Eradication of feral cats from large islands: an assessment of the effort required for success

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Abstract: Feral cats (*Felis catus*) are predators and competitors of native species on many islands and are therefore the target of control efforts. Cat eradication has been achieved on 83 islands worldwide. Six of these successes have been from large islands (over 2000 ha) and have reported sufficient data to examine how the eradication was achieved through combinations of aerial and ground-based poison baiting, fumigation in rabbit burrows used by cats, cage and leghold trapping, day and night shooting, and hunting with dogs. No common sequence of tactics was deployed although leghold traps were used in the latter phases of most projects. It took a mean reported effort of 543 ± 341 person-days per 1000 ha of island over 5.2 ± 1.6 years to completely remove cats and validate success from the six islands. These precedents may assist in planning future proposals to eradicate cats from other large islands.

Keywords: control effort; control sequence; *Felis catus*

Introduction

Predation by introduced cats (*Felis catus*) affects many native species (Dickman 1996; Gillies & Fitzgerald 2005; Loss et al. 2013) and particularly on islands where cat predation has led to extinctions of native species (Duffy & Capece 2012). Trophic interactions between feral cats, introduced primary prey (e.g. rodents or and rabbits), and native secondary prey (Sinclair et al. 1998) are at the core of debate over the order in which suites of invasive species should be eradicated (Glen et al. 2013) and the potential consequences of getting this wrong (e.g. Bergstrom et al. 2009 cf. Dowding et al. 2009). Efforts to mitigate cat impacts have led to sustained control efforts against cats on continents and very large islands (Reardon et al. 2012), removal from fenced exclosures (Young et al. 2013), and eradication from islands (Nogales et al. 2004; Campbell et al. 2011).

This paper provides an assessment of the feasibility, methods and effort required to eradicate feral cats from large islands. To do this we reviewed cat eradications from six islands of over 2000 ha where sufficient data were reported to know how this was achieved and with what effort. Worldwide there are several proposals to eradicate feral cats from even larger islands (e.g. Aguirre-Muñoz et al. 2011; Campbell et al. 2011; Parkes et al. 2012, unpubl.; Bell & Bramley 2013; Glen et al. 2013; Nogales et al. 2013), and our review indicates what it might take to achieve future success, until at least the efficiency of control methods and their application are improved (e.g. Johnston et al. 2011).

Selecting case studies: background to the analysis

Of 83 islands from which cats have been eradicated (see the lists in Nogales et al. (2004) updated by Campbell et al. (2011)) 11 were larger than 2000 ha, which we use to define 'large' for this review. However, reports from only six of these larger islands (Table 1) contained enough detailed information to allow analysis of the sequence of control events used and the effort expended.

Table 1. Islands from which feral cats have been eradicated and that met our case study criteria – over 2000 ha and where data on the project were available.

Island	Size (ha)	Country	Primary exotic prey species for cats	Reference
Marion	29 000	South Africa	Mice	Bester et al. (2002)
Macquarie	12 780	Australia	Rabbits, mice, ship rats	Copson & Whinam (2001); Robinson & Copson (2014)
Ascension	9700	UK	Rabbits, mice, ship rats	Ratcliffe et al. (2010)
San Nicolas	5896	USA	Nil	Hanson et al. (2010)
Little Barrier	2817	New Zealand	Polynesian rats	Veitch (2001)
Baltra	2620	Ecuador	Mice, ship rats	Phillips et al. (2005)

All islands are unique and all cat eradication attempts have been different. Some have begun with aerial baiting, either targeting rodents with cats as a secondary kill or more rarely targeting the cats themselves (Griffiths 2010; Johnston et al. 2011). While eradication of rodents can be achieved by baiting with an anticoagulant toxin, eradication of feral cats is more complicated because some cats usually survive baiting. Of all 63 feral cat eradications that described methods, only two have been achieved using a single aerial baiting – on Faure Island using cat baits containing sodium fluoroacetate (1080) (Algar et al. 2010) and on Mayor Island from secondary poisoning during a rodent eradication using baits containing brodifacoum (Campbell et al. 2011). In this paper we do not explore these cases other than to note that increased research on why some individuals of species (other than rodents) usually survive aerial baiting would be worthwhile, especially if the most ambitious pest-free island schemes are to be remotely affordable.

