and bait spreading costs relative to best practice by being able to sow bait at low sowing rates reliably, thereby increasing the likelihood of success.
Trail cameras with automated imagery processing software and remote sensing network.	$1m	$4.8m	Reduced data checking costs and staff time from greater efficacy. Faster response time to cat detections and significantly increased confidence in absence and eradication result.
Total	$3.4m	$10.8–12.2m*	

* Note the anticipated savings from research and development investment are included in forecast operating budget.

Research and development

The benefits of upfront investment now in new technology and capability are immense (see section 6.1 – *Research and development*). Importantly for the project, these developments will ensure feasibility, reduce risk and complexity, and increase chances of success. Additionally, they will shorten delivery time by months, and provide the opportunity to conclude pig and cat programmes quickly if detection tools provide strong confidence in validation of eradication success. They also provide extensive strategic and national benefits (e.g. PF Rakiura, PF2050) and a high return on investment (Table 17).

Next steps for quality project design:

- *Review project cost estimates once operational plans are drafted.*
- *Budget and financial management implications of different partnering models and investment scenarios need to be understood in greater depth and optimised when partnership agreements are developed.*
- *Embed shipping and helicopter industry expertise into the project team to design procurement and manage complex compliance and contract scenarios. Ensure contract management capacity is resourced appropriately.*
- *Explore option to purchase/lease two helicopters to remain on the island for the duration of the project.*

6.2.2 Funding

During the Feasibility Phase, DOC's preferred funding strategy for the project was a split between Crown and private contributions via partner organisations and individual donations. A commitment from Government is required to provide confidence to interested partners and warrant their active involvement. A strategic investment plan is required to enable project initiation.

Potential sources of funds identified to date are the International Visitors Levy Fund (IVL), Treasury funds and private investment. DOC funding decisions are dependent on DOC's optimisation of landscape scale projects framework as well as economic recovery activity.

6.2.3 External partners

DOC's Partnerships team has worked closely with the project team to develop relationships with potential partners. There has been significant interest from major national and international philanthropic organisations. These organisations have indicated comfort with the proposed budget and operations but require a commitment from Government to fund a share of the project to provide the confidence required to invest. In effect, Government funding could leverage large investment in national biodiversity gains from both local and international donors. Success would similarly encourage growth in philanthropic funding streams.

Next steps for quality project design:

- *Continue engagement with potential funding partners and stakeholders to facilitate better understanding of relative costs, wider benefits, stopping points, complexities and opportunities.*
- *DOC should lead with a commitment to the project by securing the Crown investment and articulating an investment strategy for the life of the project, this will provide investor confidence enabling the required third-party contributions.*

Plate 6. The Maukahuka Pest Free Auckland Island project will require infrastructure where the rugged environment, flexibility and transportability drive design. Custom-built field huts were installed at Smith Harbour, Auckland Island during field trials in summer 2018/19. Huts were transported to the island by cargo vessel (MV Searanger – Seaworks) (A) and were lifted into position by a B3 Type Squirrel helicopter (Southern Lakes Helicopters) (B). *Photo credits: James Ware/DOC (A) and Finlay Cox/DOC (B).*

6.3 Island infrastructure

The eradication operations will be land based, requiring installation and later removal of extensive infrastructure at strategic locations across Auckland Island. Basing all operations from land is a feasible option that has been done before for numerous island eradications.

Required infrastructure includes accommodation, bait staging and delivery sites and fuel storage (Figure 21). Infrastructure design should be flexible enough to support all three programmes, which may require some rearrangement/relocation of structures. For example, sites designated for bait loading during the mouse or cat programmes could serve as trapping and staging sites for pig operations and extra hangarage for the mouse programme provides dry storage and recreation space during the pig and cat programmes.

It is expected that a period of 12 to 18 months spread over 2–3 years (activities focussed in summer) would be required to install necessary infrastructure before pest operations commence. Initially, the infrastructure programme will require considerable boat-based support until facilities can support land-based teams across the island.

Ship-based operations were considered but discounted due to high costs (several tens of thousands of dollars per day) over the life of the project. If a ship was owned, the project would also own the risk if it became unserviceable with limited ability or funding to source an alternate option compared to a company contracted to supply shipping services. The main efficiency gained through ship operations would be logistical, with a reduction of ship-to-shore transfers for operational supplies such as food and fuel and associated back loads of fuel, empty containers and waste etc. Financially this does not equate to ongoing costs associated with crewing a ship, maintenance and daily running costs. Even if a ship were purchased (as opposed to leased), minimum operating costs are estimated at $3.1m per annum. Moreover, significant investment in land-based infrastructure would still be required to support the number of helicopters required for operations during the mouse programme; and the ground hunting phase of the pig and the cat programmes due to weather restricting reliable access to the island (Table 6, p. 40). Buildings and anchoring systems should be designed for efficient installation and removal unless other user groups justify retention of some assets beyond the life of the project.

6.3.1 Accommodation and operational support facilities

Operating from one central site or several sites was considered. Set up and demobilisation effort and time are greatly reduced by installing one central base (cargo and passenger transport, biosecurity, total infrastructure requirements). However, an assessment of flyable weather and operating experience from summer and winter trials 2018/19 across multiple sites on Auckland Island supports the concept of a main central base, coupled with two subsidiary bases, one at each end of the island to service Carnley Harbour and Port Ross. Working from multiple sites increases productivity as local boat or aerial access is greater than whole-island access across mountain passes or long distances around the coast. (Figure 21, p. 83; Table 6, p. 40; Table 18; Table 19). Low cloud and rapidly changeable weather, risks teams and helicopters getting caught out or unable to access sites without local retreats. Subsidiary bases support the rolling front operating model for pig and cat programmes and will allow satellite crews for mouse baiting to be stationed efficiently when required.

Infrastructure requirements for each programme differ and change over time (Table 19). Modular facilities are proposed to increase flexibility. For example, once the operations requiring a larger base set up are complete (pig, mouse, cat aerial baiting), the extra accommodation huts can be flown to field locations as required for the dispersed cat hunters. Further benefits of separate buildings include safety. Infrastructure design needs to consider the needs of reverse quarantine for goods and supplies that arrive on the island.

Table 18. Proposed facilities to support pest eradication operations on Auckland Island.

	MAIN BASE	SUBSIDIARY BASE	FIELD HUTS	BAIT LOADING SITES
Number of units	1	2	17*	9*
Location	Smith Harbour	Port Ross, Carnley Harbour	Island-wide and mobile	Island-wide
Construction year	2, 3	2, 3	1, 2, 3	1, 2
Beds	24	20	2–6	Fields huts catering for six people
Catering	Large kitchen	Large kitchen	Benchtop cooker	Benchtop cooker
Sanitation	Shower, toilet and laundry facilities	Shower, toilet and laundry facilities	Basic toilet and shower facilities	Basic toilet and shower facilities
Office	Yes	Desk area	-	Set up for GIS
Communications	Satellite internet and VHF	Satellite internet and VHF	VHF	Satellite internet and VHF
Hangarage	6	2	-	-
Heli pad with tie-down	Yes	Yes	-	Yes
Fuel storage capacity	c. 50 000 L	c. 50 000 L	-	5000–20 000 L
Bait storage	Pods	Pods	-	Pods
Boat shed	Yes	Yes	-	-
Dog kennels	Yes	Yes	-	-

*Field huts will have capability to be shifted by helicopter depending on the needs of the programmes, e.g. to bait loading sites during mice baiting. Field huts will have storage sheds associated with them.

Table 19. Use of proposed facilities by programme during eradication of pigs, mice and cats from Auckland Island.

FACILITY	PROGRAMME	USE
Main base	Pig	• Main accommodation for aerial hunting team. • Accommodation for ground hunting teams in adjacent blocks. • Accommodation for support staff.
	Mouse	• Accommodation and main loading/refuelling site for all staff.
	Cat	• Accommodation and main loading/refuelling site for all staff for aerial baiting. • Accommodation for support staff during ground phase
Subsidiary bases	Pig	• Refuelling and accommodation for aerial team whilst working in adjacent blocks. • Accommodation for ground-hunting team whilst in adjacent blocks.
	Mouse	• Loading and refuelling sites. Accommodation as weather dictates.
	Cat	• Loading and refuelling sites. Accommodation as weather dictates during aerial phase. • Accommodation for staff during ground phase.
Field huts	Infrastructure	• Main accommodation to support build and track cutting teams. • Additional accommodation at base sites as required.
	Pig	• Daytime shelter and emergency accommodation • Additional accommodation at base sites as required.
	Mouse	• Accommodation for bait loading teams, GIS support at bait loading sites, daytime shelter and emergency accommodation. • Additional accommodation at base sites as required.
	Cat	• Day time shelter and main accommodation for ground phase field staff. • Additional accommodation at base sites as required.

Key risk:

- *There will be a significant lag between a decision to proceed and being ready to implement the infrastructure programme due to the requirements to establish a project team, do building design work and undertaking procurement. The lag time will increase with time between the feasibility phase and project initiation (if initiated) as knowledge and team capability disperse.*

Next steps for quality project design:

- *Project infrastructure is intended to be temporary. A DOC district team decision is required if any buildings are to be retained long-term so they can be designed with that in mind.*
- *Design and test construction and function of a prototype flat-pack modular field-hut to inform further building design.*

6.3.2 Power

Reliable high-capacity power sources will be required at the three base sites. The main base will be running approximately eight large chest freezers, refrigerators, general household electronics (lighting, computers, wireless networks), washing machines, tumble dryers and other high draw devices like power tools. Contingency power generation will need to be planned for. Longevity and maintenance of power solutions for the 10-year life of the project will need to be factored into power system design.

Options for the main base are a larger generator, hydro schemes, solar panel banks or wind (Table 20). The former three are used at the Whenua Hou field base, which has >30 people at high use times. There are significant creeks next to the Smith Harbour and Port Ross base sites. It is unknown what the solar capacity would be like, especially in the winter. Generators used on Whenua Hou and Anchor Island had issues with reaching their end of life faster than expected due to the maritime environment. Wind power generation is untested in the NZSIA but experience on Macquarie Island suggests a lot of maintenance is required in the corrosive and extremely turbulent/gusty environment. To date, small petrol generators (2 kW) have been used to power the much smaller scale field trials on Auckland Island, which will suit field huts but will be insufficient for the base sites during main operations.

6.3.3 Tracks

Access tracks are needed to increase travel efficiency, productivity, safety and morale and were proven to do all these things during trials in 2018/19. Tracks and the associated hut network will allow access to the tops when weather conditions do not allow flying, thereby limiting the negative impacts of non-flyable days on productivity (Figure 21, p. 83). Tracks will be particularly important when weather constrains retrieval by helicopter and hunters need to access the coast for boat pickup or return via foot.

Table 20. Power source considerations for the main base on Auckland Island to service eradication operations.

	GENERATOR	HYDRO	SOLAR	WIND
Weather-dependant	No	Yes	Yes	Yes
Fuel required	Yes	No	No	No
Battery storage required	Optional	Optional	Yes	Optional
24-hour supply	Yes	Yes	No	Yes
Mechanical skills required	Yes	Yes	Yes	Yes
Environmentally low impact	No	Yes	Yes	Yes
Resource consent required?	No	Yes	No	Yes

Approximately 80 km of access tracks through tight scrub and forest is required to facilitate the pig programme (Figure 21, p. 83). Only minor tracks will be required to access load sites and operational areas for a mouse operation (Figure 21). Approximately 440 km of track is needed to support the cat programme (Figure 21) to facilitate implementation and servicing of detection devices, enable devices to be checked in all weather and allow quicker response to animals detected. The width/grade of a track will vary depending on purpose and location. For example, standard tracks on key access routes and main ridgelines and minimally modified routes are required for the detection network. Installing this entire network of cut routes during the infrastructure programme would benefit the pig programme.

The vegetation forms several distinct zones, which vary with regard to their ease of travel without a track (Table 21; Figure A4.1, p. 112). Vegetation lanes predominately align with the prevailing wind direction (westerly). Pig damage increases the ease of travel in areas of higher vegetation but increases the risk of travel in dense vegetation where footfall is hidden. Careful placement of tracks will reduce the amount of vegetation needing to be cleared and the effort required to establish them. Trials revealed the importance of planning routes using satellite imagery[14, 19]. Generally, vegetation to be cleared is of a stem diameter less than 5 cm and an average of 500 m per day can be cut by two people[14, 19].

Table 21. Summary of vegetation strata, coverage and ease of travel without tracks on Auckland Island.

LAND COVER TYPE	AREA (ha)	APPROX. ALTITUDE RANGE (m)	EASE OF TRAVEL ON FOOT WITHOUT TRACKS
Rātā forest and coastal rock and sand	5054	0–50	Generally easy.
Low scrub and tussock lanes	20 070	0–400	Moderate; lanes of scrub with often low vegetation between.
Tall or dense scrub	11 621	60–300	Very difficult. Wind-shorn faces especially difficult.
Alpine and tall tussock	9621	>300	Easy to moderate – can be boggy in places.
Total	46 366		

6.3.4 Communication devices

Communications are essential for health and safety, operational planning and liaising with mainland support. The remote location limits options and how communication devices may be serviced. Inconsistencies in performance of some devices have highlighted the need for multiple forms of communication both for island-based and island–mainland operations (Table 22). Satellite internet connection has functioned well at three sites spanning the length of the island in winter and summer. It provides landline-style capability (Voice Over Internet Protocol), capacity to send and receive images and stream video, a slow connection to DOC server via Amazon Workspace, and important access to weather forecasting services. Connection between field staff and family is also an important function.

