Survey of introduced mammals and invertebrates on Auckland Island, March–April 2015

James C. Russell, Stephen R. Horn, Grant A. Harper and Pete McClelland

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CONTENTS

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Abstract

Auckland Island is the only island in the New Zealand subantarctic region that is still inhabited by invasive mammals, including mice (*Mus musculus*), cats (*Felis catus*) and pigs (*Sus scrofa*). However, we currently know little about the population biology and appropriate control tools for these species on the island. Therefore, we undertook an expedition to the Port Ross area at the northeastern end of Auckland Island in March to April 2015, during which we surveyed the mouse, cat, pig and invertebrate populations, and trialled a range of pig bait and trapping methodologies. We detected a very low density of mice (<1 mouse/ha) in rātā (*Metrosideros umbellata*) forest and tussock (*Chionochloa antarctica*) habitat using a capture-recapture method, and failed to detect any cats in rātā forest using non-invasive hair sampling. Furthermore, the abundance of pigs was also low. Cafeteria bait trials showed that among the eight bait types trialled, pigs preferred kibbled corn and fish pieces, with the latter also being eaten by cats. We also set two large multi-catch live traps in rātā forest and coastal scrubland but found that pigs showed no interest in entering baited traps. Pitfall sampling in rātā forest, scrub and tussock habitat showed that the invertebrate abundance and diversity were highest in rātā forest, and the invertebrate community structure reflected both the habitat type and the presence of mice and absence of seabirds. However, in general, Auckland Island had a low abundance and diversity of invertebrates compared with nearby Adams Island, although this partly reflected our lower sampling effort. Based on these findings, we recommend that further surveys and trials are conducted to inform the eradication of introduced mammals on Auckland Island and to monitor subsequent responses in the fauna and flora.

Keywords: Auckland Island, mouse, *Mus musculus*, cat, *Felis catus*, pig, *Sus scrofa*, invertebrate, bait, trap.

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1. Introduction

1.1 A brief history of the Auckland Islands

The Auckland Islands (50.69°S, 166.08° E) are located 465 km south of New Zealand and comprise seven islands (Auckland (46 119 ha), Adams (9742 ha), Enderby (699 ha), Disappointment (286 ha), Rose (80 ha), Ewing (59 ha) and Ocean (12 ha)) and additional islets. This island group is volcanic in origin, with the main island (Auckland Island) comprising steep cliffs to the west and more gentle slopes with large fiords and small islets to the east.

Polynesians first settled on the Auckland Islands around the 13th to 14th century (Anderson 2005), while Europeans arrived much later in 1806. Throughout the 1800s, numerous shipwrecks occurred on the islands which, at that time, lay in a major maritime thoroughfare. On Auckland Island, the British settlement of Hardwicke in Erebus Cove was founded in December 1849 but lasted only 2 years and 9 months to 1852, while Māori from the Chatham Islands independently settled at Ranui Cove from 1842 to 1856 (Anderson 2005). During WWII, the Cape Expedition placed 'coastwatchers' on Auckland Island from March 1941 to October 1945.

Adams Island was protected as a nature reserve in 1910, followed by the remaining islands in the group in 1934. The Auckland Islands Marine Mammal Sanctuary was established in 1993 and the Auckland Islands – Motu Maha Marine Reserve was established 10 years later in 2003. As part of the New Zealand subantarctic region the islands were given UNESCO World Heritage status in 1998. Important terrestrial biological scientific expeditions after WWII were carried out in 1954, 1962/63, 1972/73, 1989 and 2007.

1.2 Introduced mammals

Auckland Island is the only island in the group to still be inhabited by mice (*Mus musculus*), cats (*Felis catus*) and pigs (*Sus scrofa*), with all of the introduced mammals that once inhabited the secondary islands having died out or been eradicated (Table 1).

Pigs were liberated on Auckland Island in 1807, while cats and mice were first recorded in 1840, likely having arrived some time over the previous two decades (Taylor 1968), which coincides with some of the earliest arrival times for mice in New Zealand (Ruscoe & Murphy 2005). In the North Island mice were first recorded in the Bay of Islands around the 1830s, and the mice that occur here share the same, albeit common, mitochondrial DNA haplotype as the mice that are found on Auckland Island (Searle et al. 2009). By contrast, mice did not colonise the South Island until the 1850s and appear not to have dispersed beyond Ruapuke Island in Foveaux Strait following the wreck of the *Elizabeth-Henrietta* in 1824, based on their unique genetic signature there (King 2016). Recent analysis of nuclear DNA in fact suggests that the mice on Auckland Island are a lineage independent from New Zealand with links to North America, probably through whalers or sealers (Veale et al. 2018).

