Review of feral cat eradications on islands

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Abstract Feral cats are a substantial threat to native and endemic fauna on islands and are being eradicated with increasing frequency. Worldwide, 87 campaigns have been completed on 83 islands, for a total area of 114,173 ha. Nineteen unsuccessful eradication attempts are known on 15 islands and lessons learnt from those failures are provided. At least five campaigns are currently underway. We review past cat eradication campaigns, and the methods used to eradicate and detect cats in those campaigns. We also review recent advances in eradication and detection methods. We outline proposed eradications and document a trend for increasingly larger islands being considered, but note that although post-eradication conservation impacts are generally positive, there have been some negative ecosystem impacts.

Keywords: *Felis catus*, detection methods, island restoration

INTRODUCTION

While islands make up a small percentage of the earth's total area, they harbour a relatively large percentage of biodiversity, including many threatened species. Islands have also suffered the largest proportion of historic and prehistoric extinctions (Martin and Steadman 1999; Groombridge and Jenkins 2002), many of which are attributable to non-native mammals. On islands, non-native rats (*Rattus* spp.), cats (*Felis catus*), mongoose (*Herpestes auropunctatus*), goats (*Capra hircus*), pigs (*Sus scrofa*) and other introduced mammals have caused localised extirpations, global extinctions and altered ecosystem processes (Coblentz 1978; Ebenhard 1988; Whittaker 1998; Towns *et al.* 2006; Hays and Conant 2007; Jones *et al.* 2008). Feral cats prey on many taxa from invertebrates to large seabirds, and are known to have contributed to over 8% of all bird, mammal and reptile extinctions and to the declines of almost 10% of critically endangered birds, mammals and reptiles (Bonnaud *et al*. 2011; Medina *et al*. 2011). However, invasive species eradication is becoming a well established means of restoring affected islands, with >775 eradications now documented (Keitt *et al.* 2011). Reviews of introduced insular mammal eradications have been published for feral cats, goats, donkeys (*Equus asinus*), mongoose, and commensal rodents (*Rattus* spp., *Mus musculus*) (Nogales *et al.* 2004; Campbell and Donlan 2005; Carrion *et al.* 2007; Howald *et al.* 2007; Barun *et al*. 2011). However, difficulties with collecting unpublished information about eradications and their global scope, mean that reviews typically overlook some eradications. Additionally, the rapid evolution of this field and the increasing rate at which eradications are being conducted mean that reviews are quickly out-of-date. The cat eradication review by Nogales *et al*. (2004) was a landmark paper and has set the stage for future reviews. With insular eradications becoming increasing important to the conservation of biodiversity, we feel that it is timely to update and expand the earlier review to include the numerous additional eradications and technical advances that contributed to their success.

In this paper we review those aspects of cat eradication that will provide useful information for future campaigns. We re-evaluate analyses made by Nogales *et al*. (2004), including island size and eradication methods then add analyses for detection methods. We review new developments in toxicants, baits for aerial spreading of toxicants, and their potential impact on the field of cat eradications. An overview of detection methods that are used to find the last animals and assist in confirming eradication is provided. Of these we highlight preferred techniques. Lastly, we provide an overview of post cat eradication ecosystem responses and recommendations for applied research.

ERADICATION METHODS

Cat eradications have been attempted on islands in all the world's oceans. We found 87 successful campaigns on 83 islands, representing 114,173 ha, that range in size from 5 – 29,000 ha (Appendix 1). We also identified 19 feral cat eradication campaigns that failed on 15 islands (Appendix 2). A further five campaigns are known to be in progress.

Of the 87 successful campaigns, eradication methods are known for 66 (76%). On average, each campaign employed 2.7 eradication methods including leg-hold traps (68%), hunting (59%), primary poisoning (31%), cage traps (29%), and dogs (24%) (Appendix 1).

All successful campaigns for which methods are known on islands >2500 ha (n = 9) utilised primary poisoning with toxic baits, with the exception of Santa Catalina (3890 ha) and San Nicolas (5896 ha). Interestingly, seven failed campaigns on the five largest islands (all >400 ha) for which methods are known did not use toxicants. Toxin use does not guarantee success since five campaigns with toxic baits on four islands <400 ha failed. Of the successful campaigns, 17 campaigns (26% of all) used sodium monofluoroacetate (1080) for primary poisoning. Two campaigns used an unknown toxicant, one campaign used the herbicide paraquat, and another used para-aminopropiophenone (PAPP). Secondary poisoning, leveraged through rodents poisoned with brodifacoum was used in 11 campaigns (17% of all successful), but percent mortality (knockdown) of cats varied. For example, secondary poisoning through eradications of *R. norvegicus* and *R. exulans* was attempted on the New Zealand island of Tuhua, and all cats were removed. However, on Motuihe Island (with *R. norvegicus, Mus musculus*) rabbits were also present, which appeared to be a poor vehicle for transmitting the toxin to cats, and only a 21% population reduction was achieved (Dowding *et al.* 1999; Towns and Broome 2003; P. Keeling pers. comm. 2010). Where rabbits are not present, knockdown rates of ≥80% can be expected for cats when rodents are targeted simultaneously for eradication using brodifacoum. Only three eradications have been completed solely utilising toxin-based methods. In all projects that employ toxins, managers should plan to use other eradication methods to remove remaining animals and capitalise on the population knockdown.