6.3.5 Fences

Fencing is required to divide the island into three blocks to facilitate the pig programme (see section 5.2.2 – *Fences*; Figure A4.1, p. 112). The fences will be based on the netting and barbed wire design proven by Hone and Atkinson (1983)[71]. Fences will be constructed by hand, similar to those used for sheep control and eradication on Campbell Island/Motu Ihupuku in the 1970s and 80s[72].

Fence line investigations carried out in summer 2018/19 found that valleys are a more efficient location for fences than ridge lines due to the less-challenging vegetation[14]. Vegetation clearance required for fences will be factored into the access track network. The western cliffs provide a secure end point at the western extreme of the island, although the generally soft and shallow ground at the eastern coastal end of the island and large tidal flux pose a design challenge.

Table 22. Anticipated means of intra- and off-island communication required for operations during the Maukahuka project.

METHOD	USE	CURRENT STATE	DEVELOPMENT NEEDS
Satellite internet	• Communication between teams and with mainland. • Voice over internet protocol (VOIP) landline phone. • Operational planning. • Weather report access.	• Installed at Dea's Head, Smith Harbour, Adams Island and Camp Cove during 2018/19. • Excellent speed and connectivity during summer 2018/19. • Issues with reinstallation at Dea's Head August 2019. • Initial install very precise – tricky to acquire signal • Only works when power is on at camp. • Excellent clarity on VOIP phone – no charge for calls to/from NZ.	• Training of staff on installation and problem solving – operating manual. • Weather-proofing of dishes and connectors for long term deployment. • Set up dish and stand at all field huts and move up to 10 modems around the island.
Very high frequency (VHF) radio	• Communication between field teams on island, shipping and helicopters.	• Simplex used, some issues with connectivity due to terrain. • Testing of portable repeater units to increase local signal summer 2018/19 and winter 2019. • Whip antennae installed at Dea's Head, Smith Harbour and Camp Cove winter 2019 to increase reception at base sites.	• Installation of large repeaters and portable repeater units to allow island-wide radio communications. • Lanyard attachment to prevent loss of handsets.
Personal locator beacon (PLB)	• Emergency communication. • Communication between mainland and field teams.	• Project mostly use standard PLB for emergency response. • InReach devices used for intra- and inter-island communication between teams (messaging). • Always on.	• Procure enough units for future operation.
Satellite phones	• Communication between field teams and with mainland.	• Borrowed from Southern Islands team. • Some issues with reception – very unclear. • Can only contact other units if both switched on.	• Almost superseded in function by InReach devices and internet set up but useful in emergency kits.
High frequency (HF) radio	• Back up communication with mainland.	• Not suitable for short distance communication on island. • Capable of receiving weather reports via grib files if internet not working.	

6.3.6 Hangarage

Damage to helicopters due to prolonged exposure in a marine environment was identified by suppliers as a critical issue during the Antipodes Island mouse eradication[60]. During the summer trials on Auckland Island in 2018/19, helicopters stationed outside had to relocate to Enderby Island for better shelter three times to avoid potentially damaging weather. A network of four hangars at base locations and anchored tie down points at baiting load sites are required to support helicopter operations (Figure 21, p. 83; Table 18). This will remove the need to fly to pest-free Enderby Island and reduce risk for helicopter operators. It will also reduce the risk of delay or failure from damage to sensitive and critical equipment.

Four temporary tent-style hangars, as proven on Antipodes Island (rated for 190 km/hr winds) (Figure 19), will be manually erected at the base sites at the beginning of the infrastructure phase (Table 18). Each will store two to three helicopters plus tools and provide workshop space. That way all helicopters present at any one time could be secured under cover. Additional tie down spots will be set up at bases and loading sites in case helicopters can't return to base. Each hangar will take approximately 210 person days to install.

Figure 19. Temporary helicopter hanger, Antipodes Island 2016.

6.3.7 Fuel storage

The main fuel storage required on Auckland Island is for Jet A-1 fuel (Class 3.1C) for helicopters (Table 23). Smaller volumes of petrol, diesel and LPG will be required at accommodation and work sites. The mouse programme will be the most intensive period of helicopter fuel use. Approximately 25 000 L will be used for cargo unloading and island set up for the mouse eradication. In the months that follow, approximately 134 000 L will be used for bait spreading. This is the storage capacity needed on island if resupply partway through mouse baiting is unaffordable or no vessel is available. The bunkered or cargo volume onboard an available ship will determine the number of voyages needed for delivery.

Table 23. Total estimated flight time and associated Jet A-1 fuel quantity by programme.

OPERATION	INFRASTRUCTURE	PIGS*	MICE	CATS	CONTINGENCY (10%)	TOTAL
Flight time (hr)	110	1030	800	680	262	2882
Fuel estimate (L)	19 800	185 400	160 000	122 400	48 760	536 360
Fuel drums (200 L)	99	927	800	612	244	2682

*Assuming thermal camera assisted aerial hunting

Traditionally, Jet A-1 has been drummed for transport and storage at remote sites (Figure 20). For the mouse programme this would require about 700 drums during the baiting phase and nearly 400 m² of bunded area for storage spread over several sites. Bunds at dispersed sites would need to be covered to avoid filling with rain. Bulk storage (e.g. collapsible double-skinned 50 000 L PVC rubber fuel bladders, flyable tanks) located at each base site would make more efficient use of space and reduce handling costs compared with drums. These double-skinned vessels require no additional bunding/ secondary containment. Island storage could be resupplied by transferring drummed fuel ashore or decanting bunkered fuel

Figure 20. Drummed Jet A-1 fuel in bunding, Smith Harbour, Auckland Island, February 2019.

from a ship into smaller bladders for flying ashore. Dispersed fuel supplies for bait load sites will need small vessels with secondary containment (e.g. drums in bunds or double-skinned small tanks) or placement of smaller bladders (1000 L) for pumping out of.

Establishing additional fuel depots on Auckland Island (a fuel store for emergency response exists on Enderby Island) is currently outside the CMS directive. Fuel certification normally requires monitoring to be stationed on site. Having fuel in dispersed locations and likely periods of de-staffing the island (between mouse and pig programmes) raises issues around fuel management.

Next steps for quality project design:

- *Engage industry expertise with compliance knowledge to design a supply chain solution. This should include collaboration with regulatory authorities for site certification and developing protocols for managing of fuel in remote locations without personnel present.*

6.3.8 Bait storage

More than 500 t of bait will need to be stored, transported and kept dry at every stage before use. Wooden plywood boxes or 'pods' with plastic liners were used to transport and store 65 t of bait for the Antipodes Island mouse eradication and have been proven to protect bait during transport to and storage on Auckland island. Over 300 t of bait was also successfully transported and stored this way for 2 years on Macquarie Island. Pods were recently designed to fit into shipping containers for Gough Island. Over 730 pods may be required to store the bait for this operation, requiring at least 6 months lead-in for manufacture. Additional pods will be required on site as a contingency in case of damage. They have the benefit of being discrete, secure and relocatable storage units, designed to be shifted by forklift and lifted by helicopter. They are collapsible once no longer needed. They also provide a stable bait loading platform when placed on relatively level ground.

The total footprint of pods containing bait is over 1000 m^2, so bait would have to be offloaded directly from the ship to the three base locations and several dispersed load sites (nine proposed). The distances mean the ship will need to relocate several times, extending a charter period.

Bait will be transported to the island and bait loading sites set up as a discrete task in winter (Figure 21) before bait application starts in November (spring). It is preferred that bait for both treatments is on site before baiting commences to avoid using potential baiting time to unload a ship. Some bait may need to be stored in pods exposed to the island's weather for up to 6 months before application (September to February), so pods need to be well made.

Toxic sausage-style bait for the cat programme will need to be frozen until ready for use (c. 2.6 t for three applications including contingencies). Sausage baits will be stored in chest freezers (max. 6 × 520 L chest freezers). The power supply will need to be designed with this load in mind.

6.3.9 Small boat support

Small boats will supplement helicopter support for operations, dropping off and retrieving teams at coastal sites where helicopters are unable to, or their use is inefficient. This will allow operations to continue when low cloud inhibits flight, but sea state allows boat activity. Boats should be capable of facilitating water rescue during helicopter operations. Two rigid-hull vessels with inflatable tenders for rocky-shore landings are a likely best option. As a minimum, they must be capable of transporting a pig team of six personnel and dogs. Boatsheds and sheltered moorings will be needed at each of the three base sites to support vessels and allow independent operations.

Maritime New Zealand supports the opinion that the operation of boats at Auckland Island is consistent with DOC's Marine Transport Operator Plan (MTOP; DOC-5464383).

6.3.10 Aerial support

Helicopters are essential for delivering the project and an estimated 2882 hours of flight time will be required during the project (Table 23). Auckland Island is within flying range from mainland

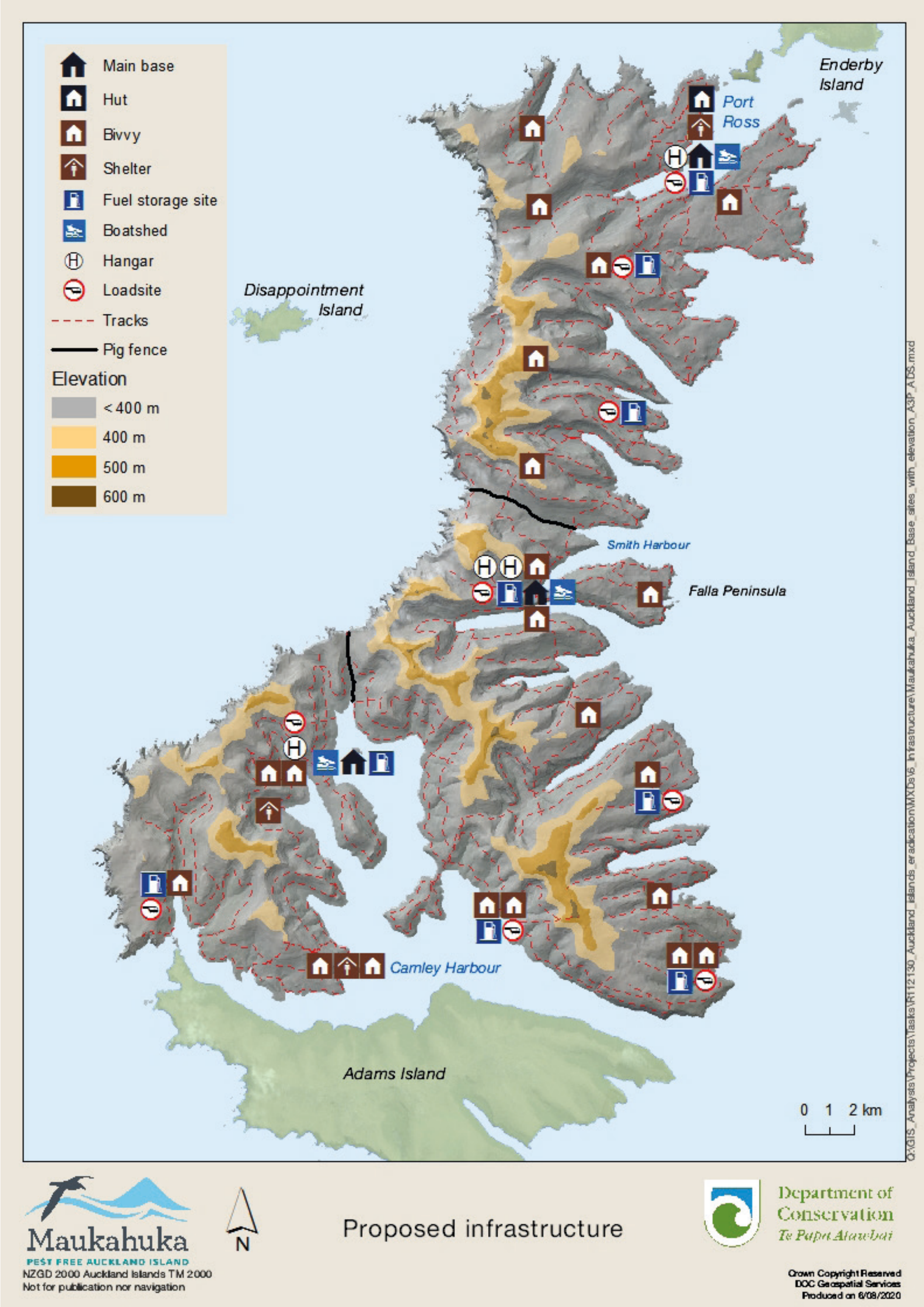

Figure 21. Proposed infrastructure to support the eradication of pigs, mice and cats from Auckland Island. Elevation ranges relevant to weather and helicopter operations are shown in shading.