Most eradications of most pest species, including cats, are currently achieved through a series of similar or different control events applied over time until no pests remain. Knowing when this has been achieved and setting stop rules is the key for this type of eradication (Parkes 2011). However, the events usually provide data that can be analysed, e.g. catch per unit effort, to estimate the probabilities that survivors remain (Ramsey et al. 2011). Of the six feral-cat eradication projects that met our criteria (size and data availability), all applied a sequence of different control tools. To attempt synthesis we divided the sequence into three phases:

- *Initial population reduction:* This 'knockdown' phase is best done as quickly as possible to avoid or limit recruitment into the population as survivors breed or as animals disperse into areas already cleared.
- *Removing remaining animals:* This 'mop-up' phase usually begins about when the cumulative kill from knockdown reaches a plateau and when known survivors are either apparently avoiding the initial control methods or are living in some physical refugium, e.g. on steep cliff faces, where the knockdown methods cannot be used. Often an alternative control method is used to get these last animals. The mop-up phase ends when no more animals are being caught and no further sign is detected by monitoring.
- *Validating success:* The aim of this phase is to establish whether the eradication has been successful. Most eradication operations continue surveillance (trapping, camera traps, search for sign, etc.) and, if no animals are detected after some time, success is claimed. Recent developments allow managers to analyse data collected during the preceding phases of the project to estimate the probability that no sign equals no animals, and to quantify the extra monitoring and surveillance required to increase this probability to some predetermined level. This level may be set by balancing the costs of even more surveillance against the risks and costs of declaring success too soon (Ramsey et al. 2011; Samaniego-Herrera et al. 2013).

Results

Marion Island

Marion Island in the southern Indian Ocean (46°54′ S, 37°45′ E) is a volcanic island with high annual precipitation (2576 mm) and snow and ice at higher elevations. Cats inhabited areas below about 500 m a.s.l. spanning 19 000 ha. The vegetation consists of grasses and herbs. Five domestic cats were introduced in 1949 and by 1975 there were an estimated 2136 ± 290 cats (van Aarde 1979). Mice (*Mus musculus*) are still present. The island is inhabited by staff of a South African meteorological station.

Biological control, through the introduction of feline panleucopaenia virus in 1977, reduced the population to 615 ± 107 cats in 1982 (Bester et al. 2002). After this, many other cat control methods (cage traps, leghold traps, hunting with and without dogs, and 1080 baiting) were tested but none, by themselves, were considered suitable to achieve eradication on Marion Island (Bester et al. 2002).

Initial population reduction: In 1986, shooting by day and at night was selected as the initial method to attempt eradication (Table 2) and eight two-person teams were used during four summer deployments (each 8 months in length) and one winter deployment (4 months in length) to shoot cats. Over these five expeditions between 1986 and 1990, a total of 872 cats were shot and 80 trapped in 14 725 person-hour's effort during 4486 hunting trips (Bloomer & Bester 1992). We assume the 4486 hunting trips equals 8972 person-days' field effort in our later comparisons between projects.

Concerns for the safety of the shooters prompted scaling-back of shooting and increased trapping; cage traps were ineffective but leghold traps accounted for 63 of the 95 cats killed on Marion Island during 1989 and 1990.

Removing the last animals: Trapping was retained as the method to target surviving cats, supplemented by baiting using 1080 in day-old chicken carcasses. The last cat was trapped in July 1991 (Bester et al. 2002).

Validating success: Two teams of 10 and 6 hunters and trappers continued to search the island for the following two years (1991–1993) but no further cats were seen or trapped.