Cage traps have been used with mixed success. Some reports indicate that cage traps were so inefficient at catching feral cats that their use was abandoned in favour of other methods (Domm and Messersmith 1990; Twyford *et al.* 2000; Bester *et al.* 2002). However, cage traps can be useful on inhabited islands where capture and sterilisation of domestic cats is a priority, where domestic cats are non-targets, or where live removal of some animals is a goal. Other traps, such as padded leg-hold live traps are effective at capturing cats and the animals can be dispatched or removed unharmed for sterilisation or live removal (e.g., Hanson *et al.* 2010). Sterilisation of domestic cats on inhabited islands has been used in 8% of all successful campaigns and is being used in two projects that are currently underway (Hilmer *et al.* 2009). Sterilisation of domestic cats is in some cases combined with registration, micro-chipping, legislation or agreements that restrict the importation of cats to sterilised animals or prohibit their importation entirely. Other campaigns, such as on Baltra (Galapagos Islands), utilised agreements to prohibit domestic cats and their importation; pet cats were exported or euthanased.

A relatively new eradication method is fumigation in holes (Springer 2006). The use of aluminium or magnesium phosphide tablets to create phosphine gas that asphyxiates cats in holes may be a valuable method in future campaigns. Cats are highly sensitive to phosphine gas, having a 30 minute lethal gas concentration of 80 ppm, compared to 2400 ppm for rabbits (CDC 1996).

Contrary to claims by proponents of Trap-Neuter-Return (TNR) that it will eventually eliminate cat populations (Longcore *et al.* 2009), feral cats have not been eradicated from any island utilising this technique. There was one unsuccessful campaign where TNR was employed (Appendix 2). Like domestic sterilised cats, neutered feral cats limit the detection methods that are suitable for confirming eradication (e.g., Ratcliffe *et al.* 2009).

We could find cost data for <10% of all successful eradications. To report costs in a single currency, we converted cost data for each year from its native currency to US$ using historical exchange rates for that year (http://fx.sauder.ubc.ca/data.html). If annual cost data were not available, we averaged costs over the years of the campaign. To report costs in a single time period, we adjusted for inflation using historical US annual inflation rates (http://inflationdata.com/). All costs, unless future predicted costs, are expressed in 2009 US dollars (US$). Successful campaigns varied in cost from US$4 – 431 / ha (Table 1).

Feral cat eradication campaigns that we reviewed had a failure rate of 22%. Failures were usually attributed to a lack of institutional support to complete the action, the use of inappropriate methods, and inappropriate timing of those methods. More than half of all successful eradications were on islands <200 ha. Although cats were usually easier to remove from small than large islands, >50% of all known failures were also on islands <200 ha (Appendix 2). Failures on small islands appear to be characterised by a lack of planning and inadequate financial and institutional support. The lack of planning is likely responsible for one of the primary causes of failure: inappropriate timing and methods.

DETECTION METHODS AND CONFIRMING ERADICATION

In addition to the elimination of cats, a second component of eradication campaigns is the use of appropriate methods of detection. Detection methods are crucial to removing the last cats and to determine that the eradication was successful, but these methods have received inadequate attention. Detection methods also help managers determine whether management actions may need modification, such as altering eradication methods, focusing effort in space to remove the last individuals, and gaining insight as to when the last animal may have been removed. In addition, these measures can provide indices of abundance, which are useful for determining the effectiveness of each eradication method employed. Ideally, some detection methods should be independent of eradication methods, so they are not influenced by any aversion induced in the animals. Managers can use detection information, combined with catch-per-unit-effort data from eradication methods to increase confidence that eradication is complete. This approach can also be formalised by conducting detection probability analyses to quantify the likelihood of an animal being detected if present (Ramsey *et al.* 2011).

Detection methods are known from 49 (56% of all) successful cat eradication campaigns (Appendix 1) to search for animals at low densities and to aid in confirming eradication. Commonly used methods were: searching for sign such as footprints, latrines, scat, prey remains (94%), trapping (71%), spotlighting (49%), track pads (43%) and dogs (43%) (Appendix 1). Other methods used were camera traps, baiting, audio and olfactory attractants,

Table 1 The cost (in 2009 US$) of successful insular cat eradication campaigns.

Island	Area (ha)	Cost US$,000s	US$ / ha	Source
San Nicolas	5896	2543*	431*	Island Conservation unpublished data
Wake Atoll (3 isl.)	650	206	317	M. Rauzon pers. comm. 2007
Raoul	2943	832	283	G. Harper pers. comm. (cats and rodents)
Macquarie	12,870	2544	198	S. Robinson pers. comm. 2008
Plata	1420	260	183	Island Conservation unpublished data
Ascension	9700	1300	134	Ratcliffe *et al.* 2009
Mayor (Tuhua)	1277	86	67	Towns and Broome 2003 (cats and rodents)
Baltra	2620	144†	55†	C. Sevilla pers. comm. 2007
Faure	5800	26	4	Algar *et al.* 2010

* Excludes $680,000 in fox mitigation and costs of live removal of cats (A. Little pers. comm. 2010), including these costs the campaign cost $547/ha.

† 47% of total expenditure was spent confirming eradication.

molecular techniques, reproductive status, hair snares and local inhabitants reporting sightings. On average, each campaign employed 3.8 detection methods.