New Zealand for some larger models of helicopters (e.g. the common and reliable AS350 squirrel; 112 B2 and B3 models are presently registered in New Zealand). Popular hunting helicopters, MD Hughes 500 model or smaller are unlikely to be positioned by direct flight and would have to be shipped. Direct flight enables specialist aerial support for various elements of the project for $20 000 to $30 000 per return trip from a lower South Island base; for example, specific long-lining skills or large lifting capacity can be obtained when required for ship unloading stages.

AS350 helicopters are proven for aerial baiting and passenger transfer. They also proved to be a stable platform for aerial hunting in windy conditions during the summer 2018/19 trials at Auckland Island and are recommended by operators following these trials, despite a previous preference for more nimble hunting helicopters.

The duration of each eradication operation will be largely determined by suitable operating conditions for helicopters. Low cloud (below 400 m 27% of the time; Table 6, p. 40) will restrict helicopter movements over ranges, particularly constraining access to the western edge of the island and south to Carnley Harbour. The three proposed helicopter base sites (with hangarage and fuel) located at the north, middle and south of the island (Figure 21), will minimise the impact of low cloud, as operations at Falla Peninsula showed that local helicopter operations could often still occur to some degree, even when long-range work wouldn't be considered. This will enable a rolling front approach for pigs, detection and response during cat eradication and efficient access to dispersed load sites for mice.

Key risk:

- *Helicopters, pilots and engineers will be difficult to secure. Suppliers should be identified early to build trust and help design solutions. Contracts for helicopter supply should include pilot and engineer resources and the requirement for backups.*

6.3.11 Maintenance and field equipment

Facilities, tracks and equipment will need to be certified and maintained throughout the operation. Complex biodiversity huts require a baseline then 4-yearly inspections by an engineer and annual inspections by an approved hut inspector. Other DOC structures must be inspected once every 2 years. LPG fixtures require biennial inspection by DOC and inspection by a registered gas fitter at a period no greater than 6-yearly.

Technical and mechanical skills must be present within the island team to ensure the reliable functioning of commodities such as power and communication systems, as well as maintenance of outboard motors and tracks (including chainsaw use). A diesel mechanic may be required if larger diesel generators are to be used. Specialist electronics/technician skills may be essential to support technology; for example, a remote sensing network connected to cameras. At least one helicopter mechanic will be present on the island while helicopter operations are being carried out.

6.4 Mainland infrastructure

6.4.1 Fuel transport and storage

The large volumes of fuel required for the project will trigger the need for managed storage as part of the supply chain. Certified storage is needed in the port of departure to ensure fuel supplies are on site and containerised before loading onboard a ship. If containerised fuel is loaded into a hold then access to a hazardous goods wharf will be required until departure, with crew on board, so charter rates will apply. Larger ports have better access to fuel supplies and supporting storage. Drummed Jet A-1 fuel for the Antipodes project and summer trials on Auckland Island in 2018/19 was sourced from Auckland and loaded at Timaru and Wellington ports respectively. If drummed fuel is used extensively, then a plan is needed for managing empty fuel drums. Empty drums have previously been returned to the supplier.

6.4.2 Bait transport and storage

Mouse bait

Over 504 t of Pestoff 20R Rodent Bait® will need to be made and shipped to Auckland Island. Orillion can make the bait quantity in a manageable timeframe but does not have room to store it. Depending on whether both production plants are used and whether the bait is packed in

25 kg double-skinned paper bags or otherwise, bait will need to be removed from the factory every 4 days (quickest production: both plants; 600 kg bags) to 13 days (slowest production: one plant; 25 kg bags). Manufacturing will take between 33 days (both plants; 600 kg bags) and 100 days (one plant; 25 kg bags). Bait will need to be stored in a bio-secure location elsewhere until a shipment is ready. Packaging in 25 kg bags is most efficient for trucking from the factory to port. Approximately 30 truck loads are required to move all the bait to port from the factory if bait is packed in 25 kg bags. Calculations are based on the current capacity of the sole trucking company (JJ Nolan) who have trailers modified for efficient loading and a total bait volume of 650 t instead of 500 t in case additional bait is required if bucket improvements can't reliably deliver bait at 4 kg/ha. The recommended shelf life of bait (12 months) and contingency for manufacture and transport needs to be built into planning to ensure bait quality. Pre-departure storage would be secure, quarantined warehouses at the port of departure (Table 24).

Table 24. Potential transport options for shipping bait and ports of departure for 650 t of Pestoff 20R required for eradication of mice on Auckland Island. Minimum total trucking distance scenario: tight packing of bait in 25 kg bags; maximum trucking distance: optimal packing of bait in 600 kg bags.

	WANGANUI	WELLINGTON	LYTTELTON	TIMARU	BLUFF
Distance from factory (km)	1	206	640	786	1210
Inter-island travel required?	No	No	Yes	Yes	Yes
Rail freight possible?	No	Yes	Yes	Yes	Yes
Total trucking distance (min; thousand km; return)	0.04	7.8	23	30	46
Total trucking distance (max; thousand km; return)	0.11	23	66	86	133

Bait will likely be stored and transported inside weatherproof 'bait pods'. Other options include cardboard pods, which were used on South Georgia to manage large volumes of bait. However, corrugated cardboard can pose an additional biosecurity risk and wooden pods provide greater security if baiting was delayed and on-island storage required for longer than expected. Bulk bags or pods directly placed in a shipping container and craned onto a barge for bait loading would avoid flying bait pods ashore, hugely reducing handling and helicopter time. However, large barges are difficult to source and risky to secure near the coast for a place with such severe weather. Biosecurity cleaning a large barge would also likely be prohibitively expensive and a vessel capable of moving a barge would most likely be required to remain with the barge. One shipping container will fit approximately 13 t of bait in pods. If not being offloaded to a barge or unless it was a necessary part of the cargo shipping solution (e.g. deck storage), containerisation of bait pods is a complicating addition.

Cat bait

The proposed sausage-style baits are manufactured by Connovation in Auckland and would be frozen until application. Sausages weigh approx. 20 g, with 25 sausages taking up 1 L. They could be transported on the mainland in wooden pods, frozen before departure then transported to the island in the chest freezers (c. 2.6 t; maximum 6 × 520 L chest freezers for three applications including contingencies).

6.4.3 Office and operational support infrastructure

Office space for 15–25 staff will be required over the course of the project. New space within the existing DOC building or a new location will be required. The Murihiku district office is planning to move buildings within the next 3 years and the expanded project team will need to be factored into investigations. Office accommodation for distributed staff will need to be secured in other hub offices (e.g. Christchurch).

Workshop space will be required for storage of equipment, materials and vehicles, as well as for working under cover. The Murihiku workshop is at capacity with district work needs. A location nearby would be advantageous. The project currently uses vehicles from the Murihiku fleet pool. At pinch points this can result in vehicles being unavailable for both project and Murihiku staff. Additional fleet vehicles will be required for the project, including a car for office staff and a ute for transport of equipment and supplies from the first year of the infrastructure programme. A DOC covered trailer and large flat-deck trailers are available locally and current usage can be absorbed, but additional trailer(s) are likely to be needed during early operational stages and onward. Large and small trucks are available to be hired as required locally, including trucks with heavy lift Hiab, as used to load field huts onto a vessel at Bluff in 2018/19. Having the main office space co-located with workshop and biosecurity store facilities will increase efficiencies and oversight.

6.4.4 Biosecurity

The mainland supply chain must include facilities and personnel to manage biosecurity risk throughout the project. The risk of introducing unwanted plant, animal or microbial pests exists with every movement of people and goods to islands. The risk is heightened by the extraordinary amount of equipment, supplies and personnel that will need to be transported to and from Auckland Island for this project. Good biosecurity systems exist for current DOC operations on the subantarctic islands. DOC already has mainland biosecurity facilities in Invercargill for use with existing subantarctic work. However, the Southern Islands Quarantine Store is too small to meet all the requirements of the Maukahuka project. The current facilities have 224 m^2 of space for processing dirty gear and 135 m^2 for storing clean gear, and a small office area for pre-departure briefings. Space and staffing capacity were stretched during the summer 2018/19 trials, which approximated the scale expected for regular staff changeover voyages during the Maukahuka project. Current capacity is not suitable for managing the large volume of cargo for 6+ cargo voyages, particularly large items for infrastructure.

There is limited space for gear storage – Maukahuka project gear is currently kept at three locations in Invercargill: at the Quarantine Store, in three shipping containers on the other side of town, and in the District office. The quarantine facility is also used for all other southern island work including Whenua Hou and is extremely busy during kākāpō breeding seasons.

Figure 22. Bait storage pods prior to Antipodes Island mouse eradication at warehousing in Timaru.

Additional standalone quarantine and bio-secure storage facilities will be required to differing levels throughout the operation to handle and store supplies and equipment. Yard storage and the ability to load shipping containers inside would be an advantage as these containers can be used to fumigate items or directly load to port. This facility would need to be leased for the duration of operations until demobilisation is complete. It would complement the current Quarantine Store which could remain focused on personal gear and small goods quarantine. Temporary large-scale, bio-secure warehousing will be needed to hold mouse bait during production and prior to deployment at the port of departure. Around 1290 m^3 is required and 1088 m^2 to 1272 m^2 of floor space, depending on stacking of pods (Figure 22).

Key risk:

- *A dedicated mainland biosecurity facility in excess of current DOC capacity is essential to support operations. Early investment in biosecurity planning and infrastructure is needed to ensure readiness for initiation of the infrastructure programme.*

6.5 Logistics

All island operations rely on the ability to safely transport personnel and general supplies to the site in a timely and organised fashion. Requirements vary over the life of the project (Figure 23) and can be supported by both maritime and helicopter options.

6.5.1 Passenger transport

Passenger transport has usually been by small vessels with capacity for up to 12 people. The voyage takes up to 48 hours from Bluff and seasickness badly affects some passengers. DOC's procurement team established a small vessel supplier panel (DOC-5515843) for the subantarctic islands in 2018. The 6-month-long process identified only one local supplier, already relied on by the project to access the site (the 25 m *MY Evohe*). The vessel operator works with other projects and could retire soon, so availability looms as a critical planning issue. Two smaller local vessels occasionally go to the subantarctic islands and prices differ significantly. The frequency of work the project requires is insufficient to sustain a supplier permanently located in Bluff solely focussed on Maukahuka, so potential transport frequency and timing will be impacted by availability.

Helicopters have occasionally been used for passenger transport to Auckland Island. However, this is expected to be constrained by changes to DOC's helicopter standard operating procedure (SOP), which is currently being revised. Pappus Consulting analysed aviation passenger transport options based on a minimum payload of six passengers plus luggage. Two helicopter options emerged with suitable payloads – the Defence Force NH90 (16 pax) and Helicopter New Zealand's AW139 (10 pax or 850 kg). NH90 availability is untested but is unlikely to be able to fully accommodate the required frequency and time-critical programmes. Additional

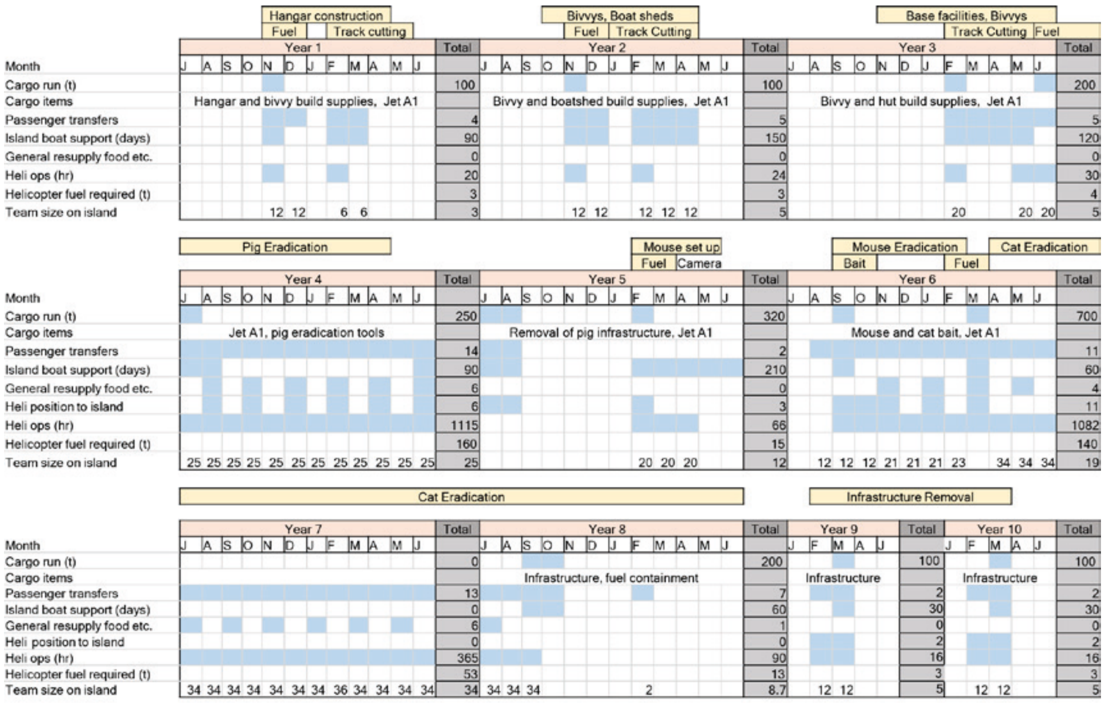

Figure 23. Anticipated logistical support for passenger and cargo requirements and primary operational tasks across the life of the Maukahuka project.

supporting infrastructure would be needed on island. Two AW139s are based in Taranaki supporting the oil industry. Availability would be subject to contract holder support and scheduling ability is unconfirmed. This option could potentially supplement a marine option.

