Feasibility of eradication or options for control of feral cats on Bruny Island, Tasmania, Australia

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John Parkes

Kurahaupo Consulting, 2 Ashdale Lane, Strowan, Christchurch 8052, New Zealand (Email: John.Parkes1080@gmail.com)

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Contents

Executive summary

Bruny Island has significant current and potential biodiversity values which might be enhanced if introduced mammals, particularly feral cats (*Felis catus*), were removed. The Federal Government selected Bruny Island as one of five Australian islands from which cats (feral, stray and domestic) might be eradicated or removed and tasked the Kingborough Council, the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) and the Federal Department of Environment to progress the planning and potential delivery of the project. In late 2017, the Kingborough Council commissioned Kurahaupo Consulting to assess whether the cats might be eradicated, if so how this might be achieved, but if not how sustained control might be applied to effectively limit the impacts of cats across the whole or key parts of the island.

Objectives:

1. To summarise the impacts of feral cats on Bruny Island and the potential benefits of their eradication.
2. To describe the potential methods available to eradicate the cats.
3. To assess the feasibility that the cats might be eradicated from the island.
4. To discuss the constraints to be managed if eradication is to be effective and efficient; including social license to operate, non-target risks, adverse consequences of removal of the cats and animal welfare issues.
5. To describe options to sustain control of cats if eradication is not feasible or attempted.
6. To provide estimates of costs or effort, where these are available, for the viable management options.
7. To describe some operational scenarios for potential ways to achieve eradication.

Main results:

Impacts of cats:

1. Bruny Island has a significant number of native and introduced animals that are potential prey for cats. This diverse supply of natural food (plus food supplied to domestic and stray cats by people) allows cats to reach higher densities in some places than those densities measured on many other islands.

2. Cats are a probable cause of the rarity of several small mammal species on Bruny Island and there is little doubt that removing cats would have significant net benefits for the native species on the island. The current species diversity on Bruny Island means removing cats as the top predator will have complex consequences among the interacting native and introduced species. Densities of common prey species (rodents and rabbits) are unlikely to change, competitors (quolls) may increase a little, rare species only eaten as by-catch (the small marsupials, skinks) or seasonally during their breeding season

(nesting seabirds) are likely to show large increases in numbers or recuitment. Some of these complexities can be clarified by research now underway.

Cat control tools:

3. The toolkit to remove cats has 12 main components but only a few are currently available (legally and practically) for use on Bruny Island – live trapping in cages, shooting under some restrictions, fencing from priority sites and sterilisation of domestic cats.

4. Additional tools, particularly leg-hold trapping with soft-jaw traps, the use of detector dogs to locate cats, and possibly localised poison baiting, will be required if eradication is to be achieved.

Feasibility of eradication:

5. Feral cats have been eradicated from 82 islands around the world including two of similar size to Bruny Island (Marion and Dirk Hartog). Only three islands (Ascension, Lord Howe and Rottnest and all smaller than Bruny) have a substantial residential human population and so the eradications were complicated by the presence of domestic cats.

6. Meeting the obligate rules for eradication will require a substantial effort using the current toolkit. Broadscale poisoning with baits developed to target cats elsewhere in Australia has been an efficient way to achieve initial reductions in cat numbers. Localised baiting may also sometimes be used to kill wary survivors. However, the method may not be suitable as a general control tool on Bruny Island because of risks to non-target species. These risks should be assessed in research trials. Leg-hold soft-jaw trapping has proved essential in all other cat eradication projects and will be necessary to achieve eradication on Bruny Island. One person can service about 30 traps per day which allows a daily transect of about 4500 m to be covered by one person. These numbers set some of the parameters needed to judge the effort required to put all cats at risk as a campaign is rolled out across different management zones on Bruny Island.

7. The effort required on other large islands from which cats have been eradicated suggests it will take well over 10 000 person-days effort to remove all feral cats from Bruny Island. How much more depends on the numbers of field staff employed (and the capacity to support this number on the island) and thus how many years it will take to roll out the program across the island. Shorter timeframes are best to avoid residual cats simply replacing some of their losses and to reduce risks of funding fatigue, but this would require either deploying more field staff, which may be logistically difficult, or potentially using toxic baiting as a more general control tool.

8. Costs will depend on how operational workers are employed (as staff, contractors, volunteers), the methods used, how the attempt is rolled out across each management unit and whether research and monitoring costs are funded by the project.

9. In practice, the island will need to be divided into smaller, more manageable zones (nine management units are suggested but some could be subdivided as the project proceeds and lessons are learnt) and the eradication effort will need to be deployed across these one at a time. Three scenarios to roll out such an eradication program are presented.

a. Scenario 1: From the center outwards.

Eradication is attempted first on The Neck as a high priority site for seabird biodiversity, as cat control is already underway at the site; to form a cat-free buffer between North and South Bruny; and to test the proposed methods to gain a better appreciation of how much effort is required to reduce a cat population to zero and maintain it with management in buffer zones. Subsequently, a campaign to treat North Bruny in three zones would start in 2022 and potentially end with validated success in 2030, followed by the five South Bruny zones beginning in 2028 and ending in 2040.

This scenario would have a variable number of field staff and would cost an estimated $42 million over 21 years, i.e. about $2 million per year on average.

b. Scenario 2: From the center outwards but in paired zones

Again the eradication campaign would begin on The Neck but then move outwards in north and south pairs of zones ending in about 2032. This scenario would also require annual variation in the numbers of field staff employed with a maximum of about 27 in 2028/29 for the largest set of zones. It would cost an estimated $29 million over 14 years, i.e. again about $2 million per year on average.

c. Scenario 3: A mixed rollout with a set number (17) of field staff

The rationale for this scenario is partly to learn how to achieve eradication in two areas (The Neck as above and a large peninsula in the south), and then to roll out the campaign first on North Bruny and then South Bruny. It would cost an estimated $42.5 million over 18 years, i.e. about $2.4 million per year on average.

10. The time to reduce the populations, mop-up survivors and validate success is, at this stage, a guess. Based on full-time deployment of the staff and judging by other cat eradication projects that used only trapping it would take about five years for each zone.

11. Defending zones from reinvasion by early detection and rapid removal of ‘immigrants’, intensive control in buffers or by fencing will be a key issue to be resolved. The Neck appears to be an area that attracts cats so managing immigration across the proposed buffer zones at each end will allow better assessment the effort and costs required to manage this issue in the other management zones.

Constraints to be managed:

12. Constraints that have to be resolved include the management of domestic cats, biosecurity measures to stop new fertile cats being introduced, mitigation of non-target impacts from key control tools, and relaxation of legal/regulatory constraints on control methods.

Alternative management strategies:

13. Eradication is an ‘all or nothing’ strategy and should not be chosen unless the necessary tools, planning, management and project structures, trained staff and resources are

committed. If these are not committed, it is better to select the alternative strategy of sustained control.

14. Cats might be controlled to low densities at high priority sites. The target densities might vary from near zero (e.g. with ongoing management of reinvaders) to some population level at which the impacts of cats are mitigated. The target cat population levels to achieve these mitigations needs to be validated by experience and adapted if required by evidence.

    The Neck, as the start point for all eradication scenarios and a priority site for seabird nesting, would naturally form one sustained control site should eradication not proceed. The Labillardiere Peninsula zone (or at least the peninsula itself) is also a high priority site that could be continued as a sustained control area under Scenario 3.

15. If the aim becomes protecting biodiversity assets at high priority sites then it is the site values that count and all threats to these could be managed. Cats may not be the only invasive species that threatens the assets and control of cats alone may allow other pests (ship rats for example) to increase their impacts. Irrespective of these possible trophic consequences it may be advantageous to control other exotic predators and heebivores at the sites.

16. There are two bioeconomic options to plan such sustained control. A more-or-less fixed annual budget might be used to determine how many sites can be effectively treated. Alternatively, the desired number of sites to be treated could determine how large the annual budget should be.

17. Research projects are underway on some of the potential benefits and trophic consequence of removing cats. Operational research also needs to be conducted in particular to test the non-target risks of leg-hold trapping and use of toxic baits.

Conclusions:

Eradication is feasible but will require a dedicated management and operational structure with adequate funding and access to as many tools as practical. It will not be achieved using cage-trapping alone.

In general, risk of eradication failure is reduced when the timeframe is shortest. However, there is an obvious trade off between maximising annual effort (there is probably a ‘carrying capacity’ for the number of field staff that can be deployed) and the time to completion. It is difficult to predict these parameters accurately as the time to reduce, mop up and validate eradication on Bruny Island conditions will remain unclear until the attempt is made in the first management zones. Planning has to adapt as results become apparent.

If the funding timeframe is critical, then the shortest scenario presented (The Neck then paired zones to the north and south) is least risky. However, if this is not critical but the capacity to manage larger numbers of field staff is difficult, then the ‘one zone at a time’ starting with The Neck, then North Bruny zones with South Bruny zones left to last is best.

Trapping and particularly soft-jaw leg-hold trapping is likely to be the main control tool at least in the initial phases of an eradication. This is a skilled task and the project managers would be wise to seek advice from people with expertise to train project staff. It is also likely that detector dogs will be required at least in the mop-up and validation phase of an eradication program.

If sustained control is the selected fall-back strategy, the priority areas for native biodiversity, currently mostly based on nesting seabird colonies, or some representative examples of important habitats could be selected. Cats are already under control in The Neck zone and this should continue if a full eradication project is rejected *a priori* or after the planned attempts fail. The extent of other sites for sustained control would depend on the amount of money committed annually in perpetuity and whether other introduced mammals such as ship rats should be controlled.

Monitoring outcomes of management has several purposes. For the eradication option, data collected during the campaign can be used to assess whether absence of further evidence of cats equals successful eradication. This may be difficult for some monitoring methods if domestic (sterilised) cats remain. Baseline data on key non-target species or indicator species should be collected to allow the benefits (and potential ecological costs) of cat eradication to be asssessed. This type of data is even more essential under a sustained control strategy to determine if the post-control residual cat population is still having significant adverse impacts, i.e. the control has been intensive enough, frequent enough and in the right places.

1 Introduction

Bruny Island has significant current and potential biodiversity values which might be enhanced if introduced mammals, such as feral cats (*Felis catus*), were removed (Anon 2013, Bryant 2018). The Federal Government selected Bruny Island as one of five Australian islands from which cats (feral, stray and domestic) might be eradicated and tasked the Kingborough Council, the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) and the Federal Department of Environment to progress the planning and potential delivery of the project. In late 2017, the Kingborough Council commissioned Kurahaupo Consulting to assess whether the cats might be eradicated, if so how this might be achieved, but if not how sustained control might be applied to effectively limit the impacts of cats across the whole or key parts of the island.

2 Objectives

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The report aims to inform decision-makers who will be responsible for developing a long-term management strategy, structure and operational plan to manage cats (feral, stray and domestic) on Bruny Island. It is divided into six parts. The first part acts as background material and briefly describes the island and its fauna and the problem caused by cats and so the benefits of managing them, provides some general background on how pest projects are structured and the place of a feasibility study within that structure and describes how eradication projects in particular may be planned. The second part summarises all the different control methods in the toolkit to manage cats and notes which are available for use in Tasmania and which are needed to achieve eradication on Bruny Island. The third part addresses the main question in the objectives – can cats be eradicated from Bruny Island and what risks and constraints will have to be managed to make it happen. The fourth part adds some notes on cat ecology and management that might be of use when detailed operational planning begins. The fifth part trespasses outside a typical feasibility study into more detail by discussing some of the strategic, tactical and logistic scenarios that might be deployed across the island to eradicate cats. The last part draws some conclusions and recommends actions required before any project to eradicate or control cats proceeds.

3 Background

3.1 The island and its introduced mammals

Bruny Island is a 35 200-ha island about 2 km off the south-east coast of Tasmania at 43º30’S 147º28’E. The island is divided into two parts joined by a 2-km long vegetated, sandy tombolo that is only 100 m wide at its narrow point which allows the possibility of managing the whole island in two parts. North Bruny is dominated by dry forests and woodlands and open pasture, while South Bruny is wetter and dominated by wet sclerophyll and rainforest at higher altitudes and coastal heathland and scrub at lower altitudes (Fig. 1, Fig. 2).

The resident human population of the island numbered 771 in 2011, with 31% living on North Bruny and 69% on South Bruny, in a total of 343 and 699 private dwellings, respectively (Wells et al. 2014). People keep domestic animals (cats, dogs, sheep, cattle, donkeys, horses, llamas) while domestic dogs and cats are present throughout the settled areas. Over 60% of the island is set aside for conservation of wildlife or is in private land but with minimal use (Fig. 3).

Six species of wild and feral introduced mammals are known to be present (Bryant 2018, Driessen et al. (2011). Cats, black rats, house mice and rabbits are present across the island, feral goats and fallow deer are present only on South Bruny, while a predator faeces found in 2011 tested positive for red fox but this was never confirmed by subsequent evidence.