Detection methods most commonly used in cat eradications (Appendix 1) were a combination of searching for sign and an absence of captures in traps. These methods are effective where appropriate substrate allows sign to be easily read and non-target species such as goats, foxes, and seabirds do not confuse or erase sign. In these situations, the probability of detecting sign is increased, trap placement is facilitated, and a paucity of non-target captures allows traps to be available exclusively for cats. Other methods are required where inappropriate substrates exist, or non-target species confound detection. Trappers often create track pads along likely cat travel routes, providing a place in which to later read sign of predictable age and facilitate trap placement. However, track pads are typically informal (a quick smoothing of existing substrate) and often go unreported. Dogs have often been used as a hunting and detection tool. There is great potential in using specialist cat dogs, which have been selectively bred or specifically trained for this purpose (e.g., Wood *et al.* 2002). Camera traps have high rates of detection probability when at appropriate densities and are cost effective when compared to other methods, particularly if substrate is poor for reading sign or when cats are at low densities (Ramsey *et al*. 2011). In a test of several types of camera traps for detecting feral cats, Reconyx Hyperfire No Glow PC900 cameras were competitively priced and had superior battery life, noise and visible light generation, trigger speed and sensitivity, and picture quality (Island Conservation unpublished data). Traps, track pads, camera traps, and hair traps may incorporate visual, auditory or olfactory lures or food baits in an attempt to attract cats.

We recommend that records of the sex and reproductive status of the last animals are kept if these data are available when methods such as trapping are used. Reproductive condition of females is a useful indicator of the presence of males. Foetuses and offspring can be aged (Knospe 2002) to determine whether the last male removed could have sired them. In addition, age of first conception in female cats, which is a minimum of 155 days (Jochle and Jochle 1993), and the presence or absence of uterine placental scars, may be used in a similar way. Further, placental scars may be used to estimate litter size and number of litters in felids (Mowat *et al.* 1996).

Prior to or during an eradication, DNA samples of the population can be collected and stored at little cost. If animals are found after the eradication, samples can then be analysed and microsatellites compared with the original population. This technique may enable determination of whether animals evaded eradication efforts, were introduced, or a combination of these (Abdelkrim *et al.* 2007). Further, DNA analysis can be used to identify individual animals, their sex and determine parent-offspring relationships, which may be important in some situations when dealing with the last animals (Forsyth *et al.* 2005). Blood, tissue samples, faeces and hair with follicles may be used to extract DNA for analysis (Forsyth *et al.* 2005).

The last cat(s) can be difficult to detect, and once detected may be extremely difficult to capture or kill, as was found on Baltra, Raoul, Santa Catalina, Wake and Serrurier Islands (Moro 1997; Phillips *et al.* 2005; A. Cox and B. Wood pers. comm. 2007; Rauzon *et al.* 2008). This highlights the importance of an eradication ethic matched with appropriate techniques and skilled staff to minimise escapes and avoid educating animals (Morrison *et al.* 2007).

Confirming the absence of cats can cost as much if not more than the rest of the eradication campaign (e.g., Baltra, Table 1). An ability to detect cats at low numbers plays a major role in the cost of confirmation and is an area where applied research is needed.

PROPOSED ERADICATIONS

Several insular cat populations are targeted for eradication in the near future. Islands on which cat eradications are in progress include: Robben (507 ha), South Africa; Juan de Nova (440 ha) and Grande Glorieuse (700 ha), France; and Home (95 ha), and West (623 ha), Australia (L. Underhill pers. comm. 2007; Hilmer *et al.* 2009; M. Le Corre pers. comm. 2010). Large islands for which cat eradications have been proposed within the last decade include: Socorro (13,200 ha) and Guadalupe (26,469 ha), Mexico; Floreana (17,253 ha), Ecuador; Auckland (45,975 ha) and Stewart or Rakiura (169,464 ha), New Zealand; and Dirk Hartog (62,000 ha), Western Australia (Beaven 2008; P. McClelland pers. comm. 2009; V. Carrion pers. comm. 2010; L. Luna pers. comm. 2010; Algar *et al*. 2011).

RECENT ADVANCES

Aerial techniques such as bait broadcast and aerial hunting along with the use of GPS and GIS have been of great benefit to rodent and goat eradications over large areas and sites with complex terrain (Campbell and Donlan 2005; Howald *et al.* 2007; Lavoie *et al.* 2007). Second generation anticoagulants have increased the feasibility of rodent eradications (Howald *et al.* 2007). Similarly, aerial baiting techniques against cats provide methods for the rapid knockdown of populations over large areas and complex terrain. The method is enabled by the development of specialist baits for toxin delivery that remain palatable for weeks (Algar *et al.* 2011; Algar and Burrows 2004). The rapid and economical knockdown of ≥90% of a cat population can enable eradications to be conducted in weeks, rather than years (Algar *et al.* 2011; Algar *et al.* 2002). Non-target species may be affected by cat eradication methods or may decrease the efficacy of those methods by consuming bait. Such species increase the complexity of eradications and are a particular challenge. Recent developments in toxins and their applications seek to minimise impacts on non-target species and increase the humaneness of this method. Alternative toxins, such as PAPP, toxicant encapsulation, and exploiting physiological attributes of cats not shared by non-target species, should reduce the risks to other species (Marks *et al.* 2006; Hetherington *et al.* 2007; Murphy *et al.* 2007; Johnston *et al*. 2011). On tropical islands, bait consumption by crabs and decreased palatability from baits being swarmed by ants can pose problems. The use of a residual insecticide, (e.g., permethrin; Coopex, Bayer, Pymble, Australia), which is now integrated into the bait matrix, reduces ant attack while not affecting bait palatability to cats (Algar *et al.* 2007). To reduce non-target bait consumption, a gantry device has been developed that allows cats to access baits but excludes crabs, rats and other non-targets (Algar *et al.* 2004; Algar and Brazell 2008). Baits and leg-hold traps have also been placed on top of buckets filled with sand to reduce crab predation and captures (Ratcliffe *et al.* 2009). Preliminary results from paired food tests indicate that aniseed (*Pimpinella anisum*) may be an effective hermit crab (*Coenobita perlatus*) deterrent (A. Wegmann unpublished data). Further, crabs consuming toxic baits are an additional risk for human populations that consume crab (Pain *et al.* 2008). Future research into compounds for deterring crab consumption of baits could increase the feasibility of conducting cat (and rodent) eradications on tropical islands.