Macquarie Island

Macquarie Island in the subantarctic (54°30′ S, 158°57′ E) is inhabited only by staff of Australian government agencies. Feral cats were present before 1820 and the island also had rabbits (*Oryctolagus cuniculus*), mice and ship rats (*Rattus rattus*) as primary prey sympatric with the cats (Copson & Whinam 2001). An attempt to eradicate the rodents and rabbits was made in 2011/12 with confirmation of success pending (Anon. 2013).

Initial population reduction: The Macquarie Island cat project began in 1974 with a low-effort sustained control project that included experimental use of toxic baits (Table 3). This evolved into an eradication aim about 1984 (Copson & Whinam 2001) with a major increase in effort in 1996 (Fig. 1). Until 1996, the main methods were trapping (39% of kills), daytime shooting (28% of kills), spotlight shooting (19% of kills) and harbour (rabbit burrow) fumigation (9% of kills) (Copson 1995). After 1996, live traps, then leghold traps plus night shooting were the main methods (Fig. 1).

Removing the last animal: The change of tactics in 1998, with the introduction of leghold traps, signalled the end of the initial reduction phase, and the reduction in the kill tallies in 1999 retrospectively identified the mop-up phase of the eradication. The last cat was killed in June 2000.

Validating success: The validation phase consisted of 2 years of search effort using detector dogs without finding a cat.

Table 2. Efficacy of hunting and trapping cats on Marion Island, 1986–1993 (Bloomer & Bester 1992; Bester et al. 2002). Each hunting event lasted on average 3.28 hours.

Year	No. staff	Daytime hunting			Night hunting			Leghold trapping		No. 1080 baits laid	Total cats killed
		Hours hunted	Cats seen	Cats shot	Hours hunted	Cats seen	Cats shot	No. traps	Cats caught		
1986/87	16	1051	135	50	2768	1395	393	0	0	0	458
1987/88	16	493	42	22	2999	786	174	0	0	0	206
1988/89	16	481	16	12	3437	603	124	5	2	0	143
1989/90	8 + 10	855	6	1	2641	310	66	144	78	0	145
1990/91	10	0			1378	61	11	410	109	0	120
1991/92	10	0			1003	0	0	1279	8	12 000	8+
1992/93	10	0			131	0	0	1387	0	18 000	0
Totals		2880	199	85	14 357	3155	768		197	30 000	1080

Table 3. Control effort and number of cats killed each year since 1996, Macquarie Island (after Copson (1995) 1974–1995, and Robinson & Copson (2014) 1996–2002).

Year	No. staff	Effort (field days)	Spotlight hours	Cage trap nights	Leghold trap nights	Days searching for cat sign	Dog-days	No. cats killed
1974–1995								1689
1996	2	501	182	27 220	0	0		264
1997	2	528	329	29 459	50	0		182
1998	6	1075	1488	21 407	4915	0		215
1999	6	1129	720	37 103	78 325	NA		99
2000	6	1336	1123	4576	13 519	1070	18	1
2001	6	1198	365	0	0	996	222	0
2002	3	522	548	0	0	283	201	0
Totals		6289	4755	119 765	96 809	2349	441	2450