All three introduced mammal species have significant impacts on the species and ecosystems of Auckland Island (Harper 2007). Eradication of pigs has been proposed as early as 1982 (Challies 1986), again in 1993 (Shaw 1993, 2002), and including cats since 2002. The eradication of any (but preferably all) of mice, cats and pigs from Auckland Island would be a significant challenge. However, this would also be a major conservation achievement for restoring the island and, indeed, the collection of New Zealand islands in the Southern Ocean.

Table 1. Status of introduced mammals on the Auckland Islands (compiled from various sources).

ISLAND	SPECIES	YEARS	STATUS
Auckland	Horses	1850–1852	Removed
	Cattle	1850–?	Died out
	Dogs	1843–1856	Removed
	Sheep	1850–?	Died out
	Goats	1865–1992	Eradicated
	Possums	1890	Failed
	Mice	<1840–today	Extant
	Cats	<1840–today	Extant
	Pigs	1807–today	Extant
Adams	Sheep	1885–?	Died out
	Goats	1885–?	Died out
Enderby	Goats	1850–?	Died out
	Sheep	1850–?	Died out
	Cattle	1850–1993	Eradicated
	Mice	<1850–1993	Eradicated
	Dogs	1843–1856	Removed
	Pigs	1850–?	Died out
	Rabbits	1840–1993	Eradicated
Disappointment	None		
Rose	Cattle	1895–?	Died out
	Sheep	1887–?	Died out
	Rabbits	1850–1993	Eradicated
Ewing	Goats	1850–?	Died out
Ocean	Sheep	1941–1945	Eradicated
	Goats	1865–1941	Eradicated

1.3 Objectives

In this report, we describe an expedition to Auckland Island that we undertook in March–April 2015, during which we addressed the following questions:

1. What is the status of mice in autumn?
2. Can cats be monitored using indirect hair sampling?
3. What bait formulation is most appealing to pigs?
4. Are corral-style traps suitable for catching pigs?
5. What is the diversity of invertebrates?

2. Methods

2.1 Field trip

The annual joint Royal New Zealand Navy (RNZN) and Department of Conservation (DOC) expedition Operation Endurance provided transport to Auckland Island from 26 March to 3 April 2015. The 'cat' team (JCR and GAH) was based on-shore at Deas Head Hut, while the 'pig' team (SRH and PM) was based on-board the HMNZS *Wellington* to conduct work around Port Ross and Carnley Harbour (Fig. 1). Transport to and from sites was provided by Navy support vessels.