The island is not suitable for establishing a runway to support fixed-wing aircraft. Seaplanes have been investigated; two models (Grumman Albatross and Grumman Mallard) are suitable but rare. Support costs are over $1.9 million per year, so it is not an affordable option.

Passenger transport logistics and associated costs will likely determine how island teams are managed. A dedicated vessel would allow teams to be rostered on and off the island frequently to keep people motivated and broaden the potential pool available for island work. Pig hunters from summer 2018/19 suggested 6-week stints would be ideal. However, this frequency is expensive and logistically challenging. Using an overlapping roster (three teams of six; two teams on the island and one off on break), a third more people would be needed relative to the island team size and half the island team would swap out every 3 weeks. A complete team changeover with no overlap would require a pool of people double the size of the island team but half the relative number of transport voyages. For a pig team of 12 on the island, it is unlikely that a total team of 24 suitable hunters + backups and support staff could be sourced. Longer stints (minimum 12 weeks) are likely to be necessary to make an alternating roster viable. Rotations of 6 months should be considered, with infrastructure reflecting personnel needs for longer deployments (e.g. recreation space, etc.). Precedent projects have successfully attracted capable staff for long deployments (3–12 months) in remote places (Raoul Island, Gough Island, Macquarie Island, Antipodes Island, Antarctic programmes).

Key risk:

- *Market options to support the irregular and infrequent passenger transport requirements are limited. Certainty of supply is a critical dependency to meet project timelines and plan operations. Engage industry experts to understand options.*

6.5.2 Cargo transport

Large volumes of cargo must be transported to and from Auckland Island, particularly to establish and remove infrastructure, transport fuel and mice bait (Figure 23) and will require cargo vessels and helicopter support for offloading of supplies. The project needs transportation solutions that can accommodate project-driven timelines and requirements.

Few (if any) suitably sized helicopter-capable cargo vessels are available in New Zealand. There are significant costs for each trip (positioning to Bluff, procurement process, health and safety, load design and vessel biosecurity) that will require months of lead time. Required seasonal timings mean a short shipping delay could delay project operations by a year each time a large vessel is needed.

The Italian Antarctic programme has recently purchased the vessel that serviced the South Georgia eradication (formerly the RV *Ernest Shackleton* and now called the RV *Laura Bassi*). This vessel is large, is helicopter capable and can bunker 150 000 L of Jet A-1 fuel on board. It can also take 20+ shipping containers internally and additional containers on deck and has a small barge for shore loading. It will be based in Lyttelton and may be available for charter outside of Antarctic operations in the summer months (November to March). The New Zealand Navy is a market alternative. However, their operating protocols are restrictive (e.g. the inability to carry fuel, Jet A-1 or petrol, for other entities), they have one subantarctic run annually and the journey is vulnerable to cancellations for national priorities (e.g. disaster relief). There is some interest from potential project partners to support the lease of a dedicated vessel.

Key risk:

- *Bespoke and infrequent cargo transport is required throughout the project with a high chance of large delays or even programme failure if a vessel(s) and helicopters cannot be reliably sourced.*

Next steps for quality project design:

- *Seek industry advice early during planning and embed industry expertise into the project team to design procurement and manage complex compliance and contract scenarios.*

6.6 Planning

6.6.1 Health and safety

Plans and Procedures

DOC has good existing systems for health and safety and managing remote island operations. Templates for health and safety planning and emergency response procedures are used. These were developed with Pam McDonald (DOC Health and Safety Advisor) for the mouse eradication project on Antipodes Island and have been modified to suit. The emergency response template is being developed into DOC's standard document for offshore island work as a whole.

The operation will be required to comply with all DOC standard operating practices (SOPs) and systems such as Risk Manager (compliance register DOC-6040470). Overlapping obligations between DOC and suppliers/contractors operating as Persons Conducting a Business or Undertaking (PCBUs) must be addressed in agreements and expressed in integrated safety plans.

DOC's Remote Offshore Island SOP states each expeditioner must go through a medical assessment by the Department's doctor, who then advises the manager if applicants should be deployed. This reduces the risk from known conditions but doesn't eliminate the risk of a severe medical event happening on the island.

New SOPs relating to the use of helicopters are yet to be released and have an unknown impact on the use of helicopters for staff transfers, flying over open water etc.

Emergency equipment

Each base will have multiple forms of communication (internet, VHF radio, satellite phone) to allow contact between sites and with the mainland in an emergency. Emergency barrels containing life-preserving equipment and supplies should be present across the island. The network of field huts will provide emergency shelter/accommodation for staff, at a maximum of 7 km apart. Firefighting equipment will be available at huts, fuel stores and helicopter refuelling sites.

All staff will have multiple communication devices whilst in the field (VHF radio, PLB, InReach etc.). Search and rescue (SAR) capability including scoop nets/stretcher to rescue people from water/field will be needed on site. There are currently no VHF repeaters on the island; therefore, radio communications are via simplex only. Installation of repeaters will be necessary for the operation. Satellite internet access is good, and surety is likely to get better with new satellites being launched. See section 6.3.4 – *Communication devices* for more detail on communication devices.

Medical capabilities

Current medical requirements are that all team leaders have outdoor pre-hospital emergency care (OPHEC) training and all team members have first aid training. For the operation, more team members could be given OPHEC training to provide greater coverage.

A medical doctor was part of the Antipodes eradication team as well as other island eradications such as Macquarie Island. Medi-vac could be several days away in adverse weather, so basic life preservation capability (appropriate medical skills in the team plus equipment) should be available on site. Automated external defibrillator devices should be considered for the three main bases. Inclusion of a 'Field Safety Officer' role as used on Antarctic programmes would help maintain safety training and provide safety oversight for daily operational planning and emergency response capability.

Evacuation and rescue capabilities

Staff will be involved in intense operational activity for 6–8 years in a remote location. It is likely that a medical evacuation may be required in that time.

DOC is currently working with Rescue Coordination Centre New Zealand (RCCNZ) to clarify the roles and the responsibilities of the organisations in an evacuation scenario. DOC may become responsible for coordinating evacuation of its staff from outlying islands.

The ability to evacuate staff in a medical emergency will be greater during the operation than currently, due to the presence of multiple helicopters and boats at the island. Fishing boats use the area (some seasonal, some year-round) and tourist operators are present in the subantarctic over the summer months and could provide support both in terms of extracting a team member or allowing access to the ship's doctor.

Auckland Island is close enough to mainland New Zealand to evacuate staff by helicopter (465 km). Twin engine rescue capabilities are available locally through Southern Lakes Helicopters and Otago Helicopters, both of which have experience in the area. Fuel provisions must be available to enable a helicopter rescue response. A BK117 will take on up to 1000 L of fuel from the island to return to the mainland and two helicopters may fly in tandem. Southern Lakes Helicopters currently maintain a fuel depot of >4000 L at Enderby Island but this has a sloping grass helipad, making it difficult for helicopters to fully refuel. There is a proposal to install a wooden helipad to improve site access for BK117 helicopters to land and refuel. There are difficulties in getting fuel to site, managing the fuel supply and, potentially, issues with the creation of new fuel depots (see Table A6.1, p. 114) and fuel storage (section 6.3.7 – *Fuel storage*) for detail.

The presence of helicopters (all phases) and small vessels (pig and cat ground phases) during the operation will inherently increase SAR capabilities on the island. Team members will need training in steep slope access/cliff rescue. There will be extensive baiting of the western cliffs, with helicopters operating close to land but over water. The possibility of a helicopter crashing off the western coast must be considered. Pilots will need the ability to recover people from the water; the western coast is generally inaccessible to boats, so any rescue from this area would rely on aerial resources.

Key risk:

- *The impact of a serious incident at any stage could have fatal consequences and/or risk the viability of the project. Engage suppliers early to involve them in planning and treat them as part of the team to develop a shared safety culture. Include a dedicated safety role on island.*

Veterinary capabilities

There is a high chance of injury to dogs from falling off bluffs, encounters with pigs, being impaled by vegetation and, potentially, some risk of suffering primary or secondary poisoning, depending on the toxin used for cats. Section 11(1) of the Animal Welfare Act 1999 states that 'The owner of an animal that is ill or injured, and every person in charge of such an animal, must ensure that the animal receives treatment that alleviates any unreasonable or unnecessary pain or distress being suffered by the animal.' The ability to provide some level of veterinary care on the island is therefore necessary. Handlers generally have good experience with basic care but professional support both on and off the island will be needed.

6.6.2 Human resourcing

Planning and implementing the project will be a large undertaking, requiring upscaling from the Feasibility Phase project team of 8.5 full time equivalents (FTE) to participation by approximately 60 personnel at the peak of the delivery (Figure 24; organisation charts, see DOC-6017426). The resourcing presented only covers the operational delivery component of the project, not the

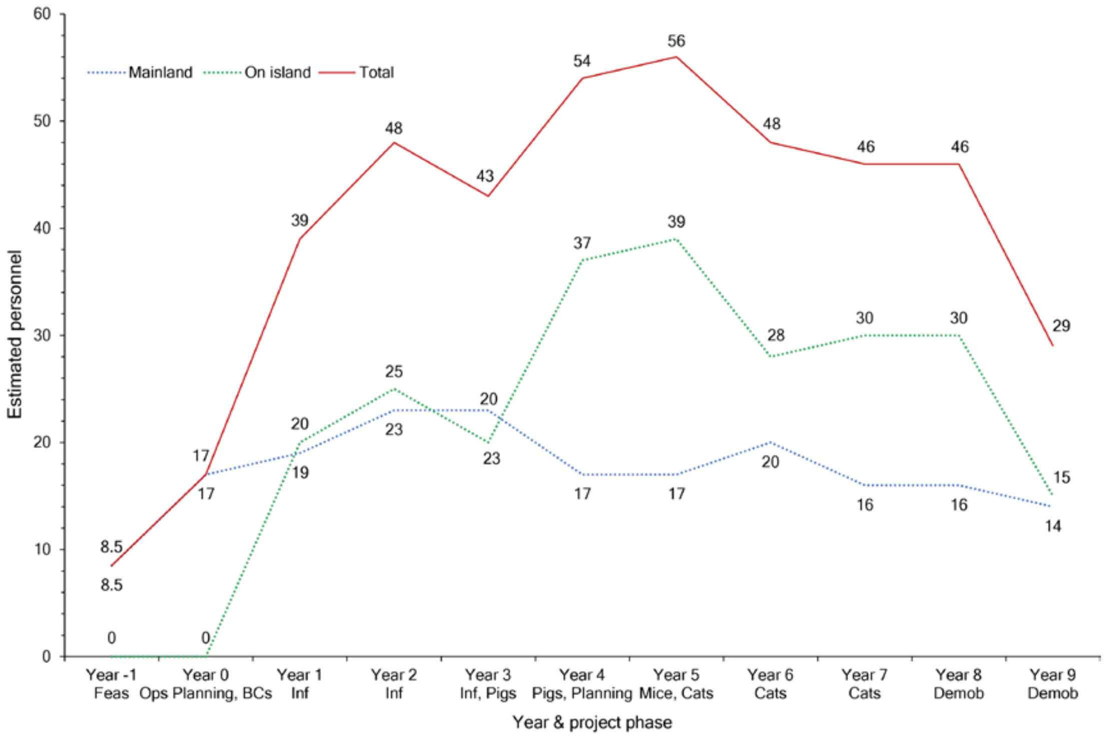

Figure 24. Predicted island personnel requirements both on the island and off it across the life of the project to eradicate pigs, mice and cats on Auckland Island. Feas. = feasibility; Ops = operational; BC = business case; Inf = infrastructure programme; Demob. = demobilisation.

wider corporate support roles required (see section 6.6.2 – *Organisational support*). The multiple programmes of work will need to operate in parallel, i.e. delivery of infrastructure while planning the pig eradication, and include staff both on and off the island and allow for rostering of field-based teams.

Considerations in the proposed team design include:

- Redundancy in case critical people become unavailable at short notice, and succession planning.
- Timely recruitment of roles to enable training and planning before delivery of each programme.
- Separate Island Manager, Programme Lead and Safety Officer roles on the island.
- Ongoing recruitment needs and engagement opportunities with Ngāi Tahu throughout the life of the project.
- Sustainable workloads.
- Reporting lines and adequate supervision capacity.
- Development opportunities throughout the life of the project.