Figure 1. Three habitat types from Bruny Island (a) The Neck sand dunes bounded by a sandy beach and mudflats, (b) farmed grasslands and dry eucalypt forest on North Bruny Island and (c) coastal scrub on South Bruny

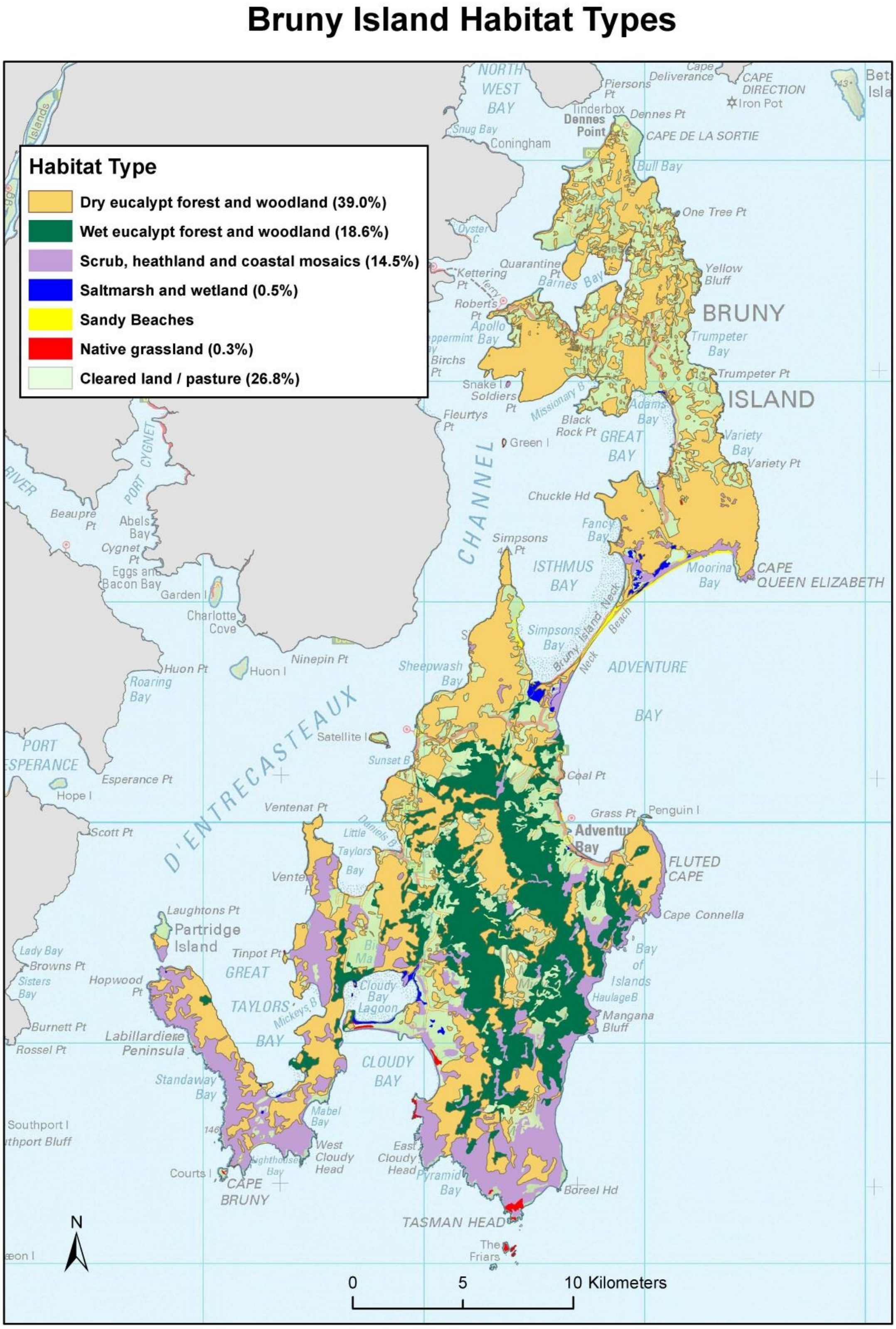


Figure 2. Vegetation distribution, Bruny Island

Bruny Island Land Use

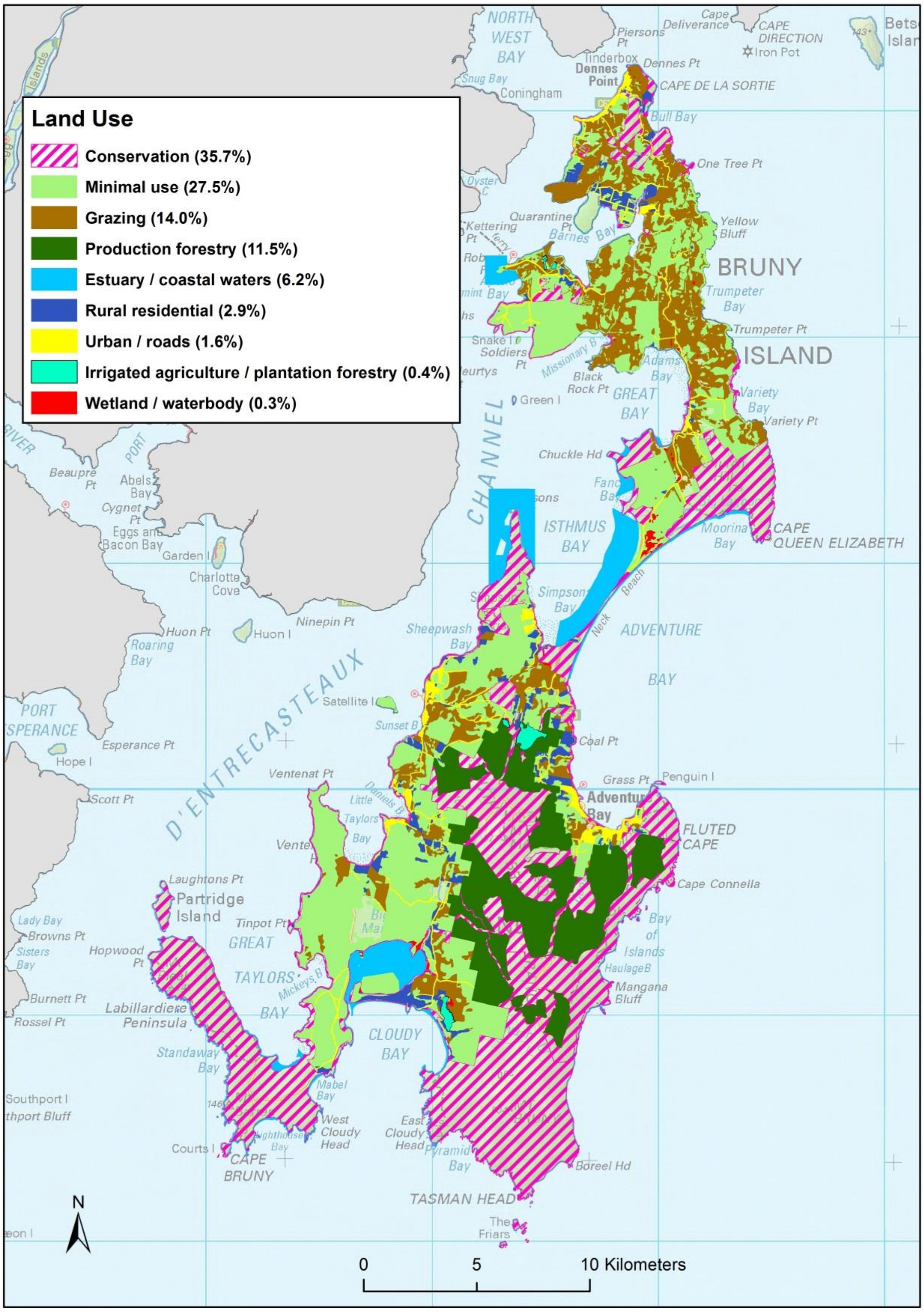


Figure 3. Landuse on Bruny Island

3.2 Justification to eradicate or control cats

There are several lines of evidence to justify removing introduced cats from native ecosystems – observed impacts on native species, diet studies, trophic studies and evidence of benefits when cat numbers are reduced.

Observed impacts: Cats are known to have caused the extinction of many insular small mammals and birds around the world (e.g. Nogales et al. 2013, Duffy & Capece 2012) and have been implicated in the extinction (particularly those weighing less than 220 g) and current threat to small native mammals, reptiles and birds active on the ground across mainland Australia (Dickman 1996). Predation by feral cats is listed as a key threatening process in the national *Environment Protection and Biodiversity Conservation Act 1999*. A Threat Abatement Plan for feral cats developed under the 1999 Act guides implementation (Woinarski et al. 2015).

On Australian islands, cats have been the main cause of the extinction of the Macquarie Island parakeet (Taylor 1979), and the local extirpation of many species, e.g. 10 of the 13 small mammal species once present on Dirk Hartog Island (McKenzie et al. 2000). On Tasman Island the cats were thought to kill over 30 000 fairy prions (*Pachyptila turtur*) every year (Bryant & Shaw 2006). On Clarke Island (lungtalanana) in Bass Strait feral cats have eliminated all but one of the small native mammal species once present (Anon 2014). The Australian Threat Abatement Plan for feral cats (Environment Australia 1999) lists 10 birds, 25 mammals one reptile and two frogs from the first schedule of the *Endangered Species Protection Act 1992* that are known or suspected of being threatened by feral cats.

Apart from small mammals, cats are known to prey (intensively in some places) on small reptiles, ground-nesting birds and larger invertebrates (Doherty et al. 2015) so are likely to be limiting the densities of the four species of lizards reported from Bruny Island (Anon 2000, 2013).

Other potential impacts of cats are more subtle. Cats carrying the parasite *Toxoplasma gondii* are present on Bruny Island (Fancourt & Jackson 2014) and may infect other species, including humans, with the disease toxoplasmosis (Hollings et al. 2013). Elsewhere, toxoplasmosis has been implicated in mortality in marine mammals, with cats being the suspected source of infection (e.g. Donahoe et al. 2014).

Bruny Island retains a diverse native fauna (see Anon 2013, Park & Roberts (2016) and Tables 1 – 3 in Allan 2015). Surveys reported in Driessen et al. (2011) and Anon (2013) record 27 species of native mammals – with more on South Bruny than North Bruny. Ten mammals (the six species of bats were not ranked) have been ranked as being at very high or high risk of predation by cats (Allan 2015). Thirty-four species of ground-nesting terrestrial and marine birds are also ranked as being of high risk (Allan 2015). A group of species are on the verge of extinction on the island, and so rare they are unlikely to be found in any cat's diet study despite the assumption that their rarity has been cause by cats. A survey (Anon 2013) failed to find mammals such as bandicoots (*Parameles gunnii* and *Isoodon obesulus*), and white-footed dunnarts (*Sminthopsis leucopus*), and rarely detected other small mammals such as dusky antechinus (*Antechinus swainsonii*) which are all in the prey range for cats. An

assumed benefit of cat eradication would be the recovery of these species or potential for re-introduction if they are extinct on the island.

Cats on Bruny Island also kill seabirds that nest on the island. Geale (2017) showed high numbers of cats used the areas of The Neck occupied by little penguins (*Eudyptula minor*) and short-tailed shearwaters (*Puffinus tenuirostris*) and suggested cat control would benefit these birds.

Dietary studies: Initial studies of the diet of 30 feral cats on Bruny Island noted at least 16 native animals (mammals, birds, reptiles and amphibians) along with introduced rabbits and house mice as prey (Allan 2015). Whether this indicates such prey are at risk at the population level is of course a moot point.

A study of the diet of cats on Wedge Island showed birds were the most common prey item. Little penguins were an important prey (Beh 1995). Fairy prions (*Pachyptila turtur*) and short-tailed shearwaters were also important prey on Wedge Island (Anon 2014).

Trophic studies: The consequences for other species if cats are eradicated is more complex. An initial prediction would be that species that act as primary prey for cats and are common on the island (native and introduced rodents and possibly rabbits) would not increase (a bottom-up predator-prey system; Pech et al. 1995), but many of the species only occasionally eaten by cats as secondary prey would increase in the absence of cats. There are also expected interactions with cats' competitors such as eastern quolls (*Dasyurus viverrinus*) (Fancourt et al. 2015) and between the other species – as indicated for example by the absence of house mice in areas with high densities of swamp rats (*Rattus lutreolus*) and swamp antechinus (*Antechinus minimus*) (Anon 2013).

The position of cats in the food web on Bruny Island is much more complex than, for example, their position on the depauparate food-web on lungtalanana (Clarke) Island in Bass Strait. On Clarke cats have extirpated all but one of the small native mammals, nesting seabirds and rabbits leaving only house mice and ship rats as their main prey (Parkes 2016). Interestingly, on Bruny Island rabbits are absent at sites (dominated by wet forest habitats) where cats are most abundant, and cats are least abundant at sites in the north where rabbits are most abundant (Parker 2016).

It could be argued that cats have a net benefit for native biodiversity if they are regulating introduced rat and mouse densities, i.e. if the rodents are having a worse effect than the cats. It is unlikely that cats do regulate rodent densities, although this has yet to be tested on Bruny Island. Most such systems are bottom-up – food abundance such as grass seeds (driven by rainfall in more arid areas) determine the number of rodents and rodent numbers then determine the number of cats (e.g. Luna Mendoza 2014). When rodent numbers fall, cats stop breeding, turn to alternative prey or starve and their population falls until a new surge in grass seed and rodents. The problem is not for the rodents but for the alternative prey called secondary prey. Such species do not affect cat numbers but may be severely affected by the cats. This is one mechanism by which predators drive prey to extinction – it is safer to be primary prey and set the trophic rules than secondary prey and bycatch. Bycatch and extinction may have been the fate of lungtalanana rabbits. Cats were introduced to control the rabbits and appear to have done so but only after rats and mice established on the island sometime after the 1970s. The rationale for this possibility is based on the status of rabbits

and rodents as primary or secondary prey of cats. It is possible that rabbits switched from being the primary prey of cats to secondary prey once rats and mice became available and thus vulnerable to extinction (e.g. Sinclair & Krebs 2002, Pech et al. 1995).

Benefits of cat control: An initial prediction would be that species that act as primary prey for cats and are common on the island would not increase (a bottom-up predator-prey system; Pech et al. 1995), but many of the species only occasionally eaten by cats as secondary prey would increase in the absence of cats. There are also expected interactions for competitors of cats such as quolls and between the other species – as indicated for example by the absence of house mice in areas with high densities of swamp rats and swamp antechinus (Anon 2013).

Figure 4 shows an initial simplified food web for cats on Bruny Island with some estimates of interactions that may be elucidated in proposed research studies.

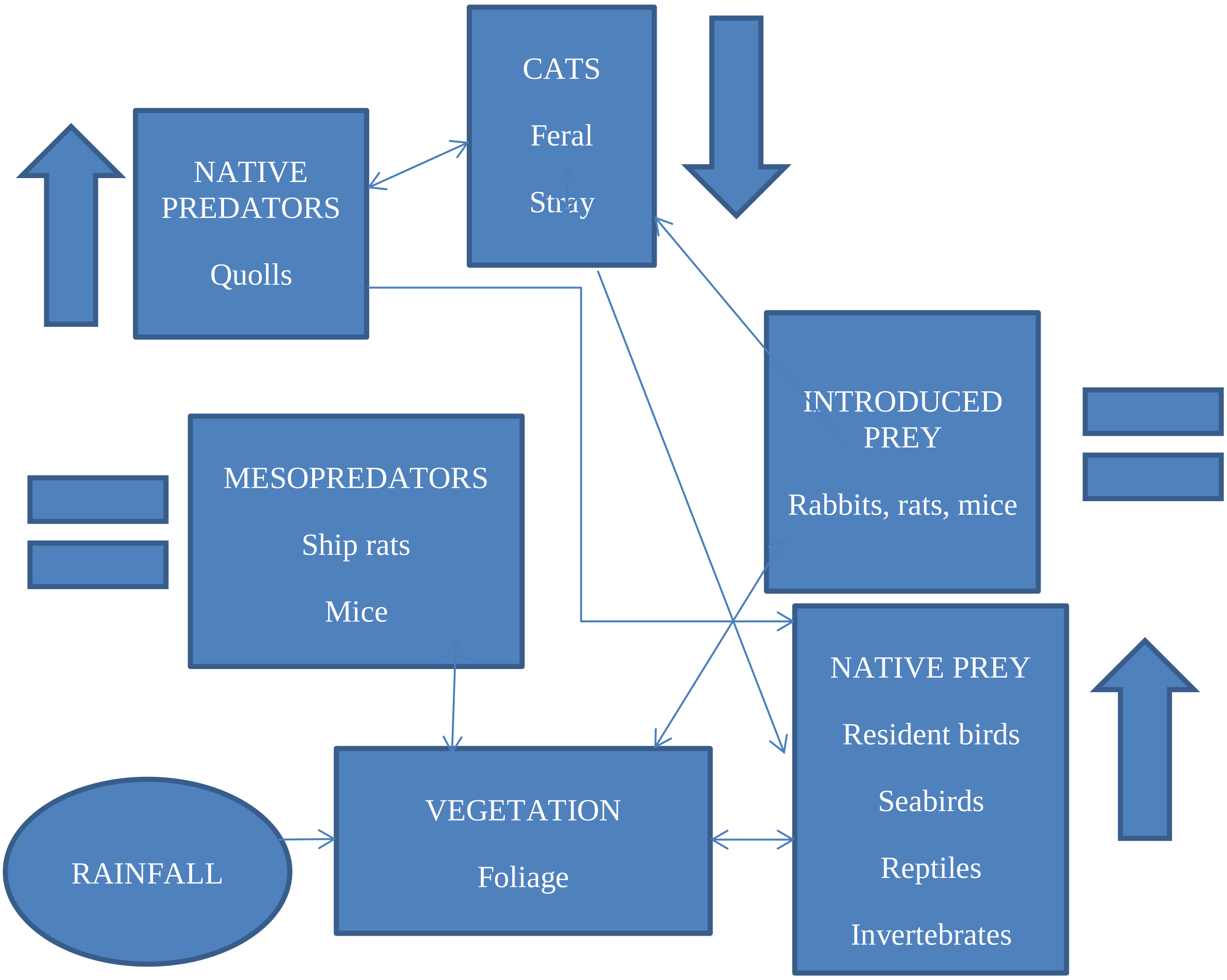


Figure 4. Predicted food web for Bruny Island showing possible directions of change in numbers if cats are eradicated or controlled