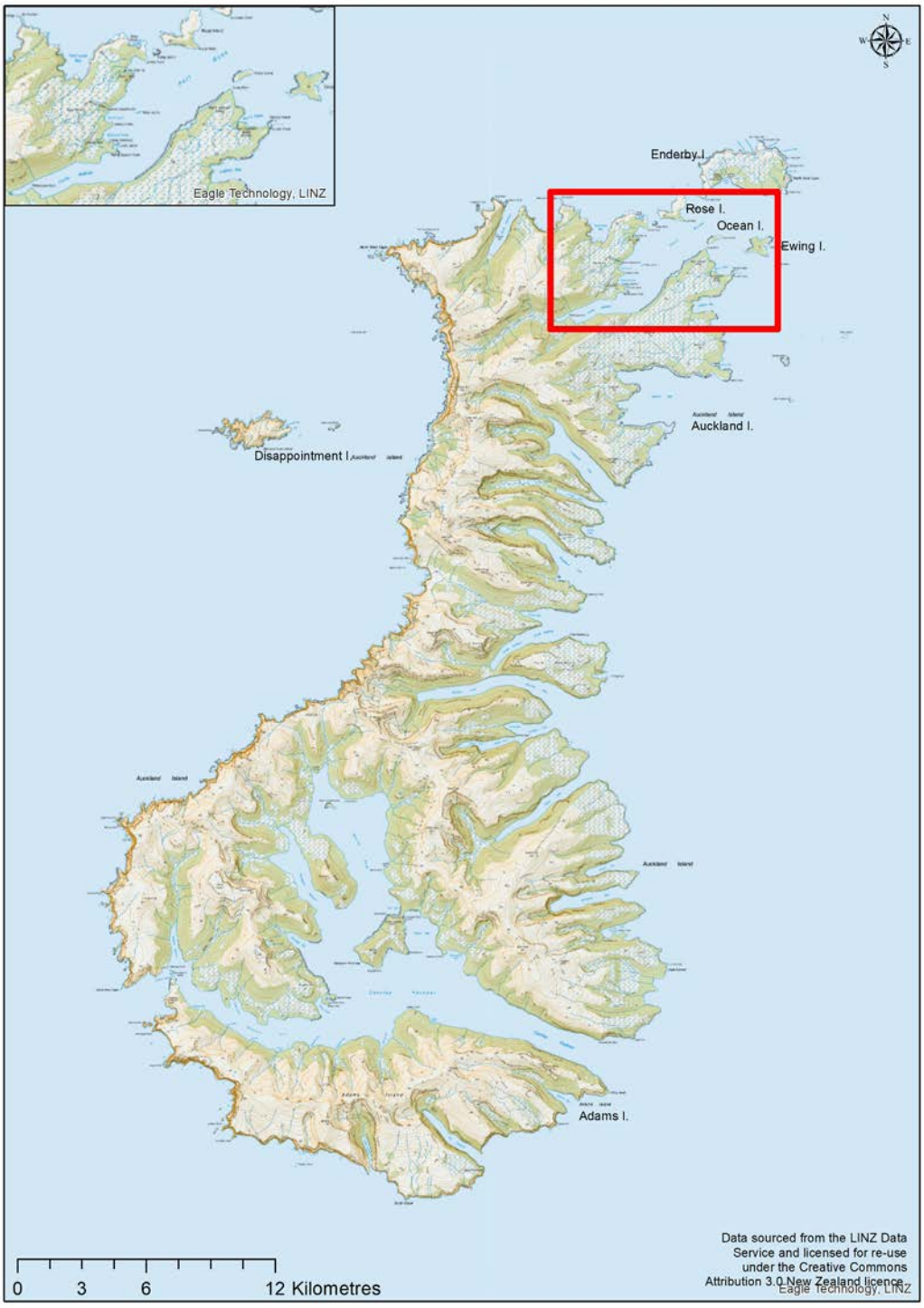

Figure 1. Map of the Auckland Islands showing the principal geographic features mentioned in the text.

2.2 Mouse live-trapping

Mice were live-trapped by setting Longworth live traps in two 7 × 7 grids with 10 m spacings, replicating the design used on Antipodes Island (Russell 2012; Elliott et al. 2015). Trapping was carried out in coastal rātā (*Metrosideros umbellata*) forest near to Deas Head Hut over 7 nights and in mid-altitude tussock (*Chionochloa antarctica*) habitat at approximately 250 m altitude near to spot height 277 over 6 nights (Fig. 2). These are the same sites that were snap-trapped for mice in winter 2007 by Harper (2010b).