It is anticipated that other PF2050 projects will require experienced staff and could provide employment opportunities as this project winds down.

Coordinated incident management system (CIMS) is a scalable framework for the management of activities generally related to response. It is becoming more widely used in DOC. Current uses include fire and emergencies, biosecurity incursions and aerial operations to control pest animals. It is worth considering during operational planning as a management tool for the implementation phase for the Maukahuka project. The CIMS framework can be used to clearly describe the control structure and resource and role allocations during operations. It is particularly helpful when multiple agencies are involved – such as during helicopter or shipping operations – and language and expectations are becoming more common in DOC. However, some situations will not warrant stringent application or over-complication, so application of CIMS should be assessed on a case-by-case basis and simplified where possible.

Field staff by programme

Based on known and estimated effort to service eradication operations, indicative staffing requirements are presented (Table 25). Formal competencies and qualifications required for operational staff are listed in Appendix 7.

Soft skills required include hunters with an eradication mind-set, backcountry travel and navigation, mental resilience, the ability to live and work in remote locations in confined social conditions etc. for long periods of time. Some of these can be taught where required – e.g. navigation – but recruitment will need to take these into account alongside hard skills and experience. Internal training will be required prior to deployment. Assessment of team fit is a critical consideration for recruitment.

Table 25. Anticipated on-island and total staffing and hard skills requirements by programme, based on a roster where two thirds of staff are on the island at any one time. Note: some roles may double up, e.g. boat skippers may also work as support staff and pig feeder maintenance may be carried out by pig hunters.

PROGRAMME	SKILL	POSITIONS REQUIRED ON ISLAND	POSITIONS REQUIRED TOTAL
Infrastructure – set up	Builder	15	23
	Track cutter	6	9
	Fencer	8	12
	Support staff	4	6
	Boat skipper	2	3
Pig – aerial	Helicopter pilot	2	3
	Helicopter engineer	1	2
	Thermal camera operator	2	3
	Aerial shooter	2	3
	Pig feeder maintenance	12	18
	Support staff	7	11
	Boat skipper	2	3
Pig – ground	Helicopter pilot	2	3
	Helicopter engineer	1	2
	Pig hunter	12	18
	Support staff	7	11
	Boat skipper	2	3
Mouse	Helicopter pilot	6	8
	Helicopter engineer	2	3
	Bait loading	12	12
	Support staff	9	14
Cat – aerial	Helicopter pilot	2	3
	Helicopter engineer	1	2
	Bait loading	1	2
	Support staff	2	3
Cat – ground	Helicopter pilot	1	2
	Helicopter engineer	1	2
	Camera service	10	15
	Trapping	10	15
	Support staff	6	9
	Boat skipper	2	3

Organisational structure

The project is too large and complex for DOC to undertake using business-as-usual management. Limitations of the status quo include the ability for sufficient focus and support from DOC managers (capacity of T2, T3 and T4 managers to devote the time required), appropriate financial delegations for the Project Manager, funding certainty, financial and decision-making agility to respond to operational opportunities and needs as they arise. These issues are addressed in more details in a project review undertaken by Keith Broome and Andy Cox in July 2019 (DOC-6011105).

Development of a project plan will articulate needs and identify the design of an optimal operational structure, as well as defining roles and responsibilities.

More broadly, initial research has been undertaken to understand operating models that would support successful governance, management, financial control and delivery of the project in collaboration with Ngāi Tahu and investment partners (DOC-6322662).
Key elements required include:

- A small, highly skilled and committed Governance group with the clear objective of supporting the key objectives of the project (i.e. ensure the operations arm is free to deliver).
- Defined and well-understood roles and relationships.
- Dedicated management.
- Technical advisory group (TAG) support.
- Logistics, planning, operations, communications, procurement etc.
- A quality project plan and live operational plan with clear objectives, actions, timelines and performance measures.
- Quality data collection, storage and analysis.
- Effective and agile systems and processes.
- Timely and structured decision-making with clarity on who the decision maker(s) is/are.
- Ability to receive and manage funds without financial year restrictions.
- Culture of trust, transparency, sharing and open progressive thinking.
- Effective communication in all elements and between elements.
- Legal framework acceptable to all parties, including international funders.
- Reporting and review culture.

This operating model will take some time to form and should commence with establishing principles for partnership agreements in association with iwi. The function of all involved is to support the project team to succeed.

Key risks:

- *If Governance is not empowered or properly resourced, it won't be able to support the needs of the project.*
- *DOC's business-as-usual management may not have the ability to provide and sustain the necessary support needed to deliver a project of this scale and complexity. The project operating model must include: dedicated high-level management support from within the organisation, delegated financial authority to a level that provides efficient approval processes and good connection with the project team, certainty of funding for the project lifespan, timely approval of budgets and support flexible use of funds between years.*

Next steps for quality project design:

- *Complete the following project design tasks as soon as possible and incorporate into project plan: finalise the relationship vision document between Ngāi Tahu and DOC, governance model, team structure, delegations and decision-making accountabilities and financial management.*

Organisational support

Coordinated support from a range of teams within DOC will be required by the project, over and above business as usual (Table 26). Given the scale, complexity and duration of the project, it would be advantageous to assign dedicated resources, where possible, to ensure continuity of support and advice. District and national planning will need to incorporate these requirements over the life of the project. Managers need to champion teamwork and allocate and prioritise resources to help the project team succeed.

The project team needs to be a discrete work unit, operating outside the local DOC district's normal shared responsibilities (e.g. duty officer, fire team, etc.).

Table 26. Anticipated support required by the Maukahuka project.

CATEGORY	DETAILS	NOTES
Partnerships	• Sourcing and developing relationships and securing funding. • Business model design and implementation.	
Finance	• Costing models for business cases. • Financial accounting advice, such as CAPEX/OPEX definition, unusual capital programme, depreciation etc. • Business accountant attached to project plus specialist support as required.	Business accountant. National management accountant.
Procurement	• Procurement plan and contract process approval. • Contribution to business case development. • Resource within team during Delivery phase. • Planning for a prime contractor for each element, e.g. passenger transfer, cargo, bait, huts. • Aviation and maritime services providers will experience positive impact via increased demand for their services. • Procurement needs to be engaged early if we require builds/fencing with support from external contractors. How will we accommodate any external contractors plus approximately 30 DOC field staff.	Procurement advisor. Specialist consultant.
HR	• Recruitment and associated administration for a range of contract structures. • Approximately 10 new roles in project year 1 peaking at about 60 personnel.	Bulk of staff recruitment occurs in first 2 years.
ISS	• Support new staff with standard DOC Toolset – MS Office, SAP, GIS (ESRI, web apps). • Data capture and governance advice. • Data storage. • Additional GIS support. • Island connectivity.	
Business Assurance	• Guidance in developing business cases, managing high-risk projects and appropriately delivering and measuring benefits. • Conduit to SLT and governance.	Risk advisor. Benefits advisor. Portfolio assurance advisor and manager.
Health and Safety	• A project team of 18 plus short-term support will be exposed to management of safety and wellbeing in remote environment undertaking complex tasks with multiple suppliers including DOC's eight critical safety factors.	H&S advisor.
Communications	• Media (print and digital), DOC and external, project webpage, design work, alignment with PF2050. • One or more roles will be based in the project team, supported by Communications Advisor(s) attached to the project and assist requests for other support as required.	Communications advisor. Media advisor.
Biosecurity and Logistics	• Warehousing, biosecurity, quarantine. • Requirement is largely linked to preparation and departure of field operations.	Ranger Subantarctic.
Specialist support	• Governance. • IEAG and TAGs. • Project reviews.	Contractors. External stakeholder representation.

CAPEX = capital expenditure; OPEX = operational expenditure; BA = business accountant; DOC = Department of Conservation; MS = Microsoft; SAP = systems and application for data processing, current DOC finance software; GIS = geospatial information services; ESRI = Environmental Systems Research Institute, current DOC geographic information system software; PF2050 = Predator Free 2050; HR = human resources; ISS = information support services; H&S = health and safety; IEAG = island eradication advisory group; TAG = technical advisory group; SLT = senior leadership team.

Key risk:

- *Insufficient and/or inconsistent DOC support services has potential to delay progress or cause bottlenecks. The required level of internal support services should be planned and assigned, dedicating the same service staff to enable continuity of support and advice (e.g. legal, finance, procurement) and ensuring they have the capacity required.*

6.6.3 Procurement and purchasing

DOC is required to follow Government procurement rules as set out in the Procurement and Supplier Management SOP (DOCDM-912450). Items or services exceeding $100 000 in value must be sourced using an open competitive process and advertised on the Government Electronic Tender Services (GETS) website. An exemption from open competition can be authorised in circumstances where a) only one supplier exists, b) no suitable suppliers were found through open competition, or c) an unsolicited unique proposal is made that aligns with Government objectives, where services are not otherwise readily available and it represents value for money. In the case of the Maukahuka project, several of the purchases exceed $100 000 and some exist where a single supplier is available (Table 27). Most are Type C procurements, involving high complexity (multi-stage sourcing, bespoke contract, unusual purchases) and high risk (high public profile, critical effect on DOC if outcomes are not achieved, involve operations in DOC's eight critical safety categories). Type C procurements require a full procurement plan and approvals from DOC's procurement team and the delegated financial authority for the plan, the Request for (RFX) documents and a final contract. The final contract also requires legal approval. A team process is used to initiate the process for Type C procurements. The various procurement approaches and their function, request for tenders (RFT), proposals (RFP), quotes (RFQ) and registration of interest (ROI) are described here (DOCDM-931917)

The process is designed to test suppliers and provide the best outcome for DOC, but is not geared well for extraordinary activities with few potential suppliers and high risk (see lessons from the Antipodes mouse eradication After Action Review DOC-2928572 and Great Mercury Island Post Operational Report (DOCDM-1477863). The same reviews record the lesson that 'suppliers are part of the project team' and a partnerships approach with good communication pays off. Suppliers for such complex operations are a critical part of operational design and planning. These relationships must be nurtured and valued.

Table 27. Summary of indicative purchases and services requiring approval at DOC Director General level (>$500 000) over life of project.

ITEM/SERVICE	ONE-OFF OR REPEAT	ESTIMATED COST
Field huts	One-off	$1.3 million
Main base	One-off	$1.8 million
Subsidiary bases	One-off	$1.1 million
Boatsheds	One-off	$900 000
Track cutting	One-off	$1.25 million
Chartered cargo shipping	Up to 8 times	$6 million (total)
Chartered passenger vessel	60+ voyages	$2.8 million (total)
Helicopter fuel	One-off	$800 000 (total)
Trail cameras	One-off	$600 000
Helicopter services for each operation	Repeat	Several $million per operation
Bait	One-off	$2.1 million
Cat traps and remote sensing network	One-off	$600 000
High-resolution thermal cameras – pigs	One-off	$500 000

Procurement of shipping and helicopter services will be the most complex process, with limited supplies of specialist shipping and helicopter services available in New Zealand. Helicopter and shipping services will be required for extended periods at several stages of the project. Variable operating requirements may require different suppliers or separate contracts at different times. Significant legal support will be needed for contract development.

The risks and impacts of remote island operations on suppliers' businesses often outweigh the financial incentives for helicopter operators. The exemption from competitive process to source helicopters for the Antipodes mouse eradication took 18 months of procurement process to achieve, as no one supplier could provide what was required. A 3-month process for helicopter services for summer trials on Auckland Island in 2018/19 attracted six suppliers to a briefing but resulted in only one tendered option, wasting time and risking getting an unsuitable operator. As part of the Antipodes After Action review, the DOC Supplier Sourcing Manager recommended that helicopter procurement be the foundation procurement and done as 'Registration of Interest' followed by a 'competitive dialogue' process with short-listed potential suppliers, allowing DOC to fully explore options and make informed decisions. Early engagement with industry to build trust and co-design solutions before going to tender is another important lesson. Once tendered on GETS, all communications with potential suppliers are directed through DOC's procurement team so quality and dedicated procurement team support is essential.

Key risk:

- *Government procurement processes deterring suppliers and lengthy processes impacting operational timelines. Investigate custom procurement options, reduce risk to attract suppliers and simplify procurement.*

Next steps for quality project design:

- *A Procurement Plan approved by the Delegated Financial Authority (DFA) and Supplier and Sourcing Manager is required to outline the proposed procurement approach for all type-C procurements (value over $100 000 or high risk or high complexity, such as for multi-stage processes) for a Treasury and/or DOC Detailed Business Case.*
- *Delegate financial authority, supported by Governance, to a level that provides efficient approval processes and good connection with the project team.*

6.6.4 Advocacy and engagement

Advocacy and engagement have three roles:

- To build private and political support for the project.
- To report on the value gained from any spending.
- To generate further revenue by engendering further public interest.

This project will likely be funded by a combination of public money, private contributions via partner organisations and individual donations. Advocacy and engagement will therefore need to target a range of audiences to effectively support the project. A communications strategy has been developed for the feasibility stage of the project and will need updating upon project initiation (DOC-5900613).