Padded-leg-hold traps such as Victor Oneida # 1.5 soft-catch round-jawed traps are the most commonly used technique in eradicating cats from islands. However, square jawed padded traps provide faster setting, and a greater effective catch area than comparative round jawed traps. Bridger #2 four spring offset custom padded traps are one option and were used effectively on Isla de la Plata. When trap anchors are driven into the ground with wire cable, trappers should use copper ferrules rather than aluminium ferrules to avoid galvanic corrosion, which can result in total decay of ferrules within 21 days, particularly on islands where soils are often high in salts and moisture (Hanson *et al.* 2010).

Leg-hold traps effectively capture feral cats when deployed appropriately (Wood *et al.* 2002), but have the disadvantage of ethical and often legal requirements to check them frequently. Two developments have the potential to fulfil ethical standards while increasing the cost effectiveness of programmes. Telemetry based trap monitoring systems have recently been used on San Nicolas Island to fulfil checking requirements. The trap monitoring system decreased person-hours required to check traps to one-tenth of the effort without the system, and increased animal welfare standards by allowing animals to be removed from traps more promptly (Will *et al.* 2010). Trap monitoring systems can be used for live and kill traps. For small projects, the use of handheld antennae rather than a system of repeaters, as used on San Nicolas, may provide an effective system that will reduce project costs. Trap tabs are small rubber or plastic reservoirs filled with a tranquilising agent and attached to the jaw of a leg-hold trap (Savarie *et al.* 2004). When canines are captured they bite the trap jaw, piercing the reservoir and are sedated, decreasing injury rates (Savarie *et al.* 2004), whereas trapped feral cats do not bite down on trap jaws. Research is underway to develop a trap tab on a throw arm for feral cats that could incorporate a toxicant (e.g., PAPP) or sedative agent (D. Algar pers. comm. 2010). Successful development of this device could provide a humane kill soon after animals were captured, potentially reducing checking requirements.

Specialist cat hunting dogs are a promising detection method, as was indicated by their use on San Nicolas Island (Hanson *et al.* 2010). If required, aversion training can ensure dogs are not a threat to non-target wildlife (Tortora 1982). Furthermore, methods exist to train dogs to avoid toxic baits, and the degradation rate of the compound in baits can be used to determine when it is safe to use dogs in treated areas. Dog tracking by GPS can provide benefits in the field and help managers evaluate terrain coverage of hunters and dogs by GIS. Astro GPS dog tracking units (Garmin, Olathe, Kansas, U.S.) make these activities more economical, but data are frequently lost when there is no line of sight radio signal between the transmitter and handler's GPS. A data saving collar would rectify this problem.

Sentinel cats fitted with radio telemetry or GPS collars incorporating mortality features may be used to monitor the effectiveness of methods (Phillips *et al.* 2005). The capture method for sentinel animals should not bias results. For example, cats captured using bait may be pre-disposed to consuming toxic bait. Blind leg-hold trap trail sets are likely to be the preferred capture method for sentinel animals in most cases. GPS collars can provide additional information on the movements of animals, and potentially alert managers to avoidance strategies being employed by remnant animals.

GIS is possibly one of the most powerful and accessible management tools available for managers of eradication projects. The recent integration of ruggedised handheld field computers with integrated GPS and custom databases facilitated the acquisition, management and interpretation of large amounts of data on San Nicolas Island (Will *et al.* 2010).

Because detecting the last individuals and confirming eradication is so costly for cats, detection probability methods should help managers of future projects to determine stopping rules based on the probability that they would have detected an animal had one been present (Ramsey *et al.* 2011). Furthermore, by combining cost-per-unit-effort with forecasts for maximising detection (and removal) probability from existing data, managers could model each method's cost effectiveness in detecting and removing the last animals and confirming eradication. This would inform decisions about how to deploy the most efficient and cost-effective methods. The incorporation of marked and sterilised cats into the population early in a campaign or before removal methods are applied should improve estimates of probability of detection and removal (Ramsey *et al.* 2011). Data from detection devices can also be used to calculate population estimates (Ramsey *et al.* 2011), and this could be used in near real time throughout a campaign and refined as data becomes available. The development of these management tools will likely only be cost effective for medium-large campaigns until the deployment of these tools becomes more frequent.