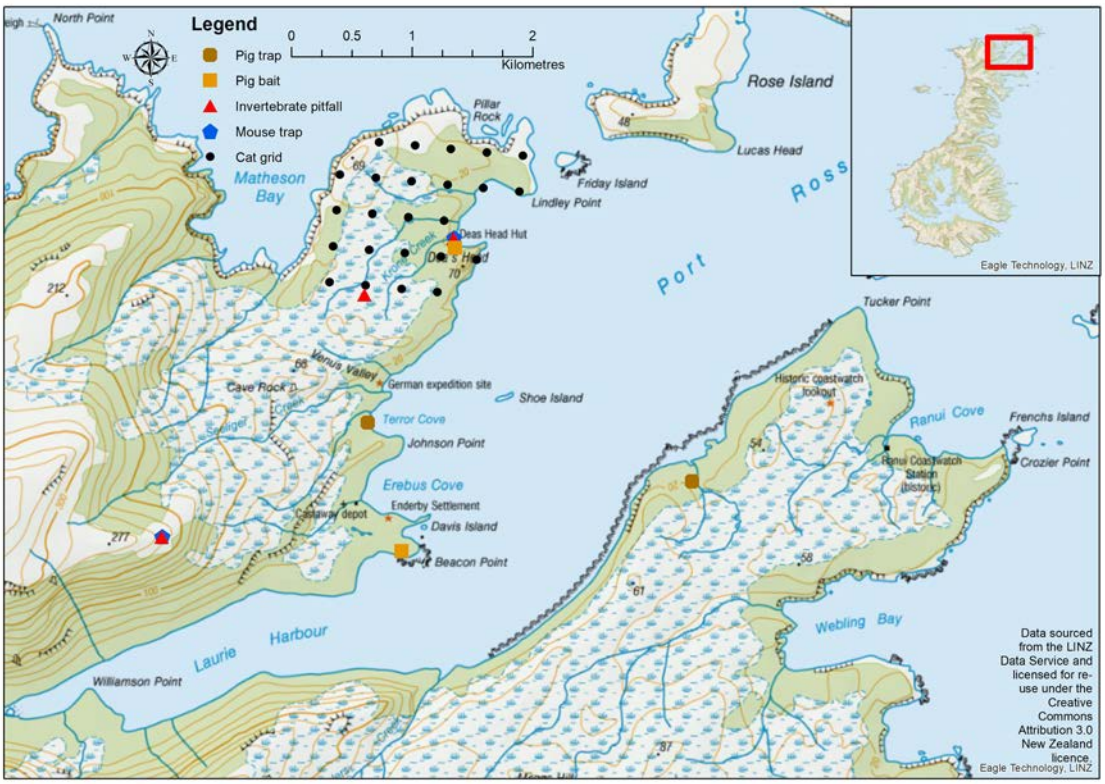

Figure 2. Location of the sampling sites around Port Ross for mouse (*Mus musculus*) live-trapping, cat (*Felis catus*) hair sampling, pig (*Sus scrofa*) bait and trap trials, and invertebrate pitfall sampling.

The density of mice was estimated using maximum likelihood spatially explicit capture-recapture methods (Borchers & Efford 2008). Due to the low densities of mice on Auckland Island, this analysis was augmented with home-range size data from Antipodes Island capture-recapture in coastal tussock habitat that were obtained in February 2011 (Russell 2012). Specifically, we assumed that the spatial decay parameter of detection, sigma (σ), was identical between the two islands to allow more reliable estimation of the capture probability at the home-range centre ($g0$) and the density on Auckland Island. This assumption is not unreasonable, as σ tends to be conservative in invasive mice and so any actual differences in σ would likely be small relative to the differences in density that we were most interested in estimating. A full likelihood model was used where the density and capture probability depended on island, in which case σ was fixed. We then calculated a single density and capture probability estimate pooled across habitats on Auckland Island. All analyses were performed in R 3.1.0 using package secr 2.9.4.

2.3 Cat hair sampling

We established a grid of 24 sampling stations at 300 m spacings across McCormick Peninsula (designated by a line from Matheson Bay to Terror Cove) north of Deas Head to non-invasively obtain genetic samples from cats (Fig. 2). We trialled two methods of sample collection at each station (Fig. 3). A scented cat rubbing pole (Schmidt & Kowalczyk 2006) was constructed by

driving a 45-cm-long wooden stake 15 cm into the ground, placing a velcro strip near the top and attaching a piece of carpet above this that was scented with two sprays of catnip (Hagen) on each side; a 20-cm-diameter plastic plate was then nailed over the top to protect the pole from the weather. In addition, a hair tunnel glue trap (Faunatech) was established 5 m north of each rubbing pole and baited with one block of dried rabbit meat (Erayz#8, Connovation). Each of these was left for 5 nights before being recollected.

Figure 3. Devices used for non-invasive cat (*Felis catus*) hair sampling: A. scented rubbing pole and B. hair tunnel glue trap.

2.4 Pig bait and trapping trials

Following previous bait preference and uptake trials in 2007 (Harper 2007), cafeteria-style bait trials were set up at Port Ross to assess the preference of pigs for different bait types that could be used to deliver a toxin or lure them into traps or open areas for shooting. These trials were conducted in open areas under the canopy of rātā forest near Deas Head and at Beacon Point (Fig. 2). At each site, equivalent volumes (c. 10 L) of eight bait formulations (Table 2) were placed in a different order in separate piles 2–3 m apart on the ground (Fig. 4) for 9 and 11 nights, respectively. The piles were roughly aligned so that all of the formulations could be seen from either end.

Table 2. Bait formulations used in the pig bait preference trials.

BAIT FORMULATION	SUPPLIER
Fish pieces (barracuda)	Unwin and Co
Porki Pig complete pellet (dry pellet)	SGT Dan Stockfoods Ltd
Fermented barley (whole grain)	Clarkes Seed and Feed
Bait-Rite paste	Connovation
Salmon food (pellet form)	Sanford
Brewers' mash	Invercargill Breweries
Prawn bait cakes (pellet form)	Ace of Baits
Kibbled corn	Clarkes Seed and Feed

We also set up corral-style pig traps at two coastal sites in Port Ross to assess the suitability of this design for catching pigs on Auckland Island (Fig. 5). Trap 1 was set up 30 m inland, southwest of Tucker Point in coastal scrubland for 6 nights and Trap 2 was set up at Terror Cove under rātā forest for 7 nights (Fig. 2). The traps were constructed by weaving sixteen 1.8-m waratahs through galvanised fence netting[1] (pig mesh) and then driving them through galvanised mesh foot plates that were placed around the inside perimeter to prevent any trapped pigs from digging out. The

[1] Note: panels of steel mesh that are generally used for reinforcing concrete could be used in place of netting and have been subsequently trialled with success in the Mataura Valley (F. Cox, DOC, unpubl. data 2015).