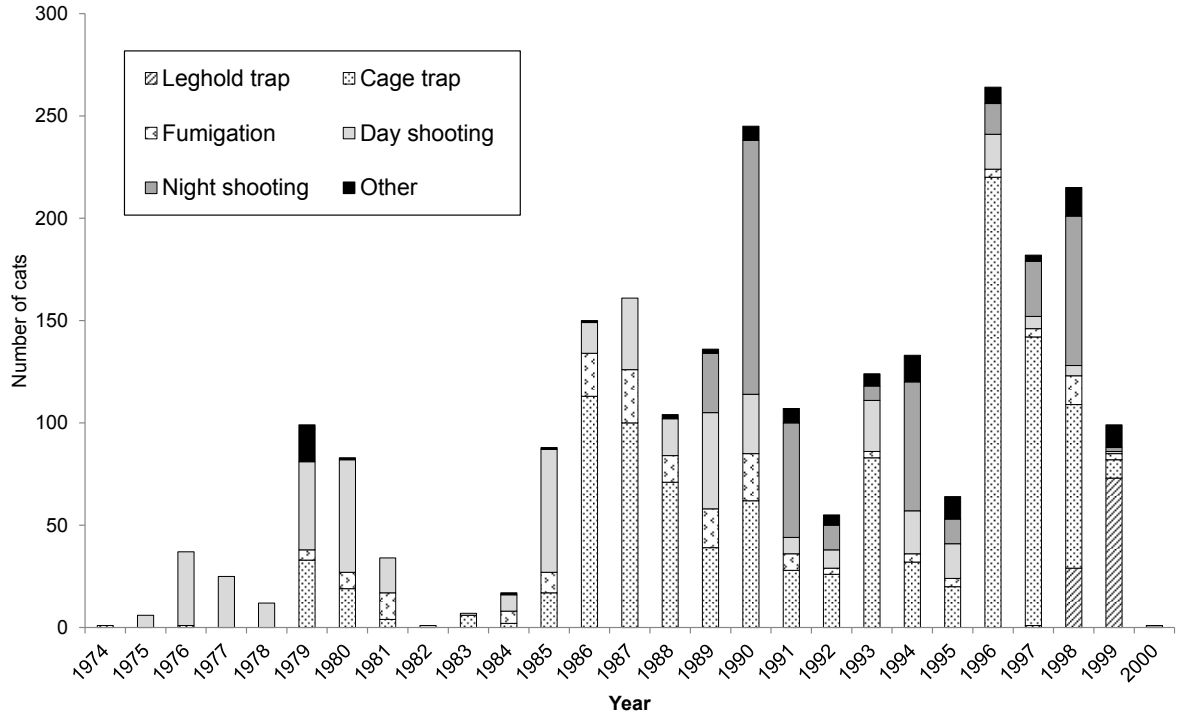

Figure 1. Number of feral cats killed on Macquarie Island, 1974–2000. Fumigation = gassed down rabbit or bird burrows.

Successful eradication of the cats was declared in 2003. About the same annual effort in terms of person-days was expended in the validation phase as in earlier phases.

Ascension Island

Ascension Island is a volcanic island (7°57′ S 14°22′ W) in the mid-Atlantic Ocean. Large areas are sparsely vegetated but exotic shrubs and trees are common in the wetter areas above about 450 m a.s.l. extending to the mountain peaks at 850 m. The island has a human population of about 900 people at a military facility. Cats were introduced in 1815 (Ratcliffe et al. 2010). Ship rats, mice, and rabbits are present and are prey for cats (Ashmole & Ashmole 2000).

Initial population reduction: Between February and October 2002, 75 902 toxic baits (fish pieces each containing 2 mg 1080) were laid by hand across the island. Of these, 6497 were removed with about 488 thought to have been eaten by cats. During this same period a cage-trapping effort comprising 42 008 trap-nights caught 70 feral and 36 domestic cats. About 15 000 person-hours were expended in this phase.

Removing the last animals: Cats apparently became wary of cage traps and baits after October 2002. After this 298 leghold trap-nights were used at sites with cat sign until 31 January 2004 when the last cat was caught. During the mop-up phase of about 9200 person-hours 3 feral cats were trapped, 4 additional cats were caught by hand in the town areas, and 2 were shot.

Validating success: Eradication success was validated by monitoring for 2 years using 800 tracking pits. During this validation phase 14 480 person-hours (i.e. about 2069 person-days) were deployed. Domestic cats are still present but in 2009 all were neutered and there is an ongoing campaign to ensure all new domestic cats taken to the island are neutered.