The presence of non-target species can influence the selection of methods but trapping techniques have been developed for areas with similar sized non-target carnivores. For example, severe injuries were reduced on endemic foxes on San Nicolas Island when padded leg-hold traps were matched to the size of the non-target species, additional swivels fitted, anchors made as short as possible, and all vegetation that could foul swivels was removed. Walk through sets were identical and a novel scent placed to facilitate recognition and avoidance by endemic foxes; being captured in traps acted as conditioned aversion training. During a 20 day trial, fox captures decreased 95% when comparing the first and last five days, while cat capture rate remained constant (Island Conservation unpublished data). This also demonstrates the risk of poorly set traps, where escape induces aversion to sets. On San Nicolas Island, costs became inflated by restrictions on methods available due to the presence of an island endemic fox (Hanson *et al.* 2010; Table 1). In contrast, although Faure Island is similar in size to San Nicolas, it lacked non-target species that required mitigation or restricted the selection of methods (Algar *et al.* 2011). Cats were eradicated from Faure Island for <1% of the cost of San Nicolas Island (Table 1).

Funding and social issues appear to be the main factors limiting many eradications occurring (Campbell and Donlan 2005; Howald *et al.* 2007), and this is also true for cats. Increasing the efficacy of eradications, particularly confirming eradication, and efficiently implementing multiple species eradications are the primary technical challenges. The use of legislation, spay and neuter, identification by micro-chipping, registration of pets and prohibition or control of importation, will become more common as eradications on inhabited islands involve feral populations of species that are also kept as pets or farm animals (e.g., Ratcliffe *et al.* 2009). Working with communities will be a key component of eradicating cats from inhabited islands. Biosecurity aimed at preventing introductions or reintroductions must also be key components of island management strategies.

POST ERADICATION IMPACTS

Positive responses have been reported for populations of small mammals, reptiles and birds when cats were eradicated (McChesney and Tershy 1998; Donlan *et al.* 2003; Keitt and Tershy 2003; Rodríguez-Moreno *et al.* 2007). Along with increases in extant populations, the creation of introduced predator free habitat can make areas suitable for re-introductions. For example, after cats were eradicated from Faure Island, four species of threatened native mammals that were extirpated by the cats have been successfully re-introduced (Richards 2007). Unassisted recolonisation of species that were extirpated is not uncommon for birds, and often begins soon after cats were eradicated (Schulz *et al.* 2005; Dowding *et al.* 2009; Ortiz-Catedral *et al.* 2009; Ratcliffe *et al.* 2009). Consideration of food web dynamics, and in some cases modelling interactions, may assist in predicting the impacts on conservation targets. For example, Russell *et al.* (2009) modelled rodent-cat assemblages and the impact of eradicating or leaving cats on islands with small long-lived seabirds. Their models suggested that superpredator eradication is crucial for the survival of long-lived insular species. However, cat eradications may also produce unexpected negative ecosystem impacts such as increased predation rates on seabirds (Rayner *et al.* 2007). A report of negative impacts induced by cat eradication on Macquarie Island (Bergstrom *et al.* 2009) was much publicised by the popular press, but several contributing factors were involved and the absence of cats may have been relatively minor among them (Dowding *et al.* 2009).

Before cat eradications are planned, potential positive and negative impacts should be considered in any feasibility analysis. Mitigation actions such as the eradication of other introduced species may also need to be planned. Mixed ecosystem responses to eradication are not restricted to cats (Zavaleta *et al.* 2001; Campbell and Donlan 2005). In addition to considering potential negative impacts on conservation values, managers should also consider the sequence in which invasive species are removed, and plan eradications so that the removal of one species will not complicate or prevent the future removal of another.

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Appendix 1 Successful cat eradication campaigns and the eradication and detection methods employed. In the methods columns a "Y" indicates that the method was used and a "–" indicates that the method was not used or there is no information.