Advocacy and engagement are currently largely covered by the Maukahuka project team with some internal support. Dedicated resources are required to adequately meet this need (both capacity and skillset) once the project is initiated. The value provided by professionals should not be underestimated, as exemplified by the positive engagement with the people who produced the teaser film. Contributions by professionals, such as design of project brochures and compelling writing have exponentially greater impact and are warranted for a project of this size. The form that this support takes and who it is provided by will be affected by the operating model of the project, which is currently undecided.

Minimum requirements are 1 FTE focussed on communications with budget to engage professionals, and further staffing resource to focus on relationship building and liaison with partner organisations. Resourcing and specific skills are needed to fulfil the objective of engaging people with subantarctic places and issues.

6.6.5 Data management

The DOC Content Management (DOCCM) system in conjunction with the project 'Home Page' index is the default storage and management solution for corporate documents (Maukahuka homepage: DOC-2999881). These are also backed up onto the Invercargill S: drive to facilitate offline work.

Images and videos from trail cameras require extremely large and reliable storage capacity. Currently these files are stored in DOC's Amazon cloud system (S3 Bucket; Amazom.com Inc, Seattle, USA) which also supports external sharing. These data will accumulate quickly as trials continue and operations commence, so it is vital that a full data management plan is developed as early as possible. This is an extremely valuable dataset (to DOC and external researchers) and warrants appropriate planning effort.

GIS data are managed to corporate standards. These standards include naming conventions, metadata, version control and a defined data steward. All data and mapping products are stored on the Q: drive, and data management checks happen regularly. Some data are also published to ArcGIS Online to enable interactive web maps, web applications, dashboards and story maps.

Field observations to date have been recorded using a combination of the Avenza Maps (Avenza Systems Inc., Toronto, Canada) mobile app and Survey123 (ESRI, Redlands, USA), with DOC mobile phones and Garmin (Garmin Ltd., Olathe, USA) GPS units. This has ensured some degree of uniformity but has limitations. An improved solution for both hardware and software will be required for the delivery phase, which will require liaison with DOC information shared and corporate architecture (DOC-6261065). Storage and indexing of photos and videos taken by expeditioners also needs to be planned and addressed from the beginning to ensure most value is obtained. Currently, these files are stored in DOC's Amazon cloud system (S3 Bucket).

6.6.6 Monitoring plan

The key motivation for invasive species eradications is to protect threatened species, ecosystems or economies. Several factors (principally tight budgets) have meant that outcome monitoring of many island eradications have been inadequately measured or reported, despite the importance of these data to inform positive ecological, social and economic outcomes, and for communicating benefits realisation to the public and stakeholders[73, 74]. Too often, the limited evidence from previous pest eradications is used to assume that positive outcomes will result from eradications in other places with differing natural and cultural community structures[74].

A monitoring plan is required to assess whether project benefits have been realised and to account for potential disbenefits of the project. The expected benefits of the project have been mapped with reference to the outcomes of the project and fall into five main categories: biodiversity, capability, iwi, partnerships and social (DOC-6035780). It is expected the project will improve DOC's processes, operations and relationships in these categories. To effectively measure and report on these benefits, a monitoring plan with specific answerable questions and timeframes, that forms part of the operational plan, is required. The monitoring plan would measure short and medium-term project outcomes with the intention of assisting DOC's Murihiku district in the development of future priorities and resource allocations for monitoring, research and management activities in the region.

The monitoring plan will be written and initially implemented during the detailed operational planning phase and will run through the life of the project. Years 0–3, prior to the eradication of pests, provides an ideal opportunity to implement a baseline monitoring programme that will allow robust before-after-control-impact sample design. Regular servicing of the island provides opportunities to support monitoring activities through the life of the project.

Next steps for quality project design:

- *Species monitoring should be initiated and undertaken immediately as opportunities arise to provide robust baseline data that will allow impacts and benefits of pest eradication activities to be understood. Findings will support key project planning documents such as the AEE and would benefit other DOC work such as the Subantarctic Science Strategy.*

6.6.7 Recommendations

A full set of recommendations to address issues, reduce risk and increase the likelihood of success of the project appear in Appendix 8; the 10 most critical recommendations were presented in Table 1 (p. 12).

Plate 7. The pest-free islands within the Auckland Islands archipelago provide a glimpse into the post-eradication future of Auckland Island – the promise of recovery and proliferation of native species through all levels of the ecosystems. Nearby Enderby Island, cleared of rabbits (*Oryctolagus cuniculus*), mice (*Mus musculus*) and cattle (*Bos taurus)* in the 1980s – 1990s showcases how quickly the mauri is restored once pests are removed; allowing vulnerable invertebrates (A – semi slug *Ranfurlya constanceae*), birds (B – Auckland Island double-banded dotterel *Charadrius bicinctus excilis*) and plants (C – megaherbs) to proliferate. *Photo credits: Jacob Osborne and Jack Mace/DOC.*

7. Acknowledgements

The need to complete the Maukahuka project has long been understood in the conservation community and work to understand how it could be achieved is a long reoccurring theme in the pest eradication space. We would like to thank those who came before, providing invaluable context and concepts that contributed to the completion of this study. We wish to particularly thank the Island Eradication Advisory Group and the technical experts who provided vital and tireless critique and feedback through the process that has led to the point of being able to say this project is feasible. Thank you to the skilled and passionate field teams, who braved the seas and scrub to test tools and techniques that prove this project feasible and worthwhile. Special thanks to Steve Kafka and the crew of the *MY Evohe* for going above and beyond to provide safe, enjoyable passage to the island and find solutions to transport all of our gear! Thanks to the Quarantine Store team for your support getting us away on time and biosecure. Thank you to DOC whanau, suppliers, stakeholders, project partners, Ngāi Tahu (especially Gail Thompson and Tā Tipene O'Regan) for your representation. Thank you to the conservation community for engaging wholeheartedly with the vision for a pest free Auckland Island – your support and enthusiasm has driven this study forward and we look forward to delivering this project with you one day soon.

This study is the culmination of decades of pioneering research, development and implementation of eradication capability in New Zealand. We stand on the shoulders of giants.

Plate 8. Feasibility field trials in 2018/19 saw 57 personnel voyage south to undertake work on Auckland Island, spending 68 days at sea across nine return voyages. Personnel built important knowledge of the site, and included helicopter pilots, pig hunters, an archaeologist, Ngāi Tahu representatives, scientists and photographers amongst others. Staff were present on the island for 140 days, equating to over three and a half people years of boots on the ground. *Photo credits: James Ware/DOC and Finlay Cox/DOC.*

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Plate 9. Travel to Auckland Island during field trials in 2018/2019 relied on *MY Evohe*. The voyage through the waters of the Roaring Forties and Furious Fifties typically takes 30–48 hours, depending on conditions. Upon arrival, personnel and gear must be safely shifted to shore and onwards to base sites. Planning gear requirements, packing efficiently and covering contingencies requires careful thought and experience. During feasibility field trials at Auckland Island in 2018/19, more than 50 t of cargo was transported to the island to facilitate work. *Photo credits: Mat Goodman and Stephen Bradley.*

Appendix 1

Glossary of terms

Adaptive management	Monitoring and data are used to inform situational decision making about the changing application of eradication tools and techniques. Often changes arise from specific knowledge of the site or target species behaviours.
AWS	Automatic weather station
Bait application rate	The target for the 'on the ground' amount of bait to be applied to the treatment area. Delivered bait application densities are estimated from pre-calibrated bait bucket swath and operational data such as helicopter speed, bait usage and the area covered. These estimates are analysed and compared against the target application rate.
Baiting prescription	A combination of factors that define how the total volume of bait will be applied such as bait application rate, timing, specific area or block variation, number of treatments, swath overlap etc.
BAU	Business as usual.
CI	Confidence interval (e.g. 95% CI).
CMS	Conservation Management Strategy – 10 year regional strategies that provide an overview of issues and give direction for the management of public conservation land, waters and species for which DOC is responsible.
Detection line hunting	A hunting technique that is designed to put all target animals at risk in a specified area. Hunters with close-range bailing dogs maintain a line (move at the same rate to ensure there is one front). Hunters are reading the terrain, target animal sign and dog behaviour. Dogs contribute to the coverage by searching an area around the hunter. Regular communication is critical to ensure a unified sweep is maintained. Spacing between hunters and hunting direction is dictated by relief and environment to ensure dogs can scent animals and there are no gaps large enough for an animal to remain undetected (maintain high detection probability). Coverage is ascertained through analysis of tracks (hunter and dog if applicable) and site-specific considerations to inform confidence. Also known as team hunting.
Detection probability	The probability of a monitoring tool detecting a target animal if the animal is present. Detection rates are influenced by target species abundance.
DOC	Department of Conservation / Te Papa Atawhai; sometimes referred to as 'the Department'.
DOOCM	Department of Conservation Content Management (document management database).

Eradication phases	Phases including knockdown, mop-up and validation used to describe eradication strategy. These phrases are theoretical constructs that describe the overarching strategic approach to an eradication. In practice these phases regularly overlap (but are sometimes distinct) so the eradication strategy is a continuum of techniques.
GETS	Government Electronic Tender Services.
Hard skills	Teachable and measurable abilities that are required to succeed in a role.
IEAG	Island Eradication Advisory Group.
IUCN	International Union for the Conservation of Nature.
IVL	International Visitor Levy – a $35 fee applied on arrival in New Zealand to support conservation and tourism functions.
Judas pig	A pest control technique that capitalises on the social nature of pigs by releasing radio-collared pigs back into an area that has been hunted and using them to seek out surviving pigs.
Knockdown	Phase of an eradication where the target species interacts with an eradication tool leading to rapid population decline. Typically, this is the first phase of an eradication attempt and the most passive tools are used.
MOC	Minister of Conservation.
Mop-up	Phase of an eradication where tools and efforts are concentrated in response to known survivors of the target species, or areas where they are suspected to persist based on evidence or prior knowledge. Typically, the second phase of an eradication, although it may run concurrently with knockdown depending on the target species. Often multiple techniques are used. This phase is often informed by site- or species-specific knowledge that is gathered during delivery (adaptive management).
NZSIA	New Zealand Subantarctic Islands Area.
RFX	Common acronyms in the procurement landscape; a catch-all term that captures all references to Request for Information (RFI), Request for Proposal (RFP), Request for Quote (RFQ), and Request for Bid (RFB).
Risk	The combination of likelihood and consequence of an issue arising in the future that could impede the goals of the project. Risks are avoided or managed by pre-planned actions to reduce their likelihood or impact. All eradications have risks that cannot be mitigated and an assessment of the project risks versus benefits before proceeding is warranted.
Rolling front	Systematic approach for deploying an eradication technique over a large area where the scale does not allow complete coverage at once. The 'front' of the technique 'rolls' over the area, leaving only treated area behind.
SAR	Search and rescue.
SLT	Senior Leadership Team, Department of Conservation / Te Papa Atawhai.

Soft skills	A combination of traits such as social skills, communication skills, attitudes, career attributes, social and emotional intelligence and personality traits that enable a person to navigate their environment and work well with others.
SOP	Standard operating procedure.
Summer trials 2018/19	Field trials undertaken on Auckland Island during summer (Nov–Mar) 2018/19 to reduce uncertainties that arose from an initial feasibility assessment.
TAG	Technical advisory group.
Treatment area	The extent of area to be treated by an eradication technique and/or strategy. In Auckland Island context, it includes all islands in the archipelago unless there is confidence the target species is absent.
UNESCO	United Nations Educational Scientific Cultural Organisation.
Validation	The final phase of an eradication attempt where tools and efforts are targeted at detecting any individuals that may persist. Target species population information, an understanding of eradication technique specific detection probabilities and how techniques were implemented (e.g. validation period and tools, risk of device avoidance, etc.) will inform the eradication result (success or failure).
Voucher specimen/sample	A preserved specimen/sample that serves as a verifiable and permanent record of wildlife at a place and point in time.
VTA	Vertebrate toxic agent.
Winter trials 2019	Field trials on Auckland Island during winter (July–Sept) 2019 undertaken to reduce outstanding or new uncertainties that arose from an initial assessment of project feasibility, and/or required follow up after the summer trials 2018/19.
ZIP	Zero Invasive Predators Ltd.

Appendix 2

Key documents

Summary feasibility report	DOC-6085426
Business cases	DOC-6119140 DOC-6119801
Research and Development Plan*	DOC-6214883 DOC-5999483
Organisational charts*	DOC-6017426
Benefits maps and inventory*	DOC-6035780
Summer 2018/19 operational report	DOC-5911275
Winter 2019 operational report	DOC-6099361
Project review July 2019	DOC-6011105
Ngāi Tahu Relationship Vision*	DOC-6262719

*Living documents and/or in draft stages

Appendix 3

Eradication tools that have been discounted for Auckland Island

Pigs

Disease

There are currently no pig diseases in New Zealand that are likely to cause widespread fatality in Auckland Island pigs. Diseases such as 'African swine fever' could be effective, but importation of such a disease would not be supported because of risk to domestic pigs (Newmann 2018, pers. comm.).