Figure 4. The eight bait formulations that were used in the pig (*Sus scrofa*) bait preference trials: A. fish pieces (barracuda); B. Porki Pig complete pellet (dry pellet); C. fermented barley (whole grain); D. Bait-Rite paste; E. salmon food (pellet form); F. brewers' mash; G. prawn bait cakes (pellet form); H. kibbled corn.

netting was then secured to the waratahs with lacing wire and the foot plates were pegged down using 35-cm-long pegs made from 12-mm ReidBar™. The total set up time was c. 30–60 min. A one-way gate was used that was set on a forward lean so that it closed with gravity and was set open by placing a long, thin stick horizontally between the gate and the frame to act as a hair trigger. A peg was placed in the ground behind the gate to stop it from opening past its balance point where it would no longer self-close[2]. Rubber strips were screwed onto the gate frame to

[2] An alternative approach would be to use a cotton thread to tie the gate back, which would then break on closing..

reduce the noise caused by the gate shutting. Each trap was baited by distributing 10 L of kibbled corn on the ground and placing four Ace of Baits fish cakes inside a staked bait-cage to ensure bait longevity. Fish oil was also dribbled on the ground at the entrance as an attractant.

Infrared motion cameras were used to record activity at each bait trial station (×4) and trap (×2). Each camera was set to record 10 s videos at 30 s intervals upon activation.

2.5 Invertebrate pitfall trapping

Surface invertebrates were sampled at the two mouse trapping sites and an additional low-altitude inland scrub site using ten pitfall traps (80 mm diameter, 90 mm deep) that were spaced more than 10 m apart (Fig. 2). Each trap was buried so that its rim was flush with the surface of the ground, covered with a green plastic lid, and filled to c. 2 cm depth with a 50/50 mix of glycol and water plus a drop of detergent. This standardised methodology replicates recent work that has been carried out on other subantarctic islands (Russell 2012; Bassett et al. 2014; Elliott et al. 2015), except the contents were removed sooner after only 4 days. The contents of each trap were subsequently identified to taxonomic unit by Melissa Houghton (Australian Antarctic Division) and qualitatively compared with the results of other studies.

3. Results

3.1 Mouse live-trapping

Only one mouse was detected across both trapping grids. This individual was captured in coastal rātā forest towards the end of the live-trapping period. Using the same value of σ as was calculated for coastal tussock habitat on Antipodes Island at the same time of year (i.e. σ = 10.7 m (Russell 2012)), the density of mice on Auckland Island was estimated to be <1 mouse/ha (95% CI = 0.1–5.6 mice/ha), despite the individual probability of capture not being unreasonably low at 0.07 (95% CI = 0.02–0.24). However, although mice were almost undetectable in both grids, seven mice were opportunistically trapped around Deas Head Hut, only 50 m from the rātā forest trapping grid.

3.2 Cat hair sampling

There was no obvious sign of cat hair at any of the stations on either of the devices. It is possible that trace amounts of cat hair were present, but these would have been easily confused with clothing fabric collected during device placement and collection. Only one recently deceased kitten was observed on the peninsula and there were several observations of cats recorded on video cameras during the pig trials. Therefore, cats were evidently present at a low abundance.

3.3 Pig bait and trapping trials

Bait consumption first became evident on day 6 of the bait trial. At Deas Head, only a single pig interacted with the bait – a black boar visited on day 6 and was then present every day, feeding heavily for extended periods until the end of the trial. This pig moved along the bait line regularly and often fed on different food types within a short period. It tried most bait types but fed heavily on only corn, barracuda, salmon food and grain mix (Table 3). Among these, kibbled corn was the preferred food, being completely consumed in a little over 2 days (Fig. 6), and the

Table 3. Consumption of bait by one pig (Sus scrofa) at Deas Head, ranked in order of preference.