					Eradication Methods													Detection/Confirmation Methods											
Island	Area (ha)	Country	Eradication Period	Year Eradicated	Aerial laid 1080 baits	Ground laid 1080 baits	10/20 Poisoning**	Leg-hold trap	Cage trap	Kill trap	Unknown Trap	Hunting	Dogs	Disease	Domestics neutered	Other	Unknown	Sign	Baiting	Dogs	Trapping	Spotlighting	Molecular	Track pads	Audio attractants	Olfactory attractant	Reproductive status	Other	Unknown
Marion[1,2]	29,000	ZA	1977-91	1991	Y	Y	-	Y	-	-	-	Y	-	Y	-	-	-	Y	Y	-	Y	Y	-	-	-	-	-	-	-
Macquarie[1,3]	12,870	AU	1975-00	2000	-	Y	-	Y	Y	-	-	Y	-	-	-	A	-	Y	-	Y	-	-	-	-	-	-	-	-	-
Tristan da Cunha[4]*†	9837	UK		1974	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Ascension[5]†	9700	UK	2002-04	2004	-	Y	-	Y	Y	-	-	Y	-	-	Y	B	-	Y	Y	-	Y	-	Y	Y	Y	-	-	H	-
San Nicolas[42]†	5896	US	2009-10	2010	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	-	Y	-	Y	Y	-	Y	Y	H	-
Faure[6]	5800	AU	2001 (3 w)	2001	Y	Y	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	Y	-	Y	Y	Y	Y	-	-	-
Santa Catalina[7]	3890	MY	2000-04	2004	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-
Raoul[8]	2943	NZ	2002-05	2005	-	Y	Y	Y	-	-	-	-	Y	-	-	-	-	Y	Y	Y	Y	-	-	-	-	-	-	-	-
Little Barrier[1,9]	2817	NZ	1977-80	1980	-	Y	-	Y	Y	-	-	Y	Y	Y	-	-	-	Y	Y	-	Y	-	-	-	-	Y	-	-	-
Baltra[10]†	2620	EC	2001-04	2004	-	Y	-	Y	Y	-	-	Y	-	-	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	-	-
Motutapu[11]†	2311	NZ	2009	2009	-	-	Y	Y	-	-	-	Y	-	-	-	-	-	Y	-	Y	Y	-	-	-	-	-	-	-	-
Kapiti[1]	1965	NZ		1934	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Monserrat[1, 37]	1886	MY	2000-01	2001	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Monserrat[39]	1886	MY	2002	2002	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Rottnest[12]	1705	AU	2001-02	2002	-	-	-	Y	-	-	-	-	-	-	-	-	-	Y	-	-	Y	-	-	Y	Y	-	Y	-	-
Partida Sur [1,37,38]∆	1533	MY	2000	2000	-	-	-	-	-	-	-	-	-	-	-	C	-	Y	-	Y	Y	Y	-	-	-	-	-	-	-
Rangitoto[11]†	1509	NZ	2009	2009	-	-	Y	Y	-	-	-	Y	-	-	-	-	-	Y	-	Y	Y	-	-	-	-	-	-	-	-
Plata[13]	1420	EC	2009	2009	-	-	Y	Y	-	Y	-	-	-	-	-	-	-	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	-	-
Mayor [1,14]	1277	NZ	2000	2000	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Hermite[1,16]	1020	AU	1999 (8 w)	1999	Y	-	-	Y	-	-	-	-	-	-	-	-	-	Y	-	-	Y	-	-	Y	Y	Y	-	-	-
Alegranza[1]	1020	ES	1997-01	2001	-	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Trinidade[17]	1000	BR		1989	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deserta Grande[1]	1000	PT		1984	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Natividad[1,15, 37]†	736	MY	1998-00	2000	-	-	-	Y	-	-	-	Y	Y	-	-	C	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Coronados[1,37]	715	MY	1998-99	1999	-	-	-	Y	-	-	-	-	-	-	-	-	-	Y	-	-	Y	Y	-	Y	-	-	-	-	-
Port Cros[18]†	640	FR	2004-06	2006	-	-	-	-	Y	-	-	-	-	-	Y	-	-	Y	-	-	Y	Y	-	-	-	-	-	H	-
Pitcairn[1]†	500	UK		1997	-	-	Y	Y	Y	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wake (Wake Atoll)[19]†	500	US	1996-04	2004	-	-	-	Y	Y	-	-	Y	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Lobos[1]	430	ES	1992-02	2002	-	-	-	Y	Y	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	Y
Jarvis[1,20]	410	US	1957-90	1990	-	-	-	Y	Y	Y	-	-	-	Y	-	G	-	Y	-	-	-	Y	-	-	-	-	-	-	-
San Francisquito[1,37]	374	MY	2000	2000	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Reevesby[1]	373	AU	1984-90	1990	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Great Dog[1]	370	AU	1991-92	1992	-	-	-	-	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Santa Barbara[21]	326	US		1950	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Angel[1]	314	US			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Curieuse[1,22]†	286	SC	2000-1	2001	-	Y	Y	Y	-	-	-	-	-	-	-	-	-	Y	Y	-	Y	-	-	-	-	-	-	-	-
Dassen[23]	273	ZA	mid 1980s-02	2002	-	-	-	-	Y	-	-	Y	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
San Martin[1,37]	265	MY	1999	1999	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Flat[1]	253	MU		1998	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Mejía[1,37]	245	MY	1999-01	2001	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Fregate[1]	219	SC	1980-82	1982	-	Y	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Serrurier[25]∆	188	AU	1996	1996	-	Y	-	-	Y	-	-	Y	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Motuihe [26]‡	179	NZ	2002-04	2004	-	-	-	Y	-	-	-	Y	-	-	-	D	-	Y	-	-	Y	Y	-	-	-	-	-	-	-
Cuvier[1,27]	170	NZ	1960-64	1964	-	-	-	Y	Y	Y	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Howland [28,29] ∏	166	US		1964	-	-	-	-	-	-	-	Y	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Howland[29]€	166	US		1986	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Gabo[1,30]	154	AU	1987-91	1991	-	Y	-	-	Y	-	-	Y	-	-	-	-	-	Y	-	-	Y	Y	-	-	-	-	Y	I	-