Pesticides

Pesticides were considered as a knockdown technique but their use was discounted because other currently available tools are considered as or more effective and do not require registration (Table 28).

Table A3.1. Toxin options considered for the eradication of pigs on Auckland Island, New Zealand.

TOXIN	CURRENTLY REGISTERED FOR USE?	OTHER ISSUES
Warfarin	No	• Inhumane
1080	No	• Bait shyness develops • High concentration required for pigs, leading to poisoning of non-target species • Risk to hunting/detection dogs
Sodium nitrite	Yes	• Bait stations only • Low efficacy
Brodifacoum	No	• Quantity needed • Impact on mice eradication

Mice

Gene drive

This tool is still in the early stages of development and is unlikely to be available for many years and would require significant testing outside of New Zealand (D Tompkins 2018, pers. comm.). Current legislation in New Zealand doesn't allow for such tools.

Cats

Shooting and spotlighting

The dense nature of the vegetation and the low density of cats on Auckland Island means hunting with a spotlight is not a viable primary mop-up tool. Shooting with a spotlight could be used in combination with other techniques (e.g. bait dumps) to target specific animals.

Fences

Using cat-proof fencing to divide the island into three blocks was discounted due to the impracticality of constructing cat-proof terminuses at either end of the fence, the cost of the materials and the necessary maintenance requirements.

Disease

The viral disease feline enteritis, or feline parvovirus, is present in New Zealand. The disease is highly contagious through direct cat-cat contact, or indirectly through vomit or faeces and can persist in the environment for a long time. It can be seeded in the population by inoculating and releasing cats or possibly by distributing infected meat. However, the disease is not registered as a biocide and achieving this would be as complex, costly and time-consuming as it would be for a new pesticide. The future use of this tool in New Zealand beyond Auckland Island is considered unlikely. Moreover, there is concern that transmission would be ineffective due to the low density of cats on Auckland Island. Given that pesticides are likely to be more effective, this potential tool is not considered further.

Appendix 4

Vegetation map

Figure A4.1. Broad vegetation classification and proposed fence lines on Auckland Island.

Appendix 5

Bait volumes

Table A5.1. Estimated bait volumes for proposed mouse baiting prescription for Auckland Island.

TREATMENT SITE	AREA	FIRST TREATMENT			SECOND TREATMENT			TOTALS	
	(ha)	BUCKET FLOW RATE (kg/ha)	NOMINAL RATE (kg/ha)	BAIT VOLUME (kg)	BUCKET FLOW RATE (kg/ha)	NOMINAL RATE (kg/ha)	BAIT VOLUME (kg)	TOTAL BAIT (kg)	FLIGHT TIME ESTIMATE (hr)
Across-island swaths (50% overlap)	45 905	2	4	183 620	2	4	183 620	367 240	459.1*
Coastal strip (deflector bucket)	1470	2	4	5880	2	4	5880	11 760	23.5†
Coastal strip (standard bucket)	3135	4	4	12 540	4	4	12 540	25 080	31.4
Steep slopes 50° to 70° (standard bucket) outside coastal strip	1051	2	2	2102	2	2	2102	4204	5.3
Cliffs > 70° (deflector bucket)	4042	2	4	16 168	2	4	16 168	320 336	64.7
Cliffs > 70° (broadcast bucket)	1078	4	4	4312	4	4	4312	8624	10.8
Named offshore islands/stacks (8)	38	2	4	151	2	4	151	302	2.0
Larger rock stacks ≥ 0.5 ha (19)	22	2	4	88	2	4	88	176	2.0
Small rock stacks ≤ 0.5 ha (156)	19	n/a	4	76 (in 200 g bags)	n/a	4	76 (in 200 g bags)	152	2.0
Infrastructure	n/a	n/a	50	50	n/a	50	50	100	n/a
Subtotal	56 760			224 987			224 987	449 974	600.1
Contingency (12%)				22 499			22 499	53 997	67.5
								503 971	668.1

* Based on productivity of 0.8 tonnes/hr inclusive of 15 min/hr for refueling and GPS downloads.

† Based on productivity of 0.5 tonnes/hr inclusive of 15 min/hr for refueling and GPS downloads.

Maukahuka PEST FREE AUCKLAND ISLAND

Appendix 6

Permissions

Table A6.1. Permissions required and standards that must be met that may have an impact on the Maukahuka project planning and operations.

NAME	CATEGORY	TYPE	ISSUING AUTHORITY	LEGISLATION	PROGRAMME	COVERS	COMMENTS
Regional Coastal Plan	Infrastructure	Coastal permit	DOC	Resource Management Act 1977	Infrastructure and Logistics.	Discharge from the land into the sea/costal marine zone. Erection, alteration and demolition of structures in the marine and coastal area. Discharge of untreated sewage from land into seas is prohibited. Carriage or use of heavy fuel oil is prohibited. Ship-to-ship transfers of MGO and MDO prohibited. Ship anti-fouling requirements.	The Coastal Plan is due for review. No information on when this is likely to happen is available, but project could contribute to new plan. Activities need to take into account the current and proposed plans. River mouth classification altered from RMA to MHWS line across river mouth.
Permission to apply pesticides	Pest control	Permission	DOC	Section 95a Hazard Substances and New Organisms Act 1996 Section 53 and 54 Wildlife Act 1953 Section 50(1) Reserves Act 1977	Cats, mice	Discharge of brodifacoum, PAPP and 1080 onto DOC land. By-kill of native species from pesticide use.	Brodifacoum and 1080 exempt from resource consent under section 360. Discharge of PAPP will require Resource Consent.
Conservation Management Strategy	Operations	Permission/rule/ standard	Conservation Board, Murihiku	General Conservation Policy 2005	All	Activities on Public Conservation Land and/or those that may affect native species.	Amendments or exemptions to rules that disallow activities proposed by Maukahuka operations are required.
Marine Reserves Act	Infrastructure	Permission	DOC	Marine Reserves Act 1971	All	Discharge of toxic substance or pollutant into reserve. Take or removal of any sand, shingle, natural material. Discharge of firearm in or into reserve. Erect any structure in or over reserve.	Legal advice received during the Antipodes Mouse Eradication indicated that resource consent is not required under the Marine Reserves Act for aerial discharge of toxin into a marine reserve.
Helicopter SOP	Helicopters	SOP	DOC		All	All helicopter flights	Not yet released Unknown impact on use of helicopters for passenger transport to and from the island

Continued on following page

Table A6.1 continued

NAME	CATEGORY	TYPE	ISSUING AUTHORITY	LEGISLATION	PROGRAMME	COVERS	COMMENTS
Carbon budget	Operations	Rule/standard	DOC		All	Regional and national carbon budgets that DOC must operate within.	Not yet released Unknown impact on project.
Civil Aviation Rules – Air transport	Helicopters	Rule / Standard	CAA	Civil Aviation Rules Parts 135 and 137	All	Flight times and duty rosters for pilots.	Will need sufficient pilots to cover mandatory rest periods.
Conservation Management Strategy – Structures	Infrastructure	Permission	DOC	Conservation Act 1987	Infrastructure and Logistics	Construction.	No new fuel depots are allowed Currently seeking advice on definition and exemption.
Storage of hazardous substances – Location Compliance Certificate and secondary containment	Dangerous goods	Rule/standard	Work Safe	Health and Safety at Work (Hazardous Substances) Regulations 2017	Infrastructure and Logistics	Required for diesel, kerosene and petrol if >2000 L and stored for >14 days.	EPA and Worksafe are to provide certainty around final storage design. Antarctic NZ and Raoul Island both hold exemptions under the legislation. Options include double-skinned bladders, bulk containment tanks or a bunding for fuel drums and containers. RCCNZ and the Defence Force are currently investigating installing fuel depots for emergency responses in the NZSIA.
Registration of new VTA	Pest control	Permission	EPA and MPI	Hazardous Substance and New Organisms Act 1996 Agricultural Compounds and Veterinary Medicines Act 1997	Cat	Registration of a new toxin for general release.	Requires data on the pesticide's chemistry, manufacturing, residues, efficacy and animal welfare, environmental and human health effects.
Resource Consent – discharge of VTA	Pest control	Consent	DOC	Resource Management Act 1977, Section 15	Cat	Discharge of a toxin to land.	Only required for PAPP, not required for 1080 or brodifacoum.
Animal Ethics Committee approval	Pest control	Permission	DOC	Animal Welfare Act 1999 Agricultural Chemicals and Veterinary Medicines Act 1997 S. 28	Cat, Mouse, Pig, Monitoring	Manipulating animals for research, testing or teaching.	DOC Vet recommendations are included in the research proposal put to AEC.
Archaeological authority	Infrastructure	Permission	Heritage New Zealand	Heritage New Zealand Pouhere Taonga Act 2014	Infrastructure and Logistics	Alteration or work in proximity to archaeological sites	Can empower person to carry out archaeological activity
Building consent	Infrastructure	Consent	SDC	Building Act 2004	Infrastructure and Logistics	Required for waste management systems and main base buildings.	Exemption currently held for huts and toilets if chartered engineer involved. If building under 10 m^2 and doesn't contain sanitary facilities, it is exempt. List of exemption reasons currently under review.

Continued on following page

Table A6.1 continued

NAME	CATEGORY	TYPE	ISSUING AUTHORITY	LEGISLATION	PROGRAMME	COVERS	COMMENTS
Resource consent – discharge to land	Infrastructure	Consent	DOC	Resource Management Act 1977	Infrastructure and Logistics	Toxic baiting activities Long drops, grey water, sewage	Standing consent exists for brodifacoum spread Discretionary activity. Must be over 50 m from coast, no water in bottom of long drop. Not required for containment toilets.
Resource consent – native vegetation clearance	Infrastructure	Permission	DOC		Infrastructure and Logistics	Track cutting and infrastructure site preparations and maintenance	
Licensed boat operator and boat survey	Shipping	SOP	DOC	Marine Transport Act 1994	Infrastructure and Logistics	Use of boats in offshore areas	DOC Boat operator ISC or MNZ license and DOC Approval for vessels <6m MNZ issued license and DOC approval for specific vessel >6m Mid-term survey within 3 years of date of first survey
Firearms License (Endorsement)	Firearms	Qualification	Police	Arms Act 1983 and Arms (Prohibited Firearms, Magazines and Parts) Amendment Act 2019, Arms Act 1983 Section 4A (1)(f)	Pig, cat	Storage and use of restricted firearms	Murihiku currently has a licensed operator for restricted E Cat firearms
Firearms – import of banned weapons	Firearms	Rule/standard	Police	Arms Act 1983 and Arms (Prohibited Firearms, Magazines and Parts) Amendment Act 2019, Arms Act 1983 Section 4A (1)(f)	Pig, cat	Import of banned weapons	Permission required to import semiautomatic rifles for aerial hunting – unclear as to procedure

1080 = sodium fluoroacetate; AEC = animal ethics committee; CAA = Civil Aviation Authority; DOC = Department of Conservation Te Papa Atawhai; EPA = Environmental Protection Agency; ISC = inshore skippers certificate; MDO = marine-safety duty officer; MGO = marine gas oil; MHWS = mean high water springs; MNZ = Maritime New Zealand; PAPP = 4'-Aminopropiophenone; RCCNZ = Rescue Coordination Centre New Zealand; RMA = Resource Management Act; SDC = Southland District Council; SOP = standard operating procedure; VTA = vertebrate toxic agent

Appendix 7

Competencies

Table A7.1. Department of Conservation competencies and other qualifications required by work programme for the Maukahuka project.

	INFRA-STRUCTURE	PIG AERIAL	PIG GROUND	MOUSE	CAT AERIAL	CAT GROUND	MAINLAND
Certified handler – dangerous goods	x	x	x	x	x	x	x
Helicopter – general	x	x	x	x	x	x	x
Quarantine procedures	x	x	x	x	x	x	x
Back country work competency	x	x	x	x	x	x	
First Aid	x	x	x	x	x	x	
OPHEC (Team leaders)	x	x	x	x	x	x	
Firefighting (extinguishers)	x	x	x	x	x	x	
DOC Boat operator ISC / MNZ licence	x		x			x	
Helicopter – working under/strop loading	x			x	x		x
Asset inspector	x						
Chainsaw – basic and high level	x						
Scrub bar	x						
Part 101 course – drones	x						
Certified engineer	x						
Working at heights	x						
Firearms license – endorsement for restricted weapons		x					
Firearms license			x			x	
Controlled drugs – license to deal in			x			x	
Veterinary sign off (DOC)			x			x	
Administration sedative to feral animals			x			x	
Dog handler team certification						x	x
HT driving license							x
Forklift license							x

DOC = Department of Conservation Te Papa Atawhai; ISC = inshore skipper certificate; MNZ = Maritime New Zealand; OPHEC = outdoor pre-hospital emergency care; HT = heavy vehicle.

Appendix 8

Recommendations

Table A8.1. Recommendations to address issues, reduce risk and increase the likelihood of success of the Maukahuka project.