3.3 Pest projects: the role of feasibility studies

Pest management projects can be divided into a logical set of components, each with different functions and each aimed at different sets of people (Parkes 2018). The first step is to define the problem, in this case the impact of feral cats on native biodiversity and whether removing the cats will allow native animals to recover and open opportunities for more active restoration. This component of the project cycle has to be developed by those people who benefit from the project and is aimed at those who have to make the decision to fund the project. Having decided that action is justified, those making the decision to proceed (and fund) the project usually want to consider all the management options they face to achieve the goals. Eradication, sustained control over the whole or key parts of the island, or no action are the options - with the feasibility of eradication the focus of this report. Once the options are considered and one is selected a project needs some management structure to deliver the chosen option. Usually for large projects there is some form of governance to represent the project proponents and funders and usually with a project manager who is responsible for overseeing the operational structure, support staff such as GIS experts, field staff, contracts, and reporting to the governance board as appropriate. A detailed operational plan is usually developed at this stage by the project manager and the operational manager. This may be approved by the governance group in principle but is aimed at the operational manager who is responsible for delivering the outcomes required. The project manager may evolve into an operational manager, but in large projects the operational manager is usually someone with operational expertise responsible for the day-to-day management of the project's delivery, data collection and monitoring. Finally, the proximal aim of the project is zero cats which needs to be validated by analysis of the data collected during the project. This is often best done by an independent analyst (e.g. see Ramsey et al. 2011) especially if performance-based contracts are used as part of the delivery process. Measuring the benefits of having no cats is of course a longer-term process and requires a separate project and additional funding past the end of the eradication project. However, if the aim is not eradication but sustained control of a pest the measurement of changes in biodiversity or some indicator of benefit is essential to set target densities of the residual cat population.

3.4 Eradication projects

The best approach for any pest eradication project is to kill all the target population in a single control event, e.g. as with aerial baiting with anticoagulant toxins for rodents where the 'event' is one or more sowings of bait over a few weeks (Parkes et al. 2011). In these projects everything must work on the day so meticulous planning and operating standards are essential (Broome et al. 2014). However, the actual operation itself provides very little information on success or failure. In contrast, most eradication projects against other species rely on a succession of control events, often changing tactics as the project proceeds, that eventually reduce the target population to zero. In these cases there is an opportunity to collect information such as catch per unit effort data, kill locations, age and sex of the animals and use the data to adapt tactics or to judge when no animals are left (e.g. Ramsey et al. 2011).

It helps management decisions, e.g. about which control tactics to use as the project proceeds, to think about these sequential projects in phases.

(a) Pre-operational information collection

Even before a final decision is made to proceed it is sensible to begin to gather some basic information on the cats and their role in the island's ecology to inform the justification for action and the feasibility study on what action is possible or best. Recent and proposed research projects, cat control at some sites and monitoring on Bruny Island provides such information (Appendix 1).

(b) Operational phase – initial reduction in pest numbers

The general rules in this phase are to reduce the population as quickly as possible using methods that put all or most individuals at risk without teaching survivors to avoid the control method used or future methods (Macdonald et al in press). The rationale for haste is that many pests have high rates of increase (cats have a high rate of increase and can double their population every year – see section 5.2).

(c) Operational phase – mop-up survivors

Depending on the control techniques used in the initial reduction phase, some animals (hopefully very few) will survive. These animals have to be located and killed. Usually a change in tactics is required because they may be wary animals having avoided the initial control, or because they are in difficult places.

(d) Operational phase – validation of success

Eventually the field staff have caught all the animals they know exist and cannot locate any more. The question is whether to stop and declare success. To be absolutely sure no pests are left one would have to search everywhere on the island with a perfect detection system; which does not exist. One option is to tentatively declare success, decommission the field effort and wait and see if unknown survivors and their offspring become obvious – by weight of numbers, and then if they do to 'eat humble pie' re-start the project and redeploy the field staff. A better alternative is to use the data collected during the initial knockdown and mop-up phases to calculate a probability that no animals found during the end-game equals no animals to be found. This approach has been used against feral cats on San Nicolas Island (Ramsey et al. 2011) and is important in projects where final payments to a contractor depend on a high probability that eradication has been achieved.

(e) Post-operational phase – biosecurity

The target pest arrived on the island at least once in the past (with or without human assistance) so logically it could do so again. Island restoration plans need a section on biosecurity, e.g. some rules about what animals are prohibited and a contingency plan for breaches of the border. This will be especially important on Bruny Island given the human population and their propensity to retain or import domestic cats (see section 5.2).

3.5 Sustained control projects

If eradication is not feasible a decision might be made to reduce pest numbers and keep them at or below some target density by ongoing control. This strategy is in many ways more complex than eradication because it requires knowledge about the relationships between cats and the other animals (primary prey, secondary prey and competitors) at different densities of cats (Choquenot & Parkes 2001). These relationships might be predicted, modelled or experimentally tested before any management occurs but need to be validated by monitoring after the actual frequency and intensity of cat control is imposed and the consquences are revealed.

As with an eradication strategy, sustained control can be organised in phases.

(a) Pre-operational information collection

The information required under the sustained control strategy is more of a baseline of the unmanaged system against which to measure the consequences once control begins, as well as the basic ecology that justifies control action.

(b) Operational phase – initial reduction to a target pest density

Reducing the population to some target density at which their adverse impacts are mitigated may, like eradication, be done quickly to avoid compensatory responses in survivors. However, unlike the initial reduction in an eradication attempt it is sometimes advisable to reduce the population in some planned way so that the relationships between pest density and asset conditions can be tracked and target densities validated.

(c) Operational phase - maintenance control to keep the pests below the target

Once the pest population is at or below the target ongoing management is required to keep them there. Target density, the actual density achieved if lower than target, the efficacy of the control tools and the rate of increase of the pest population all interact to define the frequency and intensity of this maintenance control phase.

(d) Monitoring phase

This phase is not to validate zero pests, as in an eradication project, but to check that the control effort has reduced the pests enough to provide a desired level of benefit to the assets. This is often a complex issue and many projects do not attempt to measure all responses to the pest reduction but pick some aspect of the impact that is clearly mostly affected by the pest and is easiest to measure as an ‘indicator’ of success. Rare species are often not best as indicators as they are rare for many reasons and often changes in abundance or condition are hard to quantify (see section 6.3).

(e) Post-operational phase – biosecurity

Under a sustained control strategy management of reinvasion of the island (but not of a site under control on the island) and strict management of domestic cats is not a critical issue. The addition of new cats to the feral population is a nuisance as it probably increases rates of

recovery (a little) and so affects the amount of effort required to manage the population in perpetuity, but does not fatally compromise the project.

4 Methods to control cats

There are many control tools capable of killing or catching cats (Table 1; Fisher et al. 2015). I summarise all methods in this section and merely note their suitability for use on Bruny Island. I return to those most suitable for use on Bruny Island in section 5.

Table 1. Advantages and disadvantages of methods to control feral cats on Bruny Island. [1]Curiosity baits are under consideration for registartion by the APVMA

Control Method	Main advantage	Main disadvantage	Legal in Tasmania
Secondary poisoning during rodent control	Can kill most cats	Rarely kills 100% of the cats. Large non-target risks	Yes when aimed at rodents and with APVMA minor-use permit
Primary poisoning using cat baits (a) Eradicat (b) Curiosity (c) Fish or meat baits	Broadscale use can kill most cats quickly and relatively cheaply Localised use may target wary cats that survive other control methods	Rarely kills 100% of the cats Non-target issues Maybe lower non-target risks from spot baiting	No: Restricted for use only in WA No: not registered for general use with APVMA[1] Not without special permits
Leg-hold trapping	Can trap even wary cats	Has to be visited every day	No, unless given Ministerial exemption
Cage trapping	Perception of humaness	Adult cats usually wary of cage traps	Yes
Kill traps: single catch	No need to visit traps daily	Only some types meet humaness standard	No
Kill traps: self re-setting	Multiple kills	Still under	No

types		development for cats	
Tar-baby methods (poison smeared on fur)	Multiple kills	Potential non-target issues	No
Day shooting with or without dogs	Dogs can find most cats	Needs trained dogs; find but not kill	Yes by some land managers
Spotlight shooting	Can find wary cats	Only suitable in more open habitat	Yes on private land
Biocontrol: diseases	Can kill many cats	Does not last	Would require permits
Fencing	Tactical tool to divide island into smaller blocks	Limited use and expensive in eradication	Yes
Genetic engineered tools	Might reduce fitness of cats and even eradicate populations	Currently no proof of concept for any mammals	No

4.1 Secondary poisoning during rodent control

Cats are at risk when cereal-based toxic baits, usually containing anticoagulants such as brodifacoum, are used, usually aerially (Fig. 5), to eradicate or control rodents (Alterio 1996). This method reliably kills 100% of the target rats or mice (Parkes et al. 2011) and kills sympatric predators and scavengers such as cats when they eat poisoned rodents (Dowding et al. 1999, Griffiths et al. 2015). The method has been 'tested' in 10 projects aimed at rodents on islands in the presence of feral cats (8 aerial and 2 ground baiting) but the baiting killed 100% of the cats in only one case. On Tuhua Island (1277 ha) in New Zealand, Norway rats (*Rattus norvegicus*) were eradicated using aerially-sown Pestoff 20R baits containing brodifacoum which resulted in the deaths of all of the small population of cats (Campbell et al. 2011). In other cases some cats survive the baiting, e.g. on Motuihe Island in New Zealand only 3 of 14 telemetered cats died after an aerial rodent baiting operation (Dowding et al. 1999), while some survived the brodifacoum baiting on Raoul Island (Gentry 2013). A trivial point of connection, Raoul Island was named after Bruny D'Entrecasteaux's quartermaster when the intrepid Frenchman found the Kermadec islands in 1793.

The costs to deploy baits from the air in a rodent eradication campaign average $442/ha (Holmes et al. 2016), so would cost about $15.4 million to remove mice and ship rats from Bruny Island – excluding planning costs. However, since some cats usually survive this method, these must be located and removed by secondary methods such as trapping or shooting which can be expensive. Of course the method only works where rodents can be targeted. Usually the aim is to eradicate the rodents but technically one could simply poison enough rodents across the island (either by aerial of ground baiting) to act as bait for the cats; the toxic Trojan concept noted by Read et al. (2015)

Aerial baiting aimed at rodents is legal in Tasmania having been used on Macquarie Island – although that project required 30 permits and approvals (Springer 2016). However, it is unlikely this method would ever be considered on Bruny Island given the non-target wild and domestic animals that would be at risk and presence of people.

Figure 5. Aerial baiting for rodents, possums and stoats in New Zealand

4.2 Primary poisoning targeting cats

There are several toxins that can be used to poison cats, e.g. 1080, brodifacoum, para-aminopropiophenone (PAPP), and paracetomol (Johnston et al. 2011, Eason et al. 2014) each with various constraints and relative benefits. PAPP, for example, is most toxic to carnivores and least to herbivores, and is a humane toxin (Eason et al. 2014). PAPP is registered by the APVMA for operational use against dogs and foxes and under a research permit for use against cats. Eradicat with 1080 is registered for use against cats, but only in Western Australia. Paracetomol is an effective toxin as cats are particularly susceptible and it is probably the most humane among the toxins, but is not registered for use anywhere in the world as a toxin.

The problem is getting all or most cats to eat baits with the toxins, which is potentially affected by the bait type, the toxin and how the baits are deployed . Australian agencies have developed and tested two bait types aimed at cats - Curiosity® and Eradicat® which can be sown aerially or from the ground as broadcast baits or laid in bait stations.

Curiosity® is a bait developed in Victoria that presents the toxin (1080 or PAPP) in an encapsulated pellet of degradable polymer held within a matrix of meats in a sausage similar to Eradicat® (Johnston et al. 2013). The idea of the encapsulation is to take advantage of cats' eating habits. Cats will swallow the pellet whole but non-target animals will eat the sausage but not the hard pellet (Johnston et al. 2013). Curiosity® is not yet registered for operational use by the APVMA but has been tested in several trials under experimental permits with variable results (Table 2).

Table 2. Efficacy of Curiosity® cat bait in Australian trials

Trial location	Method	Toxin	% cats killed	Reference
Karijini NP (WA)	8 cats with radio collars	PAPP	0%	Johnston et al. (2013)
Cape Arid (WA)	11 cats with radio collars	PAPP	20%	Algar et al. (undated)
Tasman Island	15 cats with radio collars	PAPP	33.3%	Robinson et al. (2015)
French Island	8 cats with radio collars	PAPP	75%	Johnston et al. (2011)
Dirk Hartog Island	15 cats with radio collars	1080	80%	Johnston et al. (2011)
Christmas Island	Change in cat activity	PAPP	87%	Johnston et al. (2011)
Roxby Downs	18 cats with radio collars	PAPP	58%	Johnston et al. (2014)

Eradicat® is registered for use in Western Australia by the APVMA and has been used in several trials and operational projects (Table 3). It has a similar sausage matrix to Curiosity® but usually contains 1080 because of the low toxicity of this toxin to native animals in Western Australia (Twigg & King 1991). If the current registration restrictions were lifted, Eradicat® could be used in Tasmania in areas with no or few non-target species, or where some losses of non-target individuals would be acceptable to gain the benefits of cat eradication. Encapsulating the toxin within the Eradicat baits reduced non-target risks (to native animals such as chuditch (*Dasyurus geoffroii*), woylies (*Bettongia pencillata*) and southern brown bandicoots (*Isoodon obesulus*) in a study using metal balls as a dummy pellet

in Western Australia (Hetherington et al. 2007). I note that kangaroos ate some sausage-based non-toxic baits in trials on Kangaroo Island (Denny 2009) suggesting macropods may be at risk from baiting with toxic meat baits.