Appendix 1 continued

					Eradication Methods													Detection/Confirmation Methods											
Island	Area (ha)	Country	Eradication Period	Year Eradicated	Aerial laid 1080 baits	Ground laid 1080 baits	10/20 Poisoning**	Leg-hold trap	Cage trap	Kill trap	Unknown Trap	Hunting	Dogs	Disease	Domestics neutered	Other	Unknown	Sign	Baiting	Dogs	Trapping	Spotlighting	Molecular	Track pads	Audio attractants	Olfactory attractant	Reproductive status	Other	Unknown
Desecheo (Puerto Rico)[31]	152	US	1985-87	1987	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Stephens[1]	150	NZ	c. 1910-25	1925	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Denis[1,22]	150	SC		2001	-	Y	Y	Y	-	-	-	-	-	-	-	-	-	Y	Y	-	Y	-	-	-	-	-	-	-	-
Guillou (Kerguelen)[1]	145	FR	1994-95	1995	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Baker[1]	145	US		1930	-	-	-	-	-	-	-	-	-	-	-	E	-	-	-	-	-	-	-	-	-	-	-	-	Y
Moutohora [21]	143	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Mou Waho [21]	140	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Putauhinu [1]	140	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Coronado Sur[39]	126	MY	2003	2003	-	-	-	Y	-	-	-	Y	-	-	-	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-
Tasman[43]	120	AU	2010	2010	-	-	-	Y	Y	-	-	Y	-	-	-	K	-	Y	-	Y	Y	Y	-	-	-	-	-	H	-
Mou Tapu[21]	120	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Aziak[21]	118	US		1964	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Mangere [1]	113	NZ		1950	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Long Cay[1,32]	111	UK	1999	1999	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Wilkes (Wake Atoll)[19]	110	US	1996-2004	2004	-	-	-	Y	Y	-	-	Y	-	-	Y	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
North West (Capricorn)[1,33]	105	AU	1984-85	1985	-	Y	-	-	Y	-	-	Y	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Todos Santos Sur[1,37]	89	MY	1997-98	1998	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Todos Santos Sur[40]	89	MY	1999	1999	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Todos Santos Sur[41]	89	MY	2004	2004	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Estanque[1,37,40]Δ	82	MY	1999	1999	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Isabel[1,24]	80	MY	1995-97	1997	-	Y	Y	Y	-	-	-	Y	Y	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	-	-	-	-
Aride[34]	68	SC		1930s	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Stevensons[21]	65	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Yerba Buena[21]	65	US			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Viwa[35]†Ω	60	FJ	2006	2006	-	-	Y	Y	Y	-	-	-	-	-	Y	F	-	-	-	-	-	-	-	-	-	-	-	J	-
San Jerónimo[1,37]	48	MY	1999	1999	-	-	-	Y	-	-	-	Y	Y	-	-	-	-	Y	-	Y	Y	Y	-	Y	-	-	-	-	-
Anacapa- E[36]	43	US		1970	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Asunción[15,37,40]	41	MY	1994	1994	-	-	-	Y	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	Y	-	-	-
Peale (Wake Atoll)[19]	40	US	1996-2004	2004	-	-	-	Y	-	-	-	Y	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-
Matakohe[1]	37	NZ	1991	1991	-	Y	-	Y	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Coronado Norte[15,37]	37	MY	1995-96	1996	-	-	-	Y	-	-	-	-	Y	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	Y	-	-	-
San Roque[15,37,40]	35	MY	1994	1994	-	-	-	Y	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	Y	-	-	-
Todos Santos Norte[40]	34	MY	1999-2000	2000	-	-	-	Y	-	-	-	-	Y	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	Y	-	-	-
Cousine[1]	30	SC	1985-90	1990	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Farallon S[21]	29	US		1972	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Herekopare [1]	28	NZ		1970	-	-	-	Y	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Ile aux Aigrettes[1]	25	MU		1994	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y
Silver[19]	25	NZ			-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Derbin[19]	15	US		2000	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	Y
Hoskyn[19]	5	AU		1979	-	-	-	-	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y

Country abbreviations: AU Australia, BR Brazil, EC Ecuador, ES Spain, FJ Fiji, FR France, MY Mexico, MU Mauritius, NZ New Zealand, PT Portugal, SC Seychelles, UK United Kingdom, US United States of America, ZA South Africa.

Other methods: ** primary/secondary poisoning with brodifacoum; A, fumigation in holes; B, hand capture; C, live removal; D, secondary poisoning from aerial 1080 for rabbit eradication and possibly pindone ground laid baits; E, clubbing w/sticks; F, paraquat herbicide in meat baits; G, ground laid baits with unspecified toxicant; H, camera traps; I, hair traps; J, local inhabitants reporting sightings; K, PAPP baits dispersed aerially and from ground. * domestic cats removed by medical officer due to toxoplasmosis in 1974. Holdgate (1965) reports feral cats over entire island, but none are present today. † inhabited. ‡ cats not eradicated in 1981 as reported by Veitch and Bell 1990. Δ single cat removed. ∏ cats reintroduced in 1966. € 1966 reintroduction was eradicated in 1986 and is reported in Nogales *et al.* (2004) as 1979 eradication. Ω one male cat hidden by villager, not neutered. No restriction on reintroduction of cats.