PRIORITY	RECOMMENDATION	RATIONALE	WHO	WHEN
Top 10				
1.	The scope of the project should encompass eradication of all three pest species delivered in sequential operations in short succession.	• Most efficient and likely way to achieve success. • Full benefits realisation, avoids disbenefits. • Lower cost than separate projects over longer timeframe. • Extract most value from the investment to establish project team, infrastructure and complex logistics solutions.	Project Sponsor	Immediate
2.	DOC should lead with a commitment to the project by securing the Crown investment and articulating an investment strategy for the life of the project; this will provide investor confidence, enabling the required third-party contributions.	• Confidence required for other partners to invest. • Protect against external disruptions. • Enables work on critical path tasks such as tools. development, vessel procurement.	DG	Immediate
3.	Invest in capability developments for technical feasibility: • Thermal camera technology and experienced aerial hunting teams. • Improved helicopter bait bucket for reliable low sow rate application. • Automated image processing software to label and triage imagery from trail cameras. • An effective toxic bait registered for cats that can be aerially applied. • Cat detection dogs and handlers.	• Technical feasibility of eradications dependant on these. • Action early (before project initiation) to ensure capability is highly reliable, operationalised and available on time • Investment would also benefit other DOC work, key suppliers and other agencies. • Increase confidence to stop early and save time/cost.	DDG Biodiversity	Ongoing
4.	Complete the following project design tasks as soon as possible and incorporate into project plan: finalise the relationship vision document between Ngāi Tahu and DOC, governance model, team structure, define delegations and decision-making accountabilities, financial management.	• Ensure co-design and good partnership with Ngāi Tahu. • Facilitate the creation of a workable partnerships agreement ready for initiation. • Reduce lag at project initiation. • Enable informed discussions with investment partners. • Establishing management structure/entity will take time	DDG Biodiversity	Design
5.	The project operating model must include dedicated high-level management support from within the organisation, so decision-makers are engaged in the project and connected to project management.	• Ensure capacity is available and applied for timely decision making and direction. • Avoid constraints experienced in Feasibility Phase due to limited capacity of DOC T2 and T3 and short-term funding cycle.	DDG Biodiversity	Design
6.	Overarching site management plans including: • NZSIA Biosecurity Plan • Subantarctic Research Strategy • Subantarctic Strategy. Plans should be updated/completed by the relevant district and national teams to guide project design and ensure strategic alignment.	• Ensure coordination and alignment of strategy and programmes; guide prioritisation of opportunities for other work in the subantarctic area with increased access. • Guide future project planning, e.g. management of olearia, inform a Departmental decision on long-term infrastructure needs, guide prioritisation of monitoring effort and selection of	Murihiku / DDG Biodiversity	Immediate

Continued on following page

Table A8.1 continued

PRIORITY	RECOMMENDATION	RATIONALE	WHO	WHEN
		ancillary activities given the opportunity to do work on site due to the unusually regular access. • A current Biosecurity Plan is needed to protect investment.		
7.	The project infrastructure plan should be shared to initiate consultation with relevant DOC teams and external authorities to progress any interim actions identified.	• Some permissions can be obtained ahead of time (e.g. Archaeological Authority), and steps taken to prepare for others. • Getting these done early reduces complexity, time pressure and delays once the project is initiated.	Project Manager	Early 2021
8.	Embed shipping and helicopter industry expertise into the project team to design procurement and manage complex compliance and contract scenarios. Ensure contract management capacity is resourced appropriately.	• To build trust with suppliers and better understand the market. • Explore custom procurement solutions. • Explore options to improve chances of certainty of supply long-term shipping and helicopter services.	Project Manager	Planning
9.	Invest in biosecurity planning and infrastructure to manage biosecurity risk appropriately and in readiness for the start of the infrastructure programme (e.g. establish additional biosecurity facilities in Invercargill for managing quarantine and storage of large-scale equipment and supplies).	• The vast amounts of gear and supplies required will require a dedicated mainland biosecurity facility in excess of current local DOC capacity. • Essential for supporting operations and should be invested in early to ensure they are functional in time. • Protects existing and project investment. • Prevents project delays that would occur if quarantine facilities do not meet needs and processing supplies leads to 'bottlenecks'	Project Manager	Planning – within first year of project initiation
10.	Continue engagement with potential funding partners and stakeholders to facilitate better understanding of relative costs, wider benefits, stopping points, complexities and opportunities.	• Understand opportunities and changing context. • Readiness to proceed when the time is right. • Contribute to project design.		Ongoing
Operational planning				
	Operational plans for infrastructure, pigs, mice, cats and native species monitoring should be drafted and peer-reviewed now.	• Record and test current thinking and share knowledge. • Assessment of environmental effects (AEE) and Archaeological Authority (AA) can then be produced for the infrastructure programme. • Maximise existing investment.	Maukahuka	31/12/2020
	Review and update project cost estimates once operational plans are drafted.	• More accurate project costing. • Capture and test current thinking.	Maukahuka	31/12/2020
	Understand how changes to protocols (e.g. Regional Coastal Plan, DOC Helicopter SOP, Conservation Management Strategy) may impact project activities and plan contingencies.	• Potential seasonal shipping restrictions in Port Ross. • Restricted helicopter passenger transfer over water. • Need for direct flights to island by single engine helicopters. • Fuel storage certification.	Project Manager	Ongoing
	Understand the future implications of carbon budgeting.	• Likely to be mandatory when the project is initiated. • Allows operating plans to initiate baseline measures to assess potential carbon sequestration following release from pest impacts against short-term carbon use.	Project Manager	Planning

Continued on following page

Table A8.1 continued

PRIORITY	RECOMMENDATION	RATIONALE	WHO	WHEN
	Budget for operational duration with enough contingencies to realistically account for potential operating conditions and resource well (e.g. base at least six helicopters on Auckland Island for the mouse eradication).	• To achieve objectives within the required timeframes. • To make rapid progress when weather conditions are suitable; thus increasing the chance of completing the work early. • Ensure required funding is available.	Project Manager	Planning
	Engage industry with compliance expertise to design a supply chain solution for helicopter fuel supply and storage. This should include collaboration with regulatory authorities for site certification and developing protocols for managing of fuel in remote locations without personnel present.	• The current CMS restricts establishment of new fuel depots on Auckland Island. • Approximately 150 000 L Jet A1 needs to be stored on island for each eradication operation.	Project Manager	Planning
	Ensure milestones for key developments are integrated into the project plan to inform stage gate decisions for governance. Design contingencies during operational planning where possible in case key developments are not available. Model potential disruption scenarios and record stopping points.	• Ensure the overall effect of delays is understood, can be anticipated, avoided or minimised and governed.	Project Manager	Planning
	Include a dedicated safety officer role on island.	• Assist with planning of day-to-day operations, reporting and debriefing to ensure lessons for safety management are recorded and shared. • A serious incident at any stage could have fatal consequences and/or risk the viability of the project. • Simplifies Operations Lead role.	Project Manager	Initiation
Research and development				
	Initiate native species monitoring; utilise opportunities as they arise based on priorities in the monitoring plan.	• Provide robust baseline data that will allow changes resulting from the eradication activities to be measured and understood.	Project Manager	Immediate
	The design and function of a prototype flat-pack modular field hut should be tested and finalised.	• Proven build method will inform design of larger base facilities. • Allows tendering for construction of several huts as soon as the project is launched, resulting in field huts ready to support initial infrastructure programme.	Maukahuka	30/06/2021
	Pursue hardware developments for trail cameras that reduce maintenance requirements and/or enable remote data transmission.	• For example, a rechargeable battery pack would avoid the need for and cost of large quantities of AA lithium batteries over a 2–3 year period. Automated alerts would remove the need to physically visit every device to download data, simplifying field logistics and reducing time to respond to a detected animal. • Benefits to other DOC programmes.	Project Manager	Planning
	Contract the helicopter supplier for the pig programme early and perhaps separately from other helicopter services so development of thermal camera capability is ready in time.	• Investment in camera technology testing aids hunting team development; time is available to train aerial hunting teams working together for a minimum of 60 hrs. • The supplier is an engaged team member.	Project Manager	Planning
	Write a research and development plan that outlines user case requirements for eradication tools and phasing to achieve development objectives in time for project implementation.	• Development objectives could be integrated into other DOC activities such as Tools to Market. • Investment in improved eradication can start before project initiation and will take time. • The work would benefit other conservation objectives.	Project Manager	31/12/2020

Continued on following page

Table A8.1 continued

PRIORITY	RECOMMENDATION	RATIONALE	WHO	WHEN
Project design				
	Review the Feasibility Phase of the project.	• Record key lessons and inform future project design.	SRO	30/10/2020
	Ensure governance is empowered, properly structured, resourced and connected to lessons from other projects.	• Optimises design and delivery and reduces risk. • Decisions are evidence based. • Benefits from investment in other projects are shared.	SLT	Planning
	Funding mechanisms and structure must provide certainty of funding for the project lifespan, timely approval of budgets and support flexible use of funds between years.	• Avoid delays to key activities such as recruitment. • Optimally support the agile operations work considering uncertainty from weather constraints, permissions.	SRO	Planning
	Delegate financial authority, supported by Governance, to a level that provides efficient approval processes and good connection with the project team.	• The project will have many contracts and associated process approvals. • Current approval processes would be too slow to allow desired project timeframe	SLT	Planning
	Establish a reporting line with direct access to decision makers; empower the team with appropriate mandate, delegation and authority to manage timeframes and risk.	• Agreed processes must allow for efficient decision making and manage scope.	DDG Biodiversity	Planning
	Carefully consider partnership commitments and ensure agreements and Governance reflect expectations, mutual benefits and accountabilities, including safety.	• A joint venture of this scale over the long timeframe will unlock the project but also has potential to complicate it. Support must be well designed, sustained and improve likelihood of success.	SRO	Planning
	Explore option to purchase/lease two helicopters to remain on the island for the whole project.	• Potential to save several million dollars in standby fees.	Project Manager	Planning
	The required level of internal support services should be planned and assigned, dedicating the same service staff to enable continuity of support and advice (e.g. legal, finance, procurement) and ensuring they have the capacity required.	• The project is currently costed as a standalone undertaking, internal support has the potential to significantly reduce budget burden (e.g. Works Officers to manage contracts). • Quality and efficient support will be required to ensure good project knowledge.	SLT	Planning
	Resource the project team well. Plan for succession and contingencies throughout all team levels (field team, team leaders, programme leaders, project and contract management, training and supplier capacity). Ensure comprehensive training plans are in place before staff selection, with adequate lead-in time planned to train staff. Use relationship vision document with Ngāi Tahu to contribute to project design for capability development.	• Optimise chances of success. • Allow for upskilling and training, succession planning and redundancy in key roles so alternate staff to be able to step up to fill critical roles when required. • Advocacy and engagement skills reflective of the project size and complexity are required to manage risk.	SRO	Planning
	Investigate simple, flexible and bespoke procurement options and understand how government procurement rules will be affected if the project is managed/governed externally.	• Risks must be shared to attract suppliers. • Avoid lengthy processes.		Planning
Stakeholders/relationships				
	Develop long-term relationships with regulatory bodies and other parts of DOC.	• To anticipate and proactively manage the impact of changing protocols, permissions and legislation which have potential to increase complexity and cost which could impact feasibility.	Project Manager	Ongoing

Continued on following page

Table A8.1 continued

PRIORITY	RECOMMENDATION	RATIONALE	WHO	WHEN
		• Potential exemptions or grandfather clauses may mitigate some of the effects for changes introduced during the project.		
	Engage with Murihiku Subantarctic team to ensure coordination and alignment of strategy and programmes.	• Identify opportunities for baseline monitoring in conjunction with other programmes. • Maximise benefit of Operation Endurance taskings. • Directives are required regarding retention of any infrastructure for future DOC use post project and management of the weed olearia.	Project Manager	Immediate
	Maintain communication with medical research company(s) interested in obtaining Auckland Island pigs and address future needs to avoid risking delays. Engage with key contacts during planning phase. Removal of further pigs should be completed as early as possible.	• Living Cell technologies has previously sourced Auckland Island pigs to use for medical research and manages a self sustaining quarantined herd for this purpose in New Zealand (due to their disease-free status). • A second New Zealand medical research company, NZeno, has indicated a desire to acquire Auckland Island pigs in the future, this should be timed well in advance of the eradication attempt.	Project Manager	Planning
	Consult with other programmes and explore opportunities to co-develop capacity.	• Large teams of field workers are required with specific skills. Other programmes in DOC could provide training opportunities or foster capability development and make good use of skills at the end of each eradication.	Project Manager	Planning
	Engage openly with suppliers, treating them as team members and seek industry advice early during planning. Design solutions collaboratively.	• Build trust; understand capacity, options and find solutions. • Options inform project design. • Improve ability to secure shipping, helicopters, pilots and engineers. • Develop shared safety culture.	Project Manager	Planning
	Increase advocacy with concessionaires, permitted visitors and the fishing industry.	• As the eyes and ears to help protect the integrity of the site as the project develops. • Increase biosecurity awareness and surveillance.	Project Manager	Initiation

New Zealand Government