Table 3. Efficacy of Eradicat® in trials and project in Western Australia

Trial location	**Method**	**Toxin**	**% cats killed**	**Reference**
Cape Arid (WA)	10 cats with radio collars	PAPP	25%	Algar et al. (undated)
Fortescue Marsh	18 cats with radio collars	1080	30%	Clausen et al. (2015)
Dirk Hartog Island	15 cats with radio collars	1080	80%	Algar (2014)
Faure Island	Track monitoring	1080	90%	Algar et al. (2010)
Arid Recovery Reserve, SA	9 cats with radio collars (over 5 baiting events)	1080	100% (but short-lived)	Moseby & Hill (2011)

Other cat eradication projects have used fresh fish or rabbit meat as bait material, usually placed in areas known to have a cat, and generally with 1080 as the toxin. These are suitable only for ground delivery.

Whether distributed by hand, in bait stations or from the air all fish or meat-based baits with 1080 present a significant risk to non-target predators and scavengers. The idea of the encapsulation of the toxin and/or the use of PAPP is to mitigate against these non-target risks outside Western Australia.

There have been some trials using Curiosity or Eradicat baits with encapsulated elements containing a non-toxic dye rather than a toxin to assess the risk to non-target species (Hetherington et al. (2007), de Tores et al. (2011), Denny (undated, 2009). The results are not definitive as although animals may be marked by the dye, it is not always clear whether they ate the simulated capsule component of the bait. In Western Australia, de Tores et al. (2011) found evidence that southern brown bandicoots, chuditch and large varanid lizards ate the encapulated component of baits. Other species common to Bruny Island (brushtail possums, house mice) suggested only weak evidence for risk. In trials on Kangaroo Island and in Scotia Sanctuary in western NSW, Denny (2009, undated) reported corvids (and cats) as the most common eaters of Curiosity baits, followed by large lizards, possums and

macropods. Corvids were also apparently at risk in a trial using Curiosity with PAPP baits at Roxby Downs (Johnston et al. 2014).

The use of toxic baits for cat control on Bruny Island, therefore, presents some risks to the local non-target animals but trials on the island would need to be conducted to see whether this risk is significant.

An alternative way to mitigate risks to non-target species is to put the baits in places only cats can reach. Algar & Brazell (2008) tested a system to suspend baits on a gantry system that cats could access but not crabs or rats. Whether this device would restrict avian non-target species such as ravens or crows is unknown.

Toxic baiting aimed at cats has been used in Tasmania on Macquarie Island in the 1980s (Robinson & Copson 2014) and on Tasman Island under an experimental permit for Curiosity® bait (Robinson et al. 2015). The method could be considered for parts of Bruny Island with few non-target animals (dense forest habitats?) or as spot-baiting during phases of an eradication attempt (to get the last wary cats).

4.3 Leg-hold soft-jaw trapping

Most large-scale cat eradication projects have used leg-hold traps at some stage (Parkes et al. 2014). Victor 1.5 softcatch leg-hold traps with two coil springs are commonly used to trap cats (Wood et al. 2002). The skill is knowing where and how to set the traps (see attached best practice manual DOC 2011 and Sharp 2012). Treadle traps where the cat is caught be a leg-snare have also been used but appear (on limited evidence) to be less successful than soft-jaw traps (Meek et al. 1995).

Briefly, traps can be set singly or as doubles, set as 'cubby sets' where the trap(s) are placed at the entrance to a dead-end or on an open-ended trail. Both sets may be enhanced with rocks or branches to guide the cat over the traps (Fig. 7), and cats may be attracted to the site by scent, sound or visual lures such as fresh rabbit meat, a mix of cat faeces and urine (Pongo lure) (e.g. Algar et al. 2007, Edwards et al. 1997, Fisher et al. 2015), and see www.connovation.co.nz/product for a spray-can aerosol lure for cats and section 6.6).

Double sets where two traps are set each within the chain-length of each other is recommended so a cat caught in one trap is also caught in the second – thereby minimising escapes and subsequent wariness in that cat. Chain lengths need to be long enough so the cat can comfortable sit or lie on the ground.

The NZ Department of Conservation recommends setting traps 100-200 m apart along linear landscape features, in isolated patches of cover or where prey abundance is high. The Mexican cat eradicators from GECI plan on expert trappers being able to check about 30 trap-sets per day, although this would be fewer if cats could not be killed on site.

Note: trap maintenance is important. Traps can be waxed to stop rusting but should not be treated with any preservative or oil as this may weaken the rubber jaws and allow escapes.

The use of leg-hold traps is not legal in Tasmania unless an exemption is given by the Minister under the *Animal Welfare Act 1993*. Recent exemptions have been given for cat eradication on Tasman Island (Robinson et al. 2015).

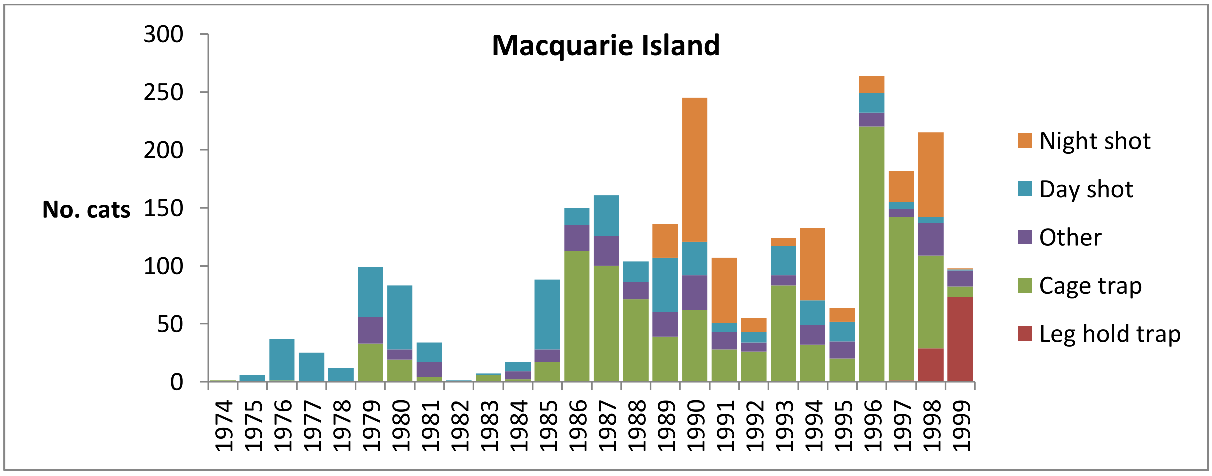
The advantages of soft-jaw leg-hold traps over other methods to remove feral cats are:

1. They catch individual cats that are wary and difficult to catch in live cage traps, and thus are often deployed towards the end of eradication projects when surviving cats avoid cage traps (Fig. 6). In one study on San Nicolas Island leg-hold traps were 12 – 15 times more efficient that cage traps (Jolley et al. 2012). However, in other studies on Tasman Island cage traps were as successful as leg-hold traps in catching the last 27 cats trapped – 20 versus seven, respectively (Robinson et al. 2015), and at Lake Burrendong in NSW there was no difference in capture efficiency between cage and leg-hold traps (Molsher 2001).

   It should be noted that cats at the end of an eradication project that began with just cage trapping are not the same (with respect to trappability) as a general cat population so we are not comparing like with like across studies. Short et al. (2002) in a study at Shark Bay (WA) noted that leg-hold traps and cage traps caught cats at similar rates, but leg-hold traps caught more adults and adult males in particular than cage traps. The latter were effective at catching cats scavenging around human settlements and rubbish tips but these were mostly young cats.

2. This efficiency means leg-hold traps can reduce a cat population, especially when deployed of relatively small areas, more quickly than many other control methods – other than poison baiting.

3. They can be set to minimise non-target captures (e.g. as raised sets) and because the soft-jaws and sprung tie-down cords cause no or few injuries to animals. Domestic cats or non-target species can be released. Larger animals can escape the 1.5 version of the traps.



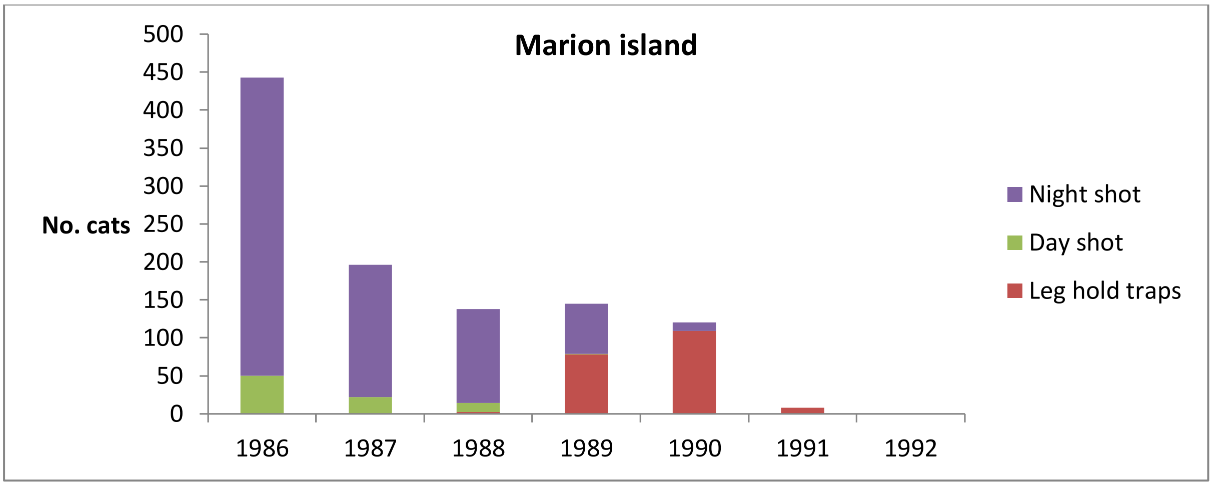


Figure 6. Sequence of control methods on two large island cat eradications. Note the project managers decided they needed leg-hold traps to 'mop up' the last cats on both island

Figure 7. Single set leg-hold trap with hazing to guide the cat across the trap

On Bruny Island there is an immediate need to reduce feral cat numbers to very low levels very quickly in small areas of the island, partly to protect seabird colonies and partly as part

of studies to investigate the benefits and potential adverse trophic consequences if a full eradication program is begun. Cage trapping alone may not achieve this in part because adult cats are usually very difficult to trap using cage traps. The alternatives are either leg-hold trapping, poison baiting or possibly night shooting in accessible areas, of which leg-hold trapping has least issues if it is approved.

Non-target issues with leg-hold traps

Non-target species are at risk of being trapped by leg-hold traps but this can be mitigated (Table 4).

There have been few cat control/eradication projects using leg-hold traps where non-target mammals are also present, but many where non-target birds are an issue. Some published examples:

Table 4. Measures to increase trap selectivity (after Jolley et al. 2012)

Measures to increase leg-hold traps to target cats	**References**	**Considerations for Bruny Island**
Pan tension calibrated for target species but not for most at risk non-targets	Phillips & Gruver (1996)	Tension set to allow macropods to pull free
Traps set only when target species is most active	Ratcliffe et al. (2010)	If set only at night what species are least at risk?
Traps set seasonally to reduce risk to non-target species	Hanson et al. (2010)	Set outside seabird breeding season
Use of species-specific lures or repellents	Algar (2010), Moseby et al. (2004)	Would cat urine-based lures repel quolls?
Traps placed to target individual cats	Bloomer & Bester (1992)	Only set traps where a cat is located
Raised sets (stilts, boards etc) (see Fig. 8)	Short et al. (2002)	Raised and lured sets to avoid non-climbing species
Width and shape of trap jaws when set	Fleming et al. (1998)	Lessons from dog trapping
Placement of obstacles around the trap	Wood et al. (2002)	Unclear if this would deter Bruny animals
Placement within the environment	Wood et al. (2002)	Training is advised

(a) San Nicolas Island in California. Cats were eradicated using soft-jaw leg-hold traps in the presence of island foxes (a small endemic species). Foxes weigh 1.7 kg and cats 2.5 kg so reducing the trap strength was not an option. The cats were eradicated (Ramsey et al. 2011) but 459 foxes were caught on 1011 occasions. Of the 1011 events, 963 foxes were released with no injuries, 44 had some injuries but only four foxes were killed (Jolley et al. 2012).

(b) Macquarie Island. Between 1998 and 2000, soft-jaw leg-hold traps (96,749 trap-days), caught 186 skuas (of which 34 were dead or had to be euthanised), 69 giant petrels (with 2 dead/euthanised), 30 kelp gulls (with 6 dead/euthanised) , 21 penguins (with 3 dead/euthanised), 1 petrel (released), and 200 rabbits and 13 rats (which were killed). (Robinson & Copson 2014).

(c) Tasman Island. Only birds (raptors and seabirds) might have been at risk on this island and none were caught in 782 trap-days using leg-hold traps. (Robinson et al. 2015).

(d) Espiritu Santo Island in the Gulf of California. Native mammals at risk were a hare (*Lepus californicus*) and a racoon-like ring-tailed cat (*Bassariscus astutus*), both weighing about 1 – 2 kg. Cats were eradicated in 2016 using leg-hold traps with no loss of any of the native animals (A. Aguirre, pers. comm.).

Figure 8. Cat caught in leg-hold traps set in raised set on as and-filled bucket with hazin

4.4 Cage live-trapping

Cage traps with a treadle operation and baited with fresh fish or meat can catch cats, especially young animals, and have been used in the initial phases of many eradication projects (Parkes et al. 2014). Cage traps are generally set in places known to have cats and care is needed in how they are set (see attached best practices. DOC 2011b and Sharp & Saunders 2012 (Fig. 9). Trials on Kangaroo Island showed cats were only 22% of the catch, with brushtail possums being the most caught species (Masters 2015).

Figure 9. Cage trap set. Note trap is covered and the closed end is a dead-end

Target cats caught in cage traps and leg-hold traps need to be euthanised. The current Tasmanian legislation (the *Cat Management Act 2009*) requires any cat captured within 1 km of a residential area has to be humanely euthanised by a person authorised under the *Cat Management Act 2009* or at a ‘cat management facility’ run by a nominated agency – the Ten Lives Cat Centre for Bruny Island.

There are several humane methods for euthanisation recommended in different jursidictions. Humane methods include a shot to the head with a .22 calibre rifle or airgun, a blow to the head with a blunt object, or injection of a drug (often intramucular anasthetic followed by a lethal intracardiac injection of pentobarbitol - trade name Lethabarb in Australia).

Probably few cats caught on Bruny would be further than 1 km from a residence, thus imposing considerable extra costs on an eradication project. In fact, euthanising a cat caught in a trap is best done on site (shooting when the cat is a cage trap) if skilled people are trained

as it reduced the stress associated with transport and holding captured cats until killed at a facility or veterinary clinic. This rule is presumably partly to avoid mistakenly killing domestic cats. Once all domestic cats on the island are microchipped and ideally tagged externally so they can be recognised from a distance this risk can be avoided by scanning all cats caught in traps.