Appendix 1 continued

Sources: [1] Nogales *et al.* 2004. [2] Bester *et al.* 2002. [3] Springer 2006. [4] Holdgate 1965; P. Ryan pers. comm. 2007. [5] Ratcliffe *et al.* 2009. [6] Algar *et al.* 2011. [7] B. Wood pers. comm. 2007 and 2009; L. Luna pers. comm. 2010; Aguirre *et al.* 2008. [8] Broome 2009; A. Cox pers. comm. 2007; G. Harper pers. comm. 2010. [9] Veitch 2001. [10] Phillips *et al.* 2005. [11] R. Griffiths pers. comm. 2010. [12] Algar *et al.* unpublished data. [13] Island Conservation unpublished data. [14] Towns and Broome 2003. [15] Donlan *et al.* 2000. [16] Algar *et al.* 2002. [17] R. Valka pers. comm. 2010. [18] Bonnaud *et al.* 2011. [19] Rauzon *et al.* 2008; M. Rauzon pers. comm. 2007. [20] Rauzon 1985. [21] Island Conservation database. [22] Merton *et al.* 2002. [23] L. Underhill and A. Wolfaardt pers. comm. 2007. [24] Rodríguez *et al.* 2006. [25] Moro 1997. [26] P. Keeling pers. comm. 2010. [27] Merton 1961. [28] King 1973. [29] M. Rauzon pers. comm. 2007. [30] Twyford *et al.* 2000. [31] Evans 1989. [32] Mitchell *et al.* 2002. [33] Domm and Messersmith 1990. [34] Parr *et al.* 2000. [35] B. Nagle and C. Morley pers. comm. 2009. [36] K. Faulkner pers. comm.; Knowlton *et al.* 2007. [37] B. Wood pers comm. 2008. [38] M. Hermosillo-Bueno pers. comm. 2010 to L. Luna. [39] Aguirre Muñoz *et al.* 2003. [40] Sánchez Pacheco and Tershy 2000. [41] Aguirre Muñoz *et al.* 2004. [42] Hanson *et al.* 2010; Ramsey *et al.* 2011. [43] Sue Robinson unpublished data.

Appendix 2 Unsuccessful cat eradication campaigns

Island	Area (ha)	Country	Methods	Campaign Year(s)	Reason for failure
Grande Terre (Kerguelen)[1]	650,000	FR	Hunting	1960, 1970-77	Effort ceased once at low numbers (both efforts).
Amsterdam[2]	5500	FR	Unknown	pre 1957	Campaign abandoned when rat and mice numbers increased which was believed to be a response to decreased cat density.
Raoul[3]	2943	NZ	Dogs, hunting	1970s	Caused inefficiency in a concurrent goat eradication campaign and was stopped.
Little Barrier[4]	2817	NZ	Disease, leg-hold traps, cage traps	1968-9	Lack of continuity / insufficient effort.
Plata[5]	1420	EC	Cage traps, trap-neuter-release	2006-07	Inappropriate methods, unable to trap all animals / not all animals at risk.
Jarvis[6]	410	US	Hunting	1964-68, 1973-78	Lack of continuity / insufficient effort / only single technique.
South Molle (Queensland)[7]	380	AU	Ground laid 1080 baits, hunting	1985-86	Staff at the resort hid cats in their rooms. Not all animals were at risk.
Serrurier[8]	188	AU	Ground laid 1080 baits, hunting	1987-90, 1995	Single cat. Failed shooting attempts caused wariness (1st attempt). Abundant food source (breeding seabirds) when baits laid; inappropriate timing (1st and 2nd attempt).
Motuihe (Hauraki Gulf)[9]	179	NZ	Brodifacoum aerial baiting for rodents and rabbits	1997	Complete eradication or knockdown on cat population anticipated by primary/secondary poisoning but only 21% population reduction achieved, possibly as rabbits poor vector for toxin. Funding for follow-up work was unavailable. Inappropriate method / not all animals at risk / lack funding.
Howland[10]	166	US	Hunting, kill traps, cage traps	1977-79	Long grass - hunting ineffective, inappropriate methods didn't put all animals at risk.
Tasman[11, 12] (Tasmania)	120	AU	Ground laid 1080 baits, hunting	1977-80	Seasonal presence of main prey species unknown at the time, contributing to not all cats being vulnerable to baiting. Program halted after 3-4 years effort. Unable to kill animals faster than they reproduced, lack of concentrated effort.
Little Green (Tasmania)[12]	87	AU	Cage traps	1983-84	Inappropriate method. Old cat scat found in December 2007 during a brief visit.
San Roque[13]	79	MY	Hunting	Late 1980s	Campaign abandoned, majority of cats removed. Insufficient institutional support.
Asunción[13]	68	MY	Hunting	Late 1980s	Campaign abandoned, majority of cats removed. Insufficient institutional support.
Wedge (Tasmania)[12]	43	AU	Leg-hold traps, cage traps, hunting, dogs	2003, 2004	Attempted on a limited budget. At the time, eradication not a priority action for the managing bodies, insufficient institutional support for each campaign. Prints and scat present 2008.

Sources: 1 Lorvelec and Pascal 2005; Chapuis et al. 1994. 2 Reppe 1957 cited in Holdgate and Wace 1961. 3 Parkes 1990. 4 Veitch 2001. 5 G. Banda pers. comm. 2007. 6 Rauzon 1985. 7 K. MacDonald pers. comm. 2007. 8 Moro 1997. 9 Veitch 2002; Dowding et al. 1999; P. Keeling pers. comm. 2010. 10 M. Rauzon pers. comm. 2007. 11 Brothers 1982. 12 S. Robinson unpublished data. 13 Donlan et al. 2000; B. Tershy pers. comm. 2010.
Country abbreviations: AU Australia, EC Ecuador, FR France, MY Mexico, NZ New Zealand, US United States of America.