BAIT FORMULATION	PIG CONSUMPTION	OTHER SPECIES
Kibbled corn	Entirely consumed by day 8	
Fish pieces (barracuda)	Entirely consumed by day 9	Heavy cat consumption
Salmon food (pellet form)	Most consumed by day 11	Occasional sea lion interest
Porki Pig complete pellet (dry pellet)	Approximately 50% consumed by day 11	Regular sea lion interest
Brewers' mash	Four brief tries	
Bait-Rite paste	Three brief tries	Light cat consumption
Fermented barley	Two brief tries	
Prawn bait cakes (pellet form)	Untouched	

Figure 5. Corral-style traps used in the pig (*Sus scrofa*) trap trial. A–D. Set up of the pig trap at Terror Cove – note the lacing of waratahs through the netting and the set up of the one way gate; E. the completed pig trap at Terror Cove; F. the completed pig trap at Tucker Point.

pig often returned to eat crumbs from the ground where the corn had been piled even when significant amounts of the other bait types remained. At Beacon Point, no pigs had visited the bait trial after 9 nights.

Figure 6. A pig (*Sus scrofa*) eating kibbled corn during the pig bait preference trial at Deas Head, Auckland Island.

In addition to the pig, a small black cat also interacted with the trial at Deas Head. This cat was first seen on day 5 and was recorded eating Bait-Rite paste on multiple occasions over the next 5 days and barracuda fish pieces on two occasions. The cat was also recorded eating within 3–5 m of the pig on multiple occasions, seemingly undeterred by its presence. In addition, a tabby cat and a smaller black cat also repeatedly visited the trial at Beacon Point from night 1. The tabby cat visited every night except for the second night, while the black cat visited on nights 4–7 but did not return after a fight appeared to occur between the two cats with the black cat submitting. Both cats spent time eating the barracuda fish pieces, which were fully consumed over the course of the trial, mostly in the last 3 nights. No other baits were consumed at Beacon Point.

Several New Zealand sea lions (*Phocarctos hookeri*) of various ages were recorded passing through both bait trials and were often seen sniffing the baits, particularly the SGT Dan Porki Pig; however, none were observed consuming bait. In addition, blackbirds (*Turdus merula*) were recorded feeding around the barracuda pile at Beacon Point once it had been largely consumed by the cats, possibly eating fish scraps or maggots.

Two different pigs were observed in the vicinity of the corral-style traps but neither attempted to enter them. One black pig visited the trap at Tucker Point on day 3 and sniffed around the trap entrance for less than 1 min, following which no further interactions were recorded. A black boar visited the Terror Cove trap on day 6 and was recorded sniffing around the gate for c. 70 s and then walking by c. 7 min later, believed to be the same adult male that interacted with the bait trial. In addition, two New Zealand sea lions and two yellow-eyed penguins (*Megadyptes antipodes*) were recorded going past the traps without attempting to go inside.

3.4 Invertebrate pitfall trapping

A total of 604 invertebrates from 10 orders (in declining abundance: Coleoptera, Collembola, Amphipoda, Araneae, Opiliones, Isopoda, Acarina and Chilopoda, Gastropoda and Dipetera) were collected in the pitfall traps. Nearly all individuals were collected in the coastal rātā forest (87%), while very few were collected in the mid-altitude tussock (9%) and low-altitude inland scrub (4%).

Most individuals were beetles (Coleoptera, 77%) and 99% of these were found in the rātā forest. Of the six beetle genera recorded, *Oopterus* was by far the most abundant (81% of individuals). The majority of the remaining invertebrates that were collected were springtails (10%) from the low-altitude scrub habitat and amphipods (6%) from the mid-altitude tussock habitat.

4. Discussion

4.1 Mouse live-trapping

Mice were almost exclusively trapped at Deas Head Hut, which strongly suggests that this was acting as a structural refugium for them. Historically, trapping rates for mice on Auckland Island have been low, with 0–22 captures per 100 uncorrected trap nights typically being obtained during intensive efforts (Taylor 1975). However, in late summer (February) 2006, a single line of ten traps in the rātā forest at South West Cape caught 20 mice per 100 corrected trap nights (G. Taylor, DOC, unpubl. data 2006), and in winter (June) 2007 intensive sampling in the same locations as this study caught 5.6–12.7 mice per 100 corrected trap nights (Harper 2010b). These high trapping rates potentially reflected mouse irruptions following tussock mast seeding events around that time but are also within the range of trapping rates that was previously recorded in summer (February) 1973 on Auckland Island (Taylor 1975).