4.5 Kill-traps: single kill types

Several traps that kill the cats have passed formal testing for humaneness by New Zealand's National Animal Welfare Advisory Committee (Fig. 10). This protocol requires 10 out of 10 cats interacting with the trap are rendered irreversibly unconcious within three minutes. The traps are the Timms trap, Belilse SuperX, the Twizel kill trap, and the Allan SA2 Kat trap (Morriss 2017). Those testing the traps suggest the SA2 Kat trap is likely to be best – although all meet the humaness standard. See also see attached best practices, DOC (2011c) and www.landcareresearch.co.nz/science/plants-animals-fungi/animals/vertebrates-pests/traps/traps-tested).

Figure 10. From top to bottom. Timms kill trap, Twizel kill trap, chimney-set to let cats in but exclude some non-target species and Allen SA2 Kat trap set on tree to limit non-target risks

4.6 Kill-traps: self-resetting, multiple kill types

Goodnature Ltd has developed devices that kill the target pest using a gas-fired bolt fired into the head of the animal, drop the dead animal out of the device and reset for the next victim (see www.goodnature.co.nz). The version for feral cats is not yet available as it has not met the humaneness tests, but was under further development. Such traps are useful for setting in remote places where daily visits would be difficult. Note the version to kill ship rats is sold

in Australia by Ensystec Australasia Ltd for about $200 per trap to give 24 kills before the gas has to be replaced.

4.7 Tar-baby or grooming poisoning

Various devices have been developed that place a smear of sticky substance containing a toxin on the target animals which then consume the toxin as they groom. Both New Zealand and Australian researchers have been testing this method. In New Zealand, the Spitfire, has been developed as a self-resetting device to control rats and mustelids (Murphy et al. 2014). In Australia, a similar device has been tested against cats and foxes in pen trials. This trial tested a ‘walk-past’ system triggered by sensor beams to apply PAPP in a gel which worked better than a tunnel system (Read et al. 2014). It is potentially possible to use species recognition software for these (and other lethal systems) to discriminate against cats and avoid other species (Meek et al. 2015). The approach could be used against cats but development is not at a stage where operational use is possible, and non-target issues are unresolved.

4.8 Diseases as biocontrols for cats

Moodie (1995) explored cat diseases that might act as a classical biocontrol agent. Only one candidate, the parvovirus feline panleucopaenia virus, was noted but with many constraints on its use. Not least of which is its lack of persistence when used in attempts to permanently reduce cat numbers. On Marion Island, release of the virus reduced the cat population by an estimated 71% while on Little Barrier Island the disease killed an estimated 80% (Parkes et al. 2014). However, unless the residual populations were immediately controlled by other means, the virus died out and the cat populations recover within a few years (Parkes et al. 2014).

Such biocontrol is unlikely to be approved in any areas where domestic cats are kept.

4.9 Day-time and spotlight shooting

Shooting cats can be effective if the animals can be found. The use of detector dogs in the daytime to locate the cats means shooting the animals, especially when they climb trees to evade the dogs is the simplest way to kill the cats. Cats are most active around dawn and dusk and may be held in a spotlight and shot, in places where a hunter has access.

In Tasmania, species listed as vermin under the *Vermin Control Act 2000* may be shot by landowners (with an appropriate firearms licence). However, feral cats are not listed under this act so the ability for the Bruny Island project team to shoot cats would require specific authorisation under the *Cat Management Act 2009*. Distinguishing domestic cats from strays and feral cats would be an issue to be resolved – presumably by requirements to have any domestic cats collared or othewise tagged so they can be recognised.

4.10 Exclusion fencing

Several fence designs have been developed to exclude feral cats from areas (e.g. Robley et al. 2006) and include several large sites on the mainland of Australia managed by the Australian Wildlife Conservancy. Fences to exclude all small mammals are very expensive – up to $350/ m – they leak if not frequently inspected and do not last forever (Norbury et al. 2014). Therefore, they are best used to protect large areas with least perimeters (e.g. peninsulas) or as tactical tools to break up a large area into smaller manageable blocks during eradication projects (e.g. Parkes et al. 2010, Bode et al. 2013). Fences that aim to exlude cats need to include some sort of cap or floppy top to stop cats climbing over (Fig. 11), and systems to stop cats finding their way around the ends of the fence when this is bounded by the sea.

Figure 11. Cat exclusion fence with hard cap to exclude feral cats from a Laysan albatross colony, Guadalupe Island, Mexico

4.11 Genetic engineering to reduce cat fitness

There are many genetic techniques being suggested as potential pest control tools (Esvelt & Gemmell 2017). One such tool is called synthetic gene drives that promote a deleterious gene to drive single sex offspring by engineering it into a population via clustered regularly interspaced short palindromic repeats (CRISPA). The idea is at early stages of development for rodents in New Zealand (Anon 2017) and for cats in Australia (Anon 2018). Whether a self-replicating genome can eradicate or even control a wild population and whether national and international concerns would permit it to be released are moot issues. In any event the tool is unlikely to be available for decades.

4.12 Fertility control

Cats can be surgically or chemically sterilised. However, the need for feral cats is to find a chemical that can be fed to the animals in the wild that would lead, ideally, to permanent sterility in those that ate baits without otherwise affecting the behaviour of the rest of the population. None of the likely candidate chemical agents – steroid implants or hormones – is effective as an oral sterilant and so not much use for feral cat control (Hinds 2015).

An alternative to chemical sterilisation is to use engineered natural viruses that act as immuno-contraceptives and spread naturally through the target population. This approach was explored for cats by Moodie (1995) who suggested feline herpes or feline calici viruses as candidates. However the failure to develop the method as a practical way to control mice, rabbits and foxes in Australia and brushtail possums in New Zealand suggests it is unlikely that any research on cats would be funded.

5 Feasibility of eradicating cats from Bruny Island

There are two ways to judge whether eradication is feasible; from precedents (who has succeeded before under similar circumstances) and by analysis of the ability to meet obligate conditions common to all eradication projects and manage the various constraints peculiar to the island in question.

5.1 Judging feasibility of cat eradication from precedents

Feral cats have been eradicated from about 82 islands around the world including about 14 Australian islands (www.islandconservation.org/, Nogales et al. 2004, Campbell et al. 2011). The largest successful eradication has been on South Africa's Marion Island (29 000 ha) (Bloomer & Bester 1992) or perhaps on Australia's Dirk Hartog Island (62 000 ha) once success for that project is confirmed (Algar 2014).

These past successes have led to eight current proposals to eradicate the cats from other large islands around the world, including the five Australian islands in the current government program (Table 5). This is an indication that decision-makers around the world think eradication of cats from islands similar in size and complexity to Bruny Island is feasible.

These judgements are based in part on the precedents of how eradication was achieved on the 'large' islands (over 2500 ha) with substantial cat populations listed in Appendix 2 – at least for those where the methods and outcomes were reported. Most projects used several methods during the initial reduction phase but nearly all projects required the use of soft-jawed leg-hold traps in the mop-up phase (see also Fig. 6 for two examples).

There are few precedents for cat eradication on islands with permanent human populations, other than meteorological station, military or ranger staff. Feral cats were eradicated from Lord Howe Island (1455 ha with about 350 residents) in the 1980s when about 84 feral and stray cats were 'destroyed by … rangers' (Miller & Mullette 1985). Ascension Island in the Atlantic Ocean (9700 ha with about 920 residents) had its domestic cats sterilised and about 600 feral cats killed between 2002 and 2004 (Ratcliffe et al. 2010). On Rottnest Island in

Western Australia (1705 ha with 334 residents) domestic cats were removed and new ones banned in 1980, and 63 feral cats were trapped between 1986 and 2001 (Algar et al. 2011).

Table 5. Current attempts or plans to eradicate feral cats from large islands

Island	Country	Area (ha)	Inhabited so with domestic cats	Status of project	Reference
Kangaroo	Australia	440 500	Yes	Planned	Masters (2015)
Dirk Hartog	Australia	62 000	No	Completed?	Algar (2014) awaits update
Auckland	New Zealand	45 975	No	Planned	www.doc.govt.nz
Bruny	Australia	35 200	Yes	Planned	This project
Guadalupe	Mexico	24 171	Yes	Underway	Luna-Mendoza et al. (2011)
French	Australia	17 000	Yes	Underway	Johnston & Znidersic (2018)
Christmas	Australia	13 500	Yes	Underway	Algar et al. (2014)
Socorro	Mexico	13 200	No	Underway	Anon (2018)
Kahoolawe	Hawaii USA	11 700	No	Planned	Parkes (2009)

Table 6. Effort (person-days) per km^2 required to eradicate feral cats from five islands with data reported in each phase of the control (after Parkes et al. 2014). Some 1080 baiting was also conducted on all islands, except San Nicolas, and the effort to do this is not included

Island	Area (ha)	Effort = total person-days per km^2 (years required) for each phase		
		Initial	Mop-up	Validation
Marion	29 000	24.1 (3.5)	11.8 (2.5)	? (2)
Socorro	13 200	20.1 (7)	14.1 (in progress)	?
Macquarie	12 780	16.5 (3)	19.2 (2)	13.4 (2)
Ascension	9700	22.0 (1)	11.3 (2)	21.3 (4)
San Nicolas	5759	about 7.0 (1)	about 7.0 (1)	? (?)
Little Barrier	3083	95.4 (3)	48.7 (1)	0.8 (1)
Baltra	2537	? (1)	19.2 (2.5)	8.5 (2)

5.2 Judging feasibility by meeting obligate rules for eradication

The rules that must be met before eradication is even possible have been set out in several ways (Parkes 1990, Parkes & Panetta 2009). For island populations they are: (i) all breeding animals must be removed and at rates faster than they can replace losses at all densities, (ii) there must be no re-invasion of breeding animals and (iii) there should be no net adverse consequences from the use of the control tools or the removal of the pests. Other conditions set out by Bomford & O'Brien (1995) include such needs as adequate funding and social license – which can be considered more as constraints to be managed to meet the main rules.

Putting all Bruny Island cats at risk

All cats can be put at risk either by applying the control techniques across the whole island all at once, or on a rolling front, or in patches - with defense of the cleared areas from reinvasion. We have to either assume that a cat might be anywhere on the island, or identify places that are occupied by cats and focussing the control there if it is known with certainty that cats do not occupy some habitats.

Information required to deploy control devices is the minimum home range sizes and range use of cats. The home range size of feral cats varies with the productivity of the landscape (presumably correlated with the amount of food available) and the population density (Bengsen et al. 2016). Female cat home range varied from 1.2 to 23.2 km^2 (median 2.5 km^2) compared with the male home range median value, at sites where both sexes were measured, of 5.1 km^2.

A study on 13 Kangaroo Island cats with GPS collars revealed minimum convex polygon home ranges of between 1.94 and 19.22 km^2 with maximum daily movements of 2275 m and 11 828 m (Bengsen et al. 2012). They recommended setting cat control devices at densities of no less than one every 1.7 km^2 – or no more than 1300 m apart. At this trap/device density at least 210 traps would be required to put all Bruny Island cats at potential risk, but I think the spacing is too far apart.

However, cats have overlapping home ranges so a much higher density of control devices is usually recommended. The New Zealand Department of Conservation recommends traps are set along linear features and spaced no further than 200 m apart (DOC 2011b, c). These recommendations are guidelines only as there is an art and skill in trapping that should finally determine the deployment.

Access to traps is one consideration as they have to be checked daily. If we consider the road and track network on Bruny Island (see LandTasmania Tasmap Bruny Island) there are approximately 600 km of roads and tracks that would require (at DOC's recommended trap density) 4000 traps. Of course an eradication campaign might be rolled out in sections if they can be defended from reinvasion (see section 7) which is the only practical approach for the project.

Removing cats faster than they can replace their losses

Cat populations have a maximum annual exponential rate of increase of about 1.0 (Hone et al. 2010) although observed rates in field situations are obviously lower, e.g. 0.23 on Marion Island (van Aarde 1979). These rates mean a population could double every 8 months (r = 1.0) or every 18 months (r = 0.23). The Bruny Island cats' rate of increase will depend largely on their per capita food supply which may vary especially in the more arid and grassland-dominated North Bruny and will increase as their density is reduced by control. The point is that culling less than about half the population every year will be insufficient to meet the 'quickly as possible' rule. The reports on Lutregala cats show only a modest reduction in cats detected in camera traps over three years despite the removal of about 20 cats from the vicinity (Bryant (2018) suggesting recruitment and immigration have more or less replaced the losses.

A consequence of removing cats at a slow rate, even when it does exceed the rate of increase, is the whole eradication campaign becomes drawn-out and risks funder-fatigue.

Managing reinvasion

The no reinvasion rule depends on island biosecurity protocols that will have to be developed before the eradication program begins and implemented in perpetuity. The main risk would be the deliberate importation of cats as pets. These might be as permanent companion animals for island residents or just as temporary imports with people holidaying on the island who find it convenient to take the pet along for a holiday. Unless rules are imposed and enforced about the breeding status of such cats, the risky animals are those left to their own devices while the owners are absent or the 'temporary' visitors which do not settle at the holiday location and are left when the owners go back to the mainland.

The ongoing costs for island biosecurity are not considered as part of the eradication project and will have to be met in perpetuity by the local authority.

Internal reinvasion is a key issue if the cat control is rolled out across the island. The options to manage reinvasion are to construct temporary fences where this makes economic sense or to attempt to control cats moving across a buffer zone into the cleared area.

5.3 Can any constraints be overcome or managed?

Legal constraints

Managers have the toolkit to eradicate feral cats but are legally constrained in using the most effective without gaining Ministerial permission to use soft-jaw leg-hold traps, or experimental permits to use cat-specific baits. These regulatory constraints can all be overcome if a good case is made to show the benefits of eradication cats, the necessity to use the tools of success is to be certain, and how the risks from using the selected tools can be minimised. There are precedents for such approvals in Tasmania.

Non-target risks

Non-target risks are always a constraint in eradication projects and have to be avoided by using control methods that are safe or mitigated and reduced when risks are unavoidable. The

risks can be measured at an individual non-target level or at the population level depending on the perception and focus of different people.

A biologist might argue that the benefits to non-target populations if the cats are removed will greatly outweigh any short term losses from the control operations (e.g Croll et al. 2016). However, an animal welfare advocate or a government regulator may place more emphasis on individual animals especially if the control tool does have signficant welfare issues or the species is iconic or listed under some threatened species legislation. The solution is of course to be aware of the population issue but mitigate for the individual risk.

Cage traps, shooting and use of detector dogs would have little or no non-target implications on Bruny Island, but the use of soft-jaw leg-hold traps or toxic baiting may. Quolls, brushtail possums and corvids are likely to be at risk from both of these tools, but the extent of the risks are discussed in section 4.2 and 4.3.

Seasonal contraints

Cats are likely to be feeding dependent kittens in spring through summer and welfare advocates may argue that killing lactating females during this period would be unacceptable as the kittens would starve. Constraining control to the non-breeding season would have severe implications for the efficacy and timeframe for an eradication project.

The options are either stop the campaign during the breeding season or to continue control year-round. If the latter, the welfare consequences would have be accepted or mitigated. It might be possible, for example, to place a GPS collar on any lactating cat trapped and release it so that the kittens can be located and dispatched – along with their mother. So far as I know this solution has not been trialled.

Managing domestic cats

Many island residents own domestic cats and most now have had their pets desexed and microchipped. There is still work to ensure 100% compliance with the Kingborough Council's proposed Bruny Island Cat By-law but it seems peer pressure and advocacy will resolve the problem of fertile domestic cats adding to the stray and feral population once the latter animals are removed.

The presence of domestic cats will compromise managers' ability to confirm eradication of the stray and feral population. Unless a sunset clause is placed on cat ownership the only partial solution is to have all domestic cats marked (with a collar or ear-tags) and chipped so at least post-eradication cat sightings can be discounted as being feral animals.

6 Notes on operational issues

Several studies can to provide detailed information for an operational plan (ecology and distribution of the cats, changes in density of rodents, trail traffic using camera traps), or as a precursor to decisions on permits or training of staff. Section 6 contains some brief notes on relevant information for potential use as the Bruny Island management and operational plans develop (and in the scenarios developed in section 7).

6.1 Costs for cat eradication on Bruny Island

Costs have been reported in a few cat eradication projects (Campbell et al. 2011), but more usually only the effort in terms of person-days are provided. However we can estimate costs from the data reported from the cat eradication project on Tasman Island which used poison baiting and trapping. This cost (in 2017 dollars) about $623 per person-day for staff employees (Robinson et al. 2015).

Parkes et al. (2014) summarised the effort required in the initial reduction, mop-up and validation phases for six islands (Table 6). The effort required was clearly variable, cat densities varied by an order of magnitude between ‘seabird’ islands such as Marion and ‘arid’ islands such as San Nicolas, and earlier projects (Little Barrier) took longer than later ones (San Nicolas). However, as a rough indication of the possible effort required for Bruny Island the average effort for the first two phases for the five islands with data was 526 ± 455 person-days/1000 ha (range 140 to 1441). If we extrapolate this average effort to 35 200-ha Bruny Island, an effort of 18 515 person-days (about 103 person-years given a working year of 180 days in the field) would be required. If the campaign was as efficient as that on San Nicolas Island the predicted effort for Bruny Island is reduced to about 5000 person-days, and if as difficult as on Socorro Island to about 12 000 person-days.

Grupo Ecologia y Conservación de Islas has reduced the feral cat population on Socorro Island (13 200 ha) by an estimated 93% using leg-hold traps and detector dogs between late 2011 and mid-2018. This took 79 500 trap-days and removed 658 cats. They estimate it will take a further 56 000 trap-days to remove the estimate 48 remaining cats. In this project, a trapper operated about 30 traps per day so to achieve eradication total of about 4500 person-days will be required.

Actual costs will also depend on how operational workers are employed (as staff, contractors, volunteers) and the methods used. Costings are developed in the spreadsheet attached to this report and average about $2 million per year but then spread over a variable number of years – with costs in later years depending on how inflation and cost increases are calculated.

In reality I think the effort required on Bruny Island would be less than the average of 18 515 person-days used in precedents because it was biased upward by the high effort (volunteer trappers) used on Little Barrier Island. More recent use of trained dogs to locate cats (e.g. on San Nicolas and Socorro Islands) also suggests an attempt would be more efficient. One advantage of a spatially-staged eradication on Bruny Island is that managers will learn what effort is really required given the specific habitats and circumstances on Bruny Island, and the capacity and constraints on the methods that can be used.

6.2 Density and distribution of cats

The density of cats has been estimated for parts of Bruny Island and for other places (Table 7).

The density of feral cats on the six large islands described in Parkes et al. (2014) ranged from 0.117/ha on Marion Island to 0.01/ha on San Nicolas Island, averaging about 0.058/ha. If we assume for the moment Bruny Island is average there would be 2042 cats present. This assumption is, however, risky and we would need surveys across more habitats to obtain a reliable estimate. Cat densities on Bruny Island appear to be highly variable and the high densities noted at two sites in Table 7 are not representative of most of the island. Cats are more abundant on South Bruny and are more prevalent close to wet forest habitats, and only present in low numbers on North Bruny – quolls have the opposite abundance and prefer agricultural habitats (Parker 2016).

In fact published estimates of cat densities elsewhere vary by orders of magnitude. Densities of up to 2800/km^2 have been reported for urban populations, but generally up to 30/km^2 for cats living mostly independent of humans (Liberg et al. 2000). Mainland populations in New Zealand rarely exceed 1/km^2 (Gillies & Fitzgerald 2005, while mainland Australian populations rarely exceed 2.5/km^2 (e.g. Jones & Coman 1982, Short & Turner 2005).

6.3 Monitoring cat numbers

Trail cameras would also be useful in this pre-operational stage to detect cats as part of the above mapping project. Cameras could be placed, for example, in likely places that are not often visited by staff or in likely places but where no other cat sign has been seen. They would also show how often a potential trap set would be disturbed by passing larger non-target species rather than by a cat and so reduce trapping efficacy. Cameras have a good detection capacity, i.e. the probability that if a cat is present in an area that it will be detected by the camera. Cameras were as good as detector dogs in one trial (Glen et al. 2016). They can also be used to estimate the change in population size of cat populations as control proceeds (Bengsen et al. 2011). Cameras set horizontally to view a scene were 1.5 times better at detecting cats than cameras set to view vertically (Nichols et al. 2017).

6.4 Breeding season

Feral cats generally breed between September and March and can produce two litters averaging 4.4 kittens/litter during that time (Jones & Coman 1982). There are humaneness issues if adult females are removed during the time they have dependent kittens, so control programs should, if possible, be concentrated in winter (to remove the breeding population) and autumn (to catch the young of the year).

Table 7. Density of feral cats measured on Bruny Island and other islands

Place	Habitat type	Area (km^2)	Cat density/km^2	How measured	Reference
Lutregala (Bruny Is.)	Saltmarsh, coastal forest	0.42	33	Camera traps	Bryant (2018)
The Neck (Bruny Is.)	Seabird colony	0.08	About 49	Camera traps and modelled density	Geale (2017)
French Island	Eucalypt woodland, heathland, farms	170	At least 3.0	Numbers killed	Johnstone (2017)
Rottnest Island	Coastal grassland/scrub	17	2.3	Number trapped	Algar et al. (2011)
Marion Island	Subantarctic grassland	290	11.7	Number killed	Bloomer & Bester (1992)
Macquarie Island	Subantarctic grassland	128	6.0	Number killed	Robinson & Copson (2014)
Ascension Island	Tropical grassland/scrub	97	6.1	Baits taken and number trapped	Ratcliffe et al. (2010)
San Nicolas	Temperate arid grassland/scrub	58	1.0	Number killed	Ramsey et al. (2011)
Little Barrier	Temperate forest	31	5.1 +	Number killed	Veitch (2001)

Baltra	Tropical arid	25	4.4 – 5.9	Number killed	Phillips et al. (2005)

6.5 Judging eradication success

A key question for all eradication projects, especially those where the process is a sequence of control events that eventually removes the last animals, is when to stop and declare success. To be 100% sure no further sign of cats equals no cats left requires either waiting until failure becomes obvious as survivors breed and cats become obvious, or all areas have to be searched with a perfect detection system – which does not exist. The first 'wait and see' option has major implications if in fact the eradication has failed. The project has to be refunded and the whole system redeployed, which would be a risky proposition for funding agencies. The second approach can use the data collected during the eradication to provide a probability that none detected equals no cats left. Managers can then decide whether this probability is enough or whether they should continue to look for survivors to increase the probability – assuming no cats are found. The costs to do this extra monitoring can be compared with the costs of stopping and having to redeploy the effort if events prove the claim of success to be incorrect (e.g. Ramsey et al. 2011).

The data required to analyse this probability of success have to be collected during the time when cats are present, for example, catch-per-unit effort data from trapping and detection abilities of devices such as camera traps or detector dogs (if a cat is in the area what is the probability that a camera set in the area or a dog searching will detect it?). There are also several analytical methods to provide the probability. One group of models uses a standardised sequence of surveys conducted across the transition period between 'cats still being trapped/detected' to 'zero cats being trapped/detected' to provide a probability of success that increases as the sequence of 'zero' surveys increases (Regan et al. 2006, Rout et al. 2009). The key is to define the extent and conditions of the 'survey' but an advantage of these models is that the detection abilities of the search devices does not have to be known.

Other models are more explicit about the spatial parameters and require the detection abilities of the search devices, which may be the traps themselves or detector dogs or camera traps, be known. This of course must be done while there are still cats to detect (Ramsey et al. 2011, Ramsey & Will 2012).

6.6 Lures and attractants

A number of devices and lures have been tested in attempts to attract cats to traps or baits. These vary from simple visual lures (a bird feather fluttering on a string above the trap), auditory lures (a loop tape of a cat meow or a rabbit distress call), attractive food lures or various scents based on cat pheromones in their urine or faeces. There have been some trials comparing lures for cats (Edwards et al. 1997, Read et al. 2015) which found several attracted cats. I do not know which is best.

There are several commercial products that purport to act as lures for trapping cats and the whole field is still under research investigation (e.g. Clapperton et al. 2017). The five-island cat program managers might swap notes on what they have found to work best.

6.7 Training trappers

Significant skills are required to set cage or leg-hold traps to maximise their effectiveness (Wood et al. 2002). The Bruny Island project might consider inviting an expert cat trapper from DPIPWE (Sue Robinson), from Western Australia (Dave Algar) or from Mexico (federico.mendez@islas.org.mx) to train staff once the project begins.

6.8 Project management options

Eradication projects can be delivered either by input-based or outcome-based contracts between a delivery contractor and the governing or funding agency, or by employees of the governing agency often with only specialised components delivered under contracts.

Tenders for contracted delivery can be structured in two tranches. The first tranche asks bidders to set out their expertise in delivering the required services which need to be specified by the governing agency. The governing agency then creates a short list of candidates. Only then is the second part of the bid opened and the price considered. This process was used by the United Nations Development Program (UNDP) in the substantial helicopter shooting part of a large project to eradicate feral goats from the Galapagos islands. The effort required from the contractor (number of aircraft, staff and flying-hours) had been explicit in the contract, i.e. it was an input based contract and so the risk that eradication was not achieved by the end of the contracted resources was entirely on the UNDP (Lavoie 2006).

An alternative contract is based on results. The contractor estimates what it will take to eradicate the pest and bids to cover that cost plus some profit margin. This was the process used by The Nature Conservancy to contract Prohunt Ltd to eradicate feral pigs from Santa Cruz Island (25 000 ha with 5000 pigs removed) in California. The risk here was taken mostly by the contractor but of course the more efficient they were (Parkes et al. 2010) the higher their profit. To be fair to both parties there had to be an independent validation of the contractor’s claims of success before the final payment was made to the contractor (Ramsey et al. (2009).

The Bruny Island cat eradication is inherently risky for a performance-based contractor because of its scale, likely timeframe, the presence of people and domestic cats and uncertain outcomes. There are also few contract companies with such expertise. Therefore, it is probably best if the project is managed with mostly in-house employees, with only components (detector dogs and handlers for example) contracted as required.

6.9 Notes on research needs

A research programme is underway with a focus on the trophic position of cats. This will inform interpretation of outcomes when cats are eradicated and provide some information on cat home ranges and diet. The null hypothesis is that the cat-primary prey system is bottom up so that removing cats will not cause primary prey to increase. Conversely, removal of cats is predicted to allow secondary prey (largely native animals?) to increase. Competition between cats and quolls is also possible and cat removal should allow an increase in quoll densities or habitat use if cats are excluding them.

The monitoring programme suggested in the funding spreadsheet should focus on the numerical response of some representative primary prey (rodents and perhaps rabbits) and secondary prey (the rarer native mammals and perhaps lizards) as cat density is reduced. It is likely different interactions will be present in the grassland/open woodland habitats on North Bruny than the dense forest/coastal scrub habitats of South Bruny.

In terms of the direct research on how to eradicate cats the following research topics are indicated:

(a) Cat (feral, stray and domestic) home range sizes by season, sex and especially habitat usage and types. This will allow fine-tuning of the trap density and location.

(b) Breeding seasonality in different habitats may be desirable especially if control is restricted when lactating mothers are feeding dependent kittens.

(c) Operational research and monitoring includes trials on leg-hold trap set systems (e.g. raised) if unacceptable non-target issues arise from ground sets; use of different lures; development of humane protocols to kill trapped cats on site; development of low-density detection systems (e.g. detector dogs, camera traps, sand pads).

(d) It is possible that the use of toxic baiting will be required at some phase of the project. Current research on non-target risks from the encapsulated cat baits (with PAPP as the toxin) have not been adequately addressed for some of the species found on Bruny Island. A research project to measure and model risk to native non-target species on Bruny Island is required before any decision is made on use of toxins.

(e) Methods to control ship rats as potential predators of native animals need to be identified for use on Bruny Island. The Goodnature multi-kill traps could be tested to see if they put native animals at unacceptable risk.

(f) Social research on peoples' attitudes to domestic cat management and biosecurity enforcement.

7 Scenarios for deployment of eradication

Some initial scenarios for an eradication program can be explored. One approach is to considering what is required to remove cats from 'representative' blocks as a learning exercise under the different constraints represented in each block. For example, the

Labillardiere Peninsula around to the National Park boundary is a least-complex area with no residents and no or few quolls. A northern block from Barnes Bay to Patricks Bight has residents, domestic cats and many quolls. The peninsula from Apollo Bay across to Missionary Creek has residents and the wharf as a biosecurity risk to consider. The Neck from about Lagoon Hill south to the Bruny Island main road and Simpsons road is one area of high biodiversity value with its nesting seabirds and a potential buffer between the two parts of Bruny Island.

A second approach is to begin and learn as a real eradication program is rolled out over the whole island. Under this latter scenario we could treat the whole island all at once. However that would be very expensive and in practice not feasible. It is therefore more likely such a roll out would start at one (or both) ends of the island or on The Neck and progressively cover the whole island over many years (e.g. over nine or ten management units: Fig. 12).