Mice have also been found to be present at similarly low densities and to have a restricted distribution on Campbell Island/Motu Ihupuku (Taylor 1978) and South Georgia Island (Parker et al. 2016). However, on both these islands, they co-existed with Norway rats (*Rattus norvegicus*), which are known to suppress mouse populations (Caut et al. 2007). By contrast, mice have reached very high densities on other islands where there is an absence of other introduced rodents, including on nearby Enderby Island (24.5–35.8 per 100 corrected trap nights, Cunningham 1986), neighbouring Antipodes Island (9.1–102.3, McIntosh 2001; 12.3–53.6, Russell 2012), Gough Island (Wanless 2007) and Marion Island (McClelland et al. 2018). On neighbouring Macquarie Island mice existing in the absence of coastal ship rats (*Rattus rattus*) on alpine plateaus were also trapped at low densities (0–27.5 per 100 corrected trap nights, but typically <10, Springer 2006). However, inferring rodent densities from relative trap indices should be done cautiously. The density of mice on Marion Island has increased over the past few decades following the eradication of cats; however, this increase has been preferentially attributed to a warming climate (McClelland 2013). Cats are unlikely to be regulating the mouse population on Auckland Island but have decimated the previously abundant seabird populations, which would have subsidised the mouse population. In addition, pigs have also decimated the previously abundant megaherbs and other palatable vegetation on the island (Campbell & Rudge 1984; Chimera et al. 1995), as well as destroyed seabird burrows. Thus the main resource subsidy for mice on Auckland Island is likely to be the mast seeding of plant species, which for tussock on Auckland Island is infrequent (G. Elliott, DOC, unpubl. data 2017). Trends in the population dynamics of mice on Auckland Island are therefore likely to reflect patterns in mast seeding of tussock on Auckland Island (White 2007).

4.2 Cat hair sampling

No cats were detected at any of the sampling stations during this study. Since both of the passive cat sampling devices that were trialled required direct interaction, they should probably have been left out for a minimum of 1 month to be effective detection tools. However, alternative sampling methods that do not rely on any interaction, such as camera-trapping, would likely have greater potential.

A study of cat scats on Auckland Island in summer 1973 found that cats probably rely more on birds than mice for food; but that mice are an important food in grasslands, as are insects in forest (Taylor 2002). A subsequent survey during winter 2007 showed that the diet of cats predominantly comprised land birds and mice, and that the cats were in relatively good condition (Harper 2010a). It is possible that the conditions in that year may have been more conducive to supporting the cat population, particularly if that winter followed a mouse irruption on Auckland Island over the previous summer (see section 4.1). However, it is clear that the density of cats on Auckland Island is currently low and likely to be much lower than once occurred on Marion Island, where they had been more recently introduced to control mice and co-existed with seabirds prior to their eradication (van Aarde 1979).

4.3 Pig bait and trapping trials

Pigs were evidently present at a low abundance at Port Ross at the time of the trial on Auckland Island as few pigs interacted with the bait trials or traps. The single pig that was observed in the bait trial at Deas Head was found to prefer kibbled corn and fish pieces, and to a lesser extent salmon food pellets. We also found that cats were attracted to the bait trial and hence could be vulnerable to poison baiting using this method, although sea lions also showed curiosity in the bait trial when transiting, but did not consume any bait. However, further trials will be required to more accurately determine the bait preference among a larger sample size of pigs, as preliminary evidence suggests that pigs have a diverse diet (Rudge 1976) and previous bait trials have yielded different preferences to those found here (Harper 2007). We also found that the corral-style traps that were used were not attractive to the two pigs that encountered them. Therefore, further trials of different pig trap designs, bait types and deployment methods (time and bait) are required.

Previous telemetry studies of 15 pigs at Port Ross on Auckland Island in June 2007 revealed that pigs have home ranges on average of 10 km^2, but with large variation among individuals (Anderson et al. 2010). Pigs were also found not to seasonally migrate to the coastal rātā forest in winter, meaning pig eradication methodology must target individuals in all habitats, and especially the preferred tussock habitat (Anderson et al. 2010). Permanent vegetation monitoring plots of various sizes were established at Port Ross in 1973 to determine the impacts of goats and pigs and a subset of these were re-surveyed in 1983 (Campbell & Rudge 1984). In anticipation of pig eradication, these plots could be re-located and re-surveyed, but additional standardised national vegetation survey (NVS) plots should be established across Auckland Island, and on other islands where pigs have never been present (Adams and Enderby Islands) for comparison.

4.4 Invertebrate pitfall trapping

Invertebrate surveys around Port Ross (Deas Head, Enderby Island, Rose Island and Ocean Island) were previously undertaken in November to December 1989 using pitfall trapping and hand collecting; however, the records for these are no longer available (B. Rance, DOC, pers. comm.). Although we undertook pitfall sampling for a much shorter period than has occurred on neighbouring subantarctic islands, it was still clear that the abundance and species composition of Coleoptera differed markedly from those of neighbouring, predator-free Adams Island, where the vertebrate-associated carrion beetle *Paracatops antipoda* dominated (Bassett et al. 2014). Furthermore, the number of individuals belonging to other Orders was also reduced compared with neighbouring Antipodes Island, even after accounting for our reduced sampling effort (Russell 2012). These findings reflect the combined effect of habitat type and mouse predation on the invertebrate community structure on Auckland Island, along with the absence of seabirds and impacts of pigs. This differs from Marion Island, where factors other than mice were considered important in structuring the invertebrate community (van Aarde et al. 2004). In anticipation of mouse eradication, invertebrate pitfall trapping should be continued on Auckland and Adams Islands, and additionally on Enderby Island.