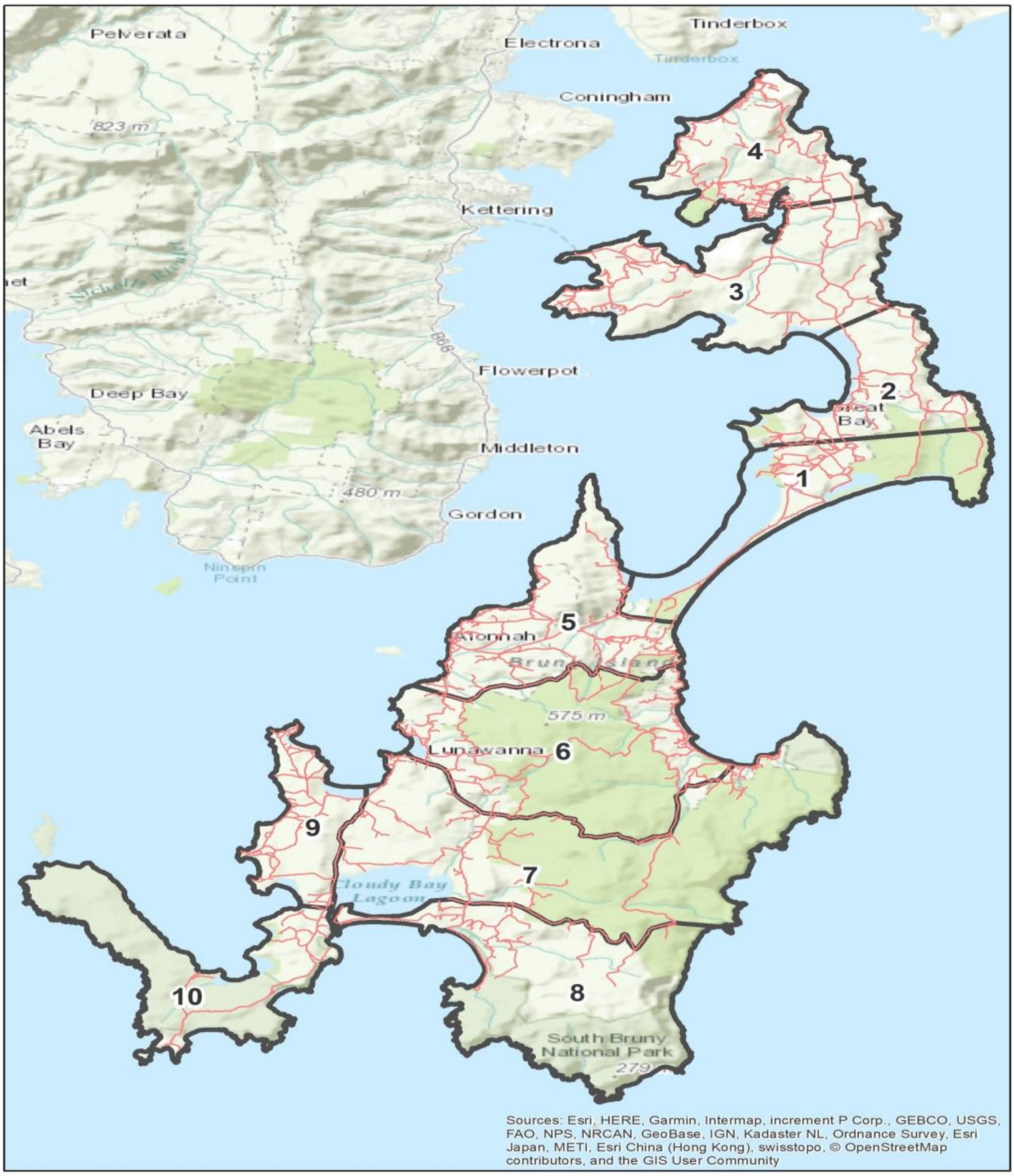


Figure 12. Possible zones and road and track locations (as main trapping lines), Bruny Island. Note zones 9 and 10 are combined in the scenarios presented

The scenarios are in the nature of planning predictions for the various phases of an eradication. They are not a substitute for an operational plan as that can only be developed once a formal management structure is developed and real-world conditions (e.g. the principles of domestic cat management and how the staff are employed are finalised) are in place. Further, the scenarios would, of course, be tested as the attempts were made and the data used to improve future planning across the rest of the island. Eventually, the

infrastructure required (number of traps, number of people and funds) to deal with the largest block will determine the maximum annual budget, assuming this should not vary too much. Therefore how a block is defined and delineated is critical. This is simple when there are clear and defensible (in part) boundaries, but less obvious for the central mountainous part of South Bruny Island – could the whole area from Mount Bounty south to Mount Bruny be treated as one management block and treated all at once? Probably not, but subdividing into smaller areas makes reinvasion into cleared areas more expensive and uncertain.

7.1 General scenario parameters and assumptions

Control in each area should follow the principles of a phased eradication:

1. Management of domestic cats where they are present. All should be sterilised and clearly marked (a collar or ear tag) so they are not inadvertently killed before any substantial eradication project begins.
2. A combination of live trapping in the initial phase, especially where domestic cats are present, followed by leg-hold trapping.
3. Leg-hold trapping and the use of detector dogs during the mop-up phase plus management of the borders of the zone. If all cats are removed from the zone decisions will have to be made to move into a rolling-front phase to remove all cats from the island.
4. A validation phase.
5. Biosecurity management on Bruny Island and at potential sources/vectors. This is outside the scope of the current project in terms of costs.

Control assumptions:

1. Control devices will be set no more than 150 m apart using roads and tracks as the main access points. This spacing is not rigid as the skill and judgement of the trapper might dictate more or fewer traps depending on the area, expected cat densities and availability of ideal trapping sites.
2. Each device will be checked daily and all feral and stray cats killed on the spot. If cats have to be killed at the registered facility this will add to the daily costs.
3. Each trapper will manage 30 devices per day in a 5-day working session at an annual cost of $75 000 per employee assuming cats are killed at the place of capture. Trappers are employed full-time.
4. Changes in capture rates will be used as triggers to change or add control methods to the toolkit. This sequence of control tools will depend, to some extent, on the area being treated with respect to initial cat densities and the presence of domestic cats. In general and as rules of thumb, the following sequence could be followed:
    a. Live cage trapping will be used in areas likely to have domestic cats until the catch-rate falls to less than 50% of the initial catch-rate or no further young cats are being caught. Leg-hold traps will be used in more remote areas during the initial reduction phase.
    b. Leg-hold trapping will replace cage trapping (other than in residential areas) until catch-rates fall to less than 5% of the initial capture rate for the leg-hold

traps. This will indicate the end of the 'initial reduction' phase of the eradication.

c. The location of surviving cats will be identified from known sign/sightings and the use of detector dogs. Focussed leg-hold trapping and spotlight shooting will be used to 'mop-up' these survivors. If this fails, spot poisoning using one of the cat baits (Curiosity with PAPP to avoid most non-target risks) will have to be considered.

5. True eradication in each area may be difficult to validate but once capture rates fall such that x trapping sessions result in no cats and no cats are being detected by the detector dogs the decision to move into adjacent areas will be made. The actual trap-catch data collected during each operation can be used to determine x (e.g. see Rout et al. 2009).
6. It is not known how long it will take to achieve eradication, or how many trapping sessions this will take. On Socorro Island, where the habitat is structurally similar to that on Bruny Island, 35 trapping sessions (where a trapping session had between 384 and 5880 trap-days effort with a total of 79 466 trap-days over eight years) has not yet eradicated the cats (over 600 removed to date) over the 13 200 ha island – in.

   The scenarios can give an estimate of direct costs for each year but cannot predict how long it will take to achieve eradication and so cannot provide a total cost other than by making bold assumptions based on how long eradications have taken on other islands. The islands listed in Appendix 2 where eradication was completed using ground-based methods show it took between two (San Nicolas) and seven (Macquarie) years to complete. Socorro Island has taken eight years and is still not complete. Socorro Island is remote and the project cannot maintain year-round effort but the trapping effort at an average of about 10 000 trap-days per year shows the task on islands such as Bruny is likely to take many years even with intensive efforts.

7.2 Rolling out the campaign

Three eradication scenarios are presented in Appendix 3 and a sustained control option covering all introduced mammals for The Neck is discussed below.

Scenario 1: From the center outwards.

Eradication is attempted first on The Neck as a high priority site for seabird biodiversity, as cat control is already underway at the site; to form a cat-free buffer between North and South Bruny; and to test the proposed methods to gain a better appreciation of how much effort is required to reduce a cat population to zero and maintain it with management in buffer zones. Subsequently, a campaign to treat North Bruny in three zones would start in 2022 and potentially end with validated success in 2030, followed by the five South Bruny zones beginning in 2028 and ending in 2040.

This scenario would have a variable number of field staff and would cost an estimated $42 million over 21 years, i.e. about $2 million per year on average.

Scenario 2: From the center outwards but in paired zones

Again the eradication campaign would begin on The Neck but then move outwards in north and south pairs of zones ending in about 2032. This scenario would also require annual variation in the numbers of field staff employed with a maximum of about 27 in 2028/28 for the largest set of zones.

It would cost an estimated $29 million over 14 years, i.e. again about $2 million per year on average.

Scenario 3: A mixed rollout with a set number (17) of field staff

The rationale for this scenario is partly to learn how to achieve eradication in two areas (The Neck as above and a large peninsula in the south), and then roll out the campaign first on North Bruny and then South Bruny. This scenario would also require a variable number of field staff (between 4 and 19 per year) and would perhaps have more flexibility in start years for each zone. The risk is the length of time it would take with an endpoint in about 2036.

The peninsulas on the south of the island (the Labillardiere peninsula and the block of land from up to Ventenat Point) cover about 5000 ha and could be treated as a single zone or divided if, for example, the Labillardiere Peninsula was considered a high priority site for rapid eradication or eventual sustained control. The area is under National Park tenure for the Labillardiere Peninsula or ‘minimal use’ tenure with only a few residents. The habitat is mostly coastal scrub and shrubland with areas of dry eucalypt forest and smaller blocks of wet eucalypt forest (Figs. 2 & 3). The eastern boundary is marshland which may be a partial barrier to immigration from adjacent areas. The area has about 85 km of road and track. There is a high density patch of rabbits near the lighthouse. The cats present are likely to be all feral animals, at least on the Labillardiere Peninsula, and no quolls were detected by Parker (2016). This avoids some of the complications where large numbers of domestic cats and non-target quolls are present and so represents the least complex scenario.

Including the eastern part of this block is recommended because it does have a few residents. Learning how to manage these people and their domestic cats as the feral cat eradication project encompasses their properties and animals will be useful, and should lead to a second front in the campaign (once protocols, lessons and capacity is proven in the south) in the northern part of North Bruny (above Barnes Bay) where there are many more people and domestic cats.

This scenario would require the least number of field staff with a variable annual effort peaking at about 19 trappers as the last large areas are treated. It would cost an estimated $42.5 million over 18 years, i.e. about $2.4 million per year on average.

Scenario 4: Sustained control of cats and rats on The Neck and other sites

If eradication is not possible over the whole island a fall-back position is to manage the threats to biodiversity at high priority sites in perpetuity – sustained control. Under this strategy the goal is not to remove the pests per se but to remove enough of them often enough to eliminate or reduce their adverse impacts on the assets present at the site.

Sustained control is in some ways a more complex strategy than eradication. Eradication has a clear goal, no pests, while sustained control is focussed on the condition of the assets being affected by the pests. It asks how few pests are few enough to allow the assets to thrive? Sustained control therefore, requires an understanding of the relationships between pest density, asset condition and harvest/culling intensity and frequencies. The assets, as in the case of Bruny Island native species, are affected by several interacting pest species making it likely that benefits are maximised if all threats are controlled.

The native animals on The Neck are affected by predation by cats and a sustained control project might aim to reduce the cats to zero density but with sustained action to remove immigrants. The same tools and efforts noted in the eradication objectives apply to the cats under this strategy.

The native biota may also be adversely impacted by ship rats and perhaps mice and different tools would be required to reduce their populations. Several questions arise. First it is possible that the introduced rodents are only critical pests when they are at high densities so predicting these times (if they exist) requires research. Second, they may only be a problem when birds are nesting, although are likely to impact on smaller prey and invertabrates. Understanding these timing events might allow control to be focussed at appropriate frequencies. Lastly, there is a large toolbox of methods to control rodents (bait stations, various forms of trapping) but all would require research to assess non-target risks. The self-reseting rat traps from Goodnature Ltd may be the best rat control tool but are likely to trap/kill native rats as well – a trial would be required. Bait stations that admit only small mammals such as mice would need to be tested – or at least the baits/lures, to see if they can be made species-specific.

8 Conclusions and recommendations

Eradication is feasible but will require a dedicated management and operational structure with adequate funding and access to as many tools as practical. It will not be achieved using cage-trapping alone but will require at least the use of soft-jaw leg-hold traps, detector dogs to assist in identifying areas with residual cats, spotlight shooting and potentially spot baiting to kill animals that avoid all other control methods.

A rolling front or site-based deployment of effort is recommended providing boundaries and buffer zones can be defended against reinvasion. North Bruny would be a simpler proposition to test methods because there are fewer cats and access is simpler. However, a South Bruny site would be a suitable, non-trival, test of methods and effort. In general, risk of eradication failure is reduced when the timeframe is shortest. However, there is an obvious tradeoff between maximising annual effort (there is probably a ‘carrying capacity’ for the number of field staff that can be deployed) and the time to completion. It is difficult to predict these parameters accurately as the time to reduce, mop up and validate eradication on Bruny Island conditions is not certain. Planning has to adapt as results become apparent.

If the funding timeframe is critical, then the shortest scenario presented (The Neck then paired zones to the north and south) is least risky. However, if this is not critical but the

capacity to manage larger numbers of field staff is difficult, then the ‘one zone at a time’ starting with The Neck, then North Bruny zones, followed by South Bruny zones is best.

Trapping is likely to be the main control tool at least in the initial phases of an eradication. This is a skillful task and the project managers would be wise to import some people with expertise to train project staff.

If sustained control is the selected fall-back strategy, the priority areas for native biodiversity, currently mostly based on nesting seabird colonies, or some representative examples of important habitats could be selected. The extent of these would depend on the amount of money committed annually in perpetuity.

Monitoring outcomes of management has several purposes. For the eradication option, data collected during the campaign can be used to assess whether absence of further evidence of cats equals successful eradication. This may be difficult for some monitoring methods if domestic (sterilised) cats remain. Baseline data on key non-target species or indicator species should be collected to allow the benefits (and potential ecological costs) of cat eradication to be asssessed. This type of data is even more essential under a sustained control strategy to determine if the post-control residual cat population is still having significant adverse impacts, i.e. the control has been intensive enough, frequent enough and in the right places.

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11 Appendices

Appendix 1. Relevance of recent, current and proposed projects for cat management on Bruny Island

Project theme	Where on island	When?	Who?	Key points of relevance to cat management	References
Cat abundance	Lutregala	2015 -	TLC	Cat density of c. 0.2/ha; 2 clusters	Bryant (2017, 2018)
	North Bruny	2017 -	DPIPWE		Pauza
	2 sites with 2 without seabirds	2015	Uni. Tas.	More cats at sites with seabird colonies	Geale (2017)
	Courts Island	2016 -	DPIPWE	No cats	
Cat movements	The Neck	2017-	DPIPWE	Home ranges small for ♀ large for ♂. Beaches for travel	
Cat diet	All island	2008 -	Private	Broad diet of native and introduced species	
Trophic position	South Bruny	2018 -	Uni. Tas. PhD	Aims to elucidate cat-quoll-rabbit interactions, diet, etc	

Impact of cat control		2013 -	Birdlife Tas.	Baseline densities of birds	
Domestic cats	All island	2016 -	Kingborough Council	General support for managing cats	Anon (2016)
Social science	All island	2018 -	UNE	Aims to identify community attitudes to cat management	

Appendix 2. Sequence of control methods in different phases of cat eradication projects on 14 islands (updated after Parkes et al. 2014).