5. Recommendations

Based on the results of this preliminary study and previous work, we recommend that the following research is carried out prior to undertaking any further predator management on Auckland Island:

- Studies on the population biology, home range, habitat preferences and limiting factors for mice on Auckland Island.
- Studies on the population biology, home range, habitat preferences, abundance and detectability of feral cats on Auckland Island.
- Further trials of bait types to confirm their attractiveness and palatability on Auckland Island as a lure or bait for pigs and cats.
- Trials of corral-style pig traps over a longer period with an extended pre-feed period during which the door is wired open. Once pigs are regularly entering the trap to feed, the door can be set to half open on a hair-trigger. This can be trialled on the mainland to test the integrity of the design and its ability to catch and hold multiple pigs.
- Pitfall trap baseline studies of macroinvertebrates on Auckland Island for comparison with neighbouring predator-free islands (Adams and Enderby Islands) and to monitor the response following any predator management in the future.
- Study of the timing of mast seeding events and consequent resource subsidy impacts on introduced mammals.
- Resurvey Port Ross vegetation plots on Auckland Island and establish additional plots and photo points across a range of habitats and islands (Adams and Enderby Islands) prior to any pig eradication to give a baseline for any changes in flora composition and density.

6. Acknowledgements

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Appendix 1

Annotated list of the birds seen on and near Auckland Island around McCormick Peninsula, 26 March – 3 April 2015

Yellow-eyed penguin (*Megadyptes antipodes*): A few pairs moulting along coast from Deas Head to Hardwicke.

Light-mantled sooty albatross (*Phoebetria palpebrata*): Four birds observed in display above Matheson Bay on 28 March. Nest with chick under Deas Head cliffs.

Northern giant petrel (*Macronectes halli*): Occasionally seen in bay and congregation of 30 observed on 30 March feeding on dead sea lion north of Deas Head.

Auckland Island shag (*Leucocarbo colensoi*): Occasionally seen in bay and common in outer region of Port Ross.

New Zealand falcon (*Falco novaeseelandiae*): Heard twice in Deas Head bay.

Black-backed gull (*Larus dominicanus*): Adults and juveniles regularly seen in bay.

Red-billed gull (*Larus novaehollandiae*): Adults and juveniles regularly seen in bay.

White-fronted tern (*Sterna striata*): Regularly seen in bay.

Red-crowned parakeet (*Cyanoramphus novaezelandiae*): Heard daily in rātā forest.

Bellbird (*Anthornis melanura*): Common across rātā forest and scrubland.

Tūī (*Prosthemadera novaeseelandiae*): Common in rātā forest around coast.

Tomtit (*Petroica macrocephala*): Common across rātā forest and scrubland.

Silvereye (*Zosterops lateralis*): Common across rātā forest and scrubland.

Blackbird (*Turdus merula*): Common across rātā forest.

Song thrush (*Turdus philomelos*): One heard in song at Hardwicke cemetery on 31 March.

Pipit (*Anthus novaeseelandiae*): Regularly observed on coast and in scrubland.

Redpoll (*Carduelis flammea*): Common across rātā forest and scrubland.

Appendix 2

Marine mammal notes

- New Zealand sea lion (*Phocarctos hookeri*) abundant in coastal rātā forest, including a number of creches. Sea lion pup red flipper P04 under hut on 31 March. Sea lion adult female left blue 4046 observed in Krone Creek on 2 April recovering pup.
- A small number of New Zealand fur seals (*Arctocephalus forsteri*) were observed around the coast near Deas Head Hut.
- No whales were observed.

Appendix 3

Specimens collected and stored at the Auckland War Memorial Museum

ACCESSION NUMBER	SPECIES	MUSEUM SPECIMEN CATEGORY	LOCALITY DESCRIPTION
LB15029	*Megadyptes antipodes*	Bones	Lindley Point Beach
LM1579	*Mus musculus*	Alcohol*	Deas Head Hut
LM1580	*Mus musculus*	Alcohol*	Deas Head Hut
LM1581	*Mus musculus*	Alcohol*	Deas Head Hut

* Whole specimen preserved in alcohol.