Phase of project	**Area (ha)**	**Preliminary trials**	**Initial reduction**			**Mop-up**			**Validation**		
Island/Reference			**Methods**	**Effort**	**Years**	**Methods**	**Effort**	**Years**	**Methods**	**Effort**	**Years**
Dirk Hartog (Australia)[1]	62000	Aerial Eradicat 1080 baits	Aerial Eradicate 1080 baits								
Marion (South Africa)[2]	29000	Biocontrol, trapping, poisoning	Shooting	11229 (hours)	1986-89	Shooting	5877 (hours)	1990-92	Shooting	1003 (hours)	1991-92
						Leg-hold traps	1833 (trap-days)	1989-91	Leg-hold Traps	1387 (trap-days)	1992-93

Christmas (Australia)[3]	13500	Desexing domestics	Cage traps Leg-hold traps Eradicat baits	5270 (trap-days) 57 (trap-days)	2011 -12 2012 2011 12	?			?		
Socorro (Mexico)[4]	12033		Leg-hold and kill traps, hunting with dogs, shooting	79466 (trap-days)	2011-18	To begin			Detection dogs		
Macquarie (Australia)[5]	12780	Trapping, poisoning, shooting, fumigation	Shooting Cage traps	511 (hours) 56679 (trap-days)	1996-97 1996-97	Shooting Cage traps	3331 (hours) 58510 (trap-days)	1998-99 1998-99	Shooting Cage traps	2036 (hours 4576 (trap-days)	2000-02 2000

						Leg-hold traps	83240 (trap-days)	1998-99	Leg-hold traps Dog searches	13519 (trap-days) 882 (days)	2000 2000-02
Ascension (UK)[6]	9700	Sterilising of 168 domestic cats	1080 baiting, cage traps	75 902 baits, 42 008 trap-days	2002	Leg-hold traps		2002-04	Sand tracking pads 584000 days	14 480 days	2004-05
San Nicolas (USA)[7]	5759	Leg-hold traps	Leg-hold traps		2009-10	Leg-hold traps		2010	Detector dogs, camera traps		2010
Faure (Australia)[8]	5198	None	Aerial baiting 1080 Eradicat			Leg-hold traps			Sand tracking pads		

Rangitoto/Motutapu (NZ)[9]	3820		Secondary poisoning from rat aerial baiting with brodifacoum			Spotlight shooting, leg-hold and cage traps			Detector dogs, spotlight searches		
Beaver (UK)[10]	3800		Shooting, leg-hold traps								
Little Barrier (NZ)[11]	3083	Biocontrol, trapping	Cage, leg-hold traps, hunting with dogs, 1080 baiting			Trapping			Searches by people		
Raoul (NZ)[12]	2938	Hunting with dogs	Secondary poisoning after aerial baiting for rats			Leg-hold traps, hunting with dogs			Dog searches		
Baltra (Ecuador)[13]	2537	Cage traps	Cage traps, 1080 baits			Cage and leg-hold traps, 1080			Searches by people		

						baits					
Gabo (Australia)[14]	154	Shooting, trapping in 1970s	1080 poisoning		1998	1080 poisoning Cage traps	 454 trap-days for 1 cat	1990 1998-91	Spotlight searches Day shooting Scat searches	31 (hours)	1990 -91
Tasman[15] (Australia)	120	1080 poisoning, shooting	PAPP poisoning	1 day	2010	Cage traps Leg-hold traps	503 (trap-days) 782 (trap-days)	2010 2010	Spotlight searches	45 nights	2010-11

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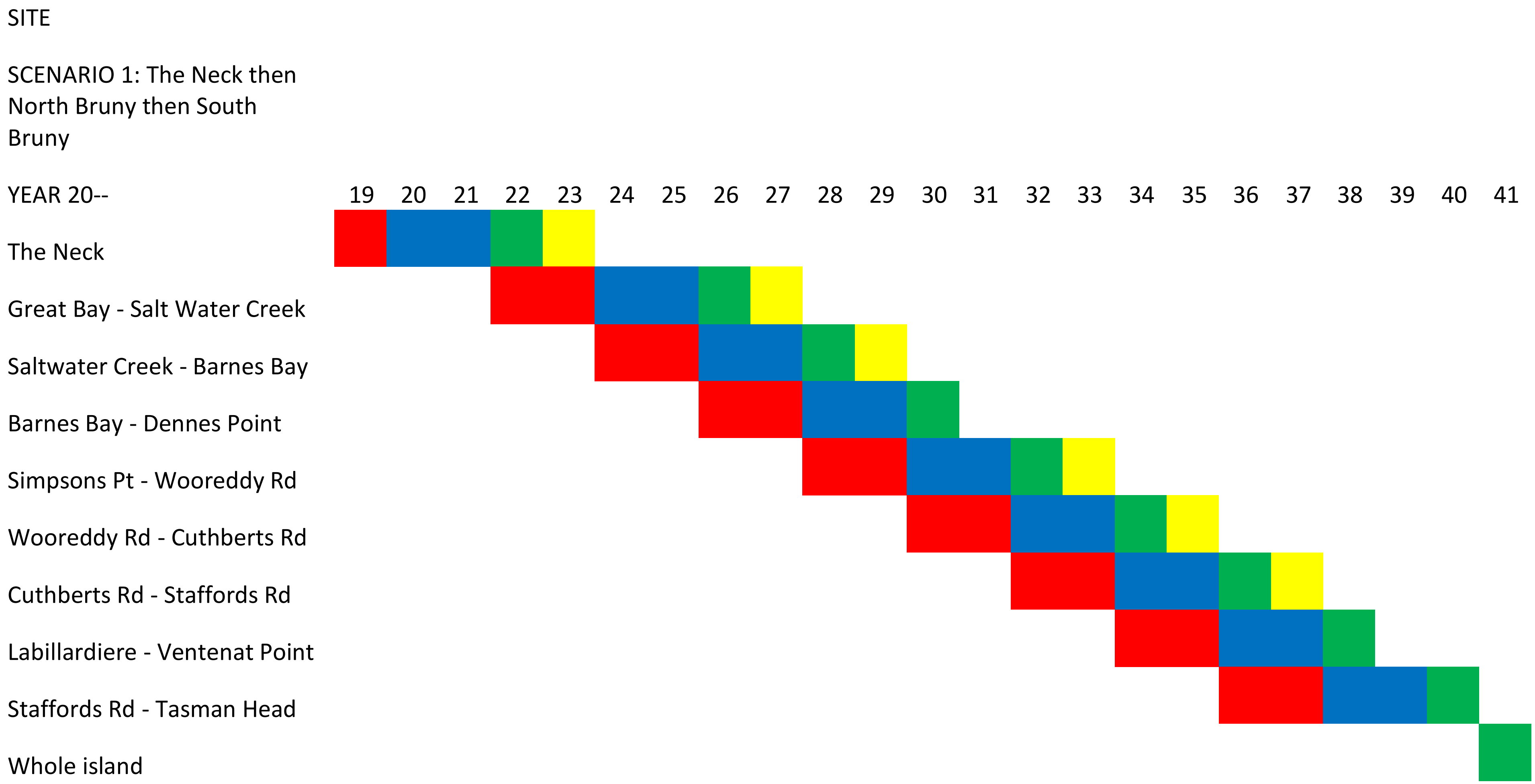
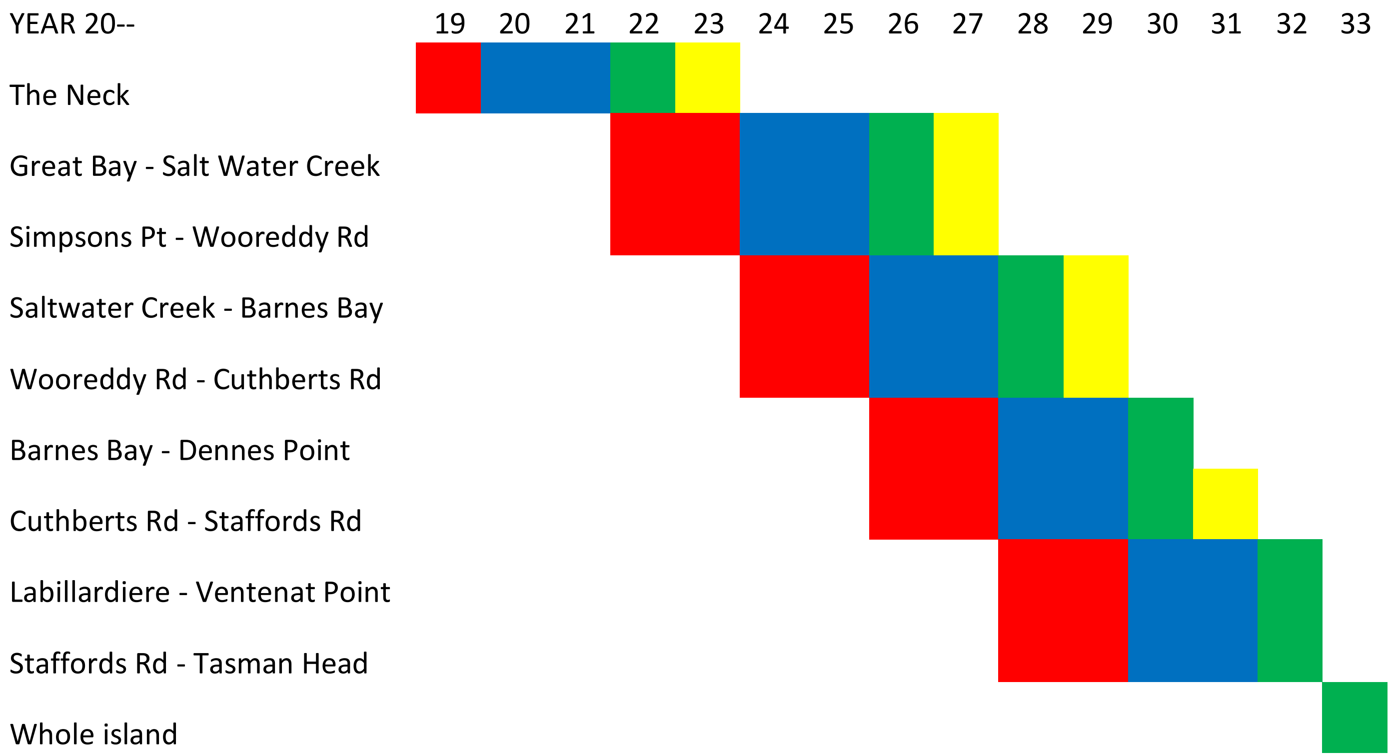
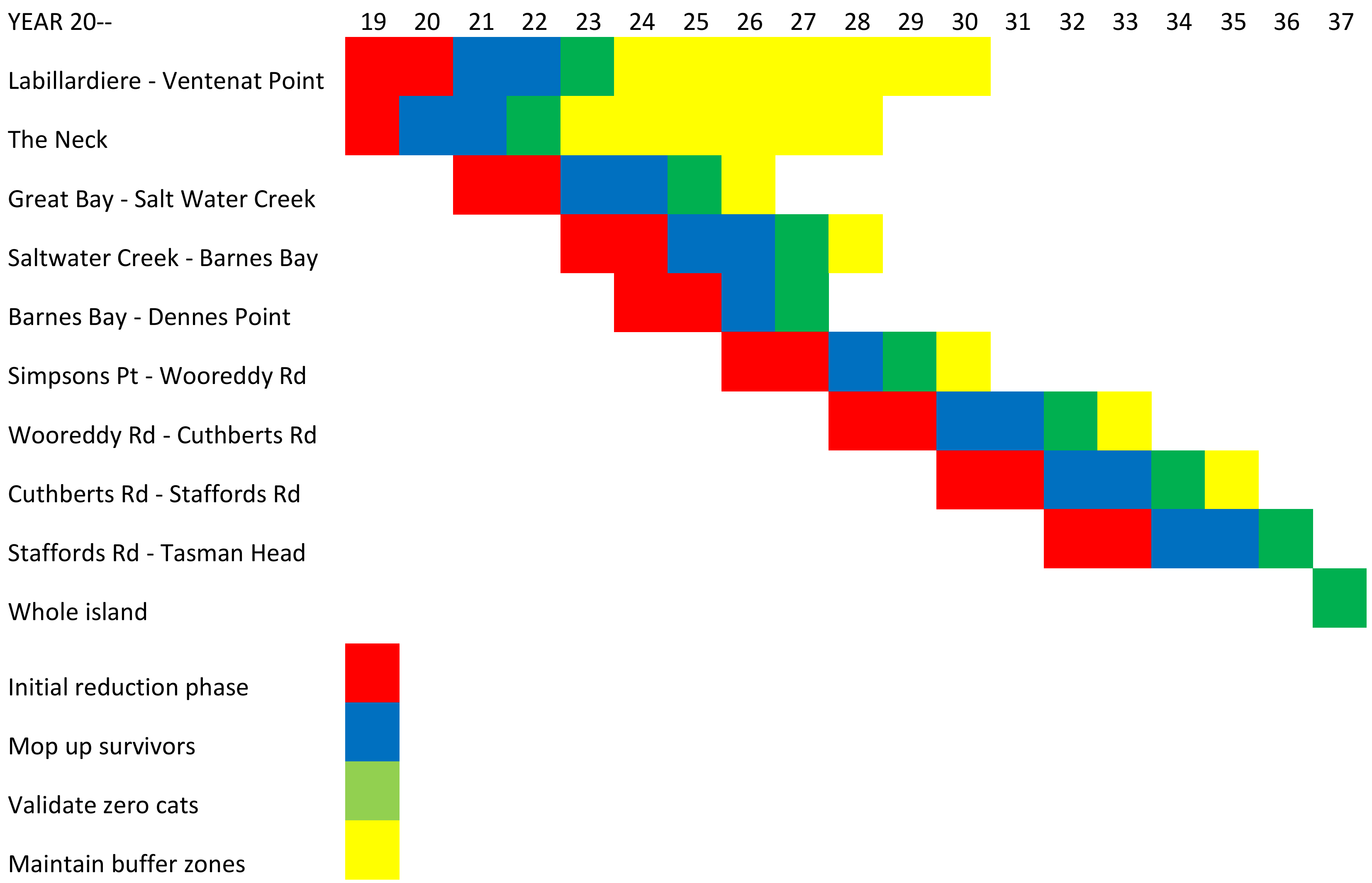
Figure 12. Three roll-out scenarios to eradicate cats from Bruny Island



SCENARIO 2: The Neck then pais of sites north and south



SCENARIO 3: The Neck and Labillardiere then North Bruny then the rest of South Bruny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Labillardiere - Ventenat Point
The Neck
Great Bay - Salt Water Creek
Saltwater Creek - Barnes Bay
Barnes Bay - Dennes Point
Simpsons Pt - Wooreddy Rd
Wooreddy Rd - Cuthberts Rd
Cuthberts Rd - Staffords Rd
Staffords Rd - Tasman Head
Whole island
Initial reduction phase
Mop up survivors
Validate zero cats
Maintain buffer zones