San Nicolas Island

San Nicolas Island in the Channel Islands, California (33°14′ N, 119°31′ W), is arid (annual rainfall less than 200 mm) with sparse vegetation. Feral dogs (*Canis familiaris*) were removed in 1857 and farmed sheep were removed in the 1940s. Cats may have been present since these times but were reported in the 1950s (Ramsey et al. 2011). There were no introduced rodents on San Nicolas but the endemic deermouse (*Peromyscus maniculatus exterus*) and three species of lizard plus terrestrial birds were the main vertebrate prey for the cats (Schoenherr et al. 1999).

Initial population reduction: Cats (n = 14) were removed in 2006 in a trial to test traps for impacts on non-target foxes (*Urocyon littoralis dickeyi*). The main cat eradication project ran from June 2009 to April 2010 using 236 leghold traps over 30 201 trap-nights, removing 57 cats (Hanson et al. 2010; Ramsey et al. 2011). Traps were not set over the whole island at any one time but were deployed on a 'rolling front' across 11 zones over 69 days with an average of six people working on the island during this period for a total of 414 person-days (Hanson et al. 2010). The initial reduction of the population took about 15 000 trap-nights with 85% of cats removed in the first three months of trapping.

Removing the last animals: The last four cats were trapped in mid-November 2009 over an additional 15 000 trap-nights' effort, which we assume took 414 person-days.

Validating success: Searches for sign of cats, including the use of dogs, were conducted during the trapping campaign and camera traps were used after December 2009. Two further cats were detected and removed during the validation phase.

Ramsey et al. (2011) used the above data from trap-catch per-unit effort, dog hunting effort, sign searches and camera traps to estimate the probability that cats remained in April 2010. They estimated there was a 95% chance that between 1 and 4 cats remained. Subsequent control showed that 2 cats were in fact present (the estimated probability of this being 0.25). Ramsey et al. (2011) also estimated the amount of extra monitoring required to increase the probability to 99%, and to balance the costs of increasing the probability against the costs of falsely declaring eradication success. The project managers were very risk averse and deployed much more monitoring than recommended (after the last cat was removed) to be 99% certain of success (Ramsey et al. 2011).

Little Barrier Island

Little Barrier (Hauturu) Island (722 m a.s.l.) is a steep, dissected, forested island in the outer Hauraki Gulf of New Zealand (36° 12′ S, 175°04′ E). Cats were present in the late 19th century and contributed to the extinction of several birds and the decline of many other native species. *Rattus exulans* were present during the entire time cats were present, but were eradicated in 2004 (Bellingham et al. 2010).

Cats had been subject to control since 1897. Between 1951 and 1967 the local rangers removed 264 cats. A formal 'eradication' project began in 1968 when some cats were trapped, infected with panleucopaenia virus (feline enteritis), and released. This and some trapping were claimed to have reduced the cat population by 80% but the effect was short-lived, with cats at pre-release numbers by 1974 (Veitch 2001). A renewed attempt to eradicate cats began in 1977 and was completed in 1980. This was achieved by cage trapping, leghold trapping, use of hunting dogs, and by spot poisoning with 1080 fish baits (Veitch 2001). About 67 km of tracks were cut across the island to facilitate access for control and monitoring.

Initial population reduction: Assuming the population had recovered from the 1968/69 release of the disease and trapping, the 1977 eradication attempt removed at least 146 cats over the first three years plus an unknown number killed by the 1080 spot poisoning for a total effort of about 2500 person-days (Table 4).

Removing the last animals: Searches for cat sign in early 1980 identified 6 cats. Trapping caught 4 cats, one was assumed to have been poisoned as bait was taken within its known range. The final cat appeared to expand its range but was trapped on 23 June 1980. This phase took about 1372 person-days (Table 4).

Validating success: Searches for cat sign along 67 km of tracks were made on average 23 times (range 12–38 on different sections of track) between July and September 1980 and no further sign was detected. The effort to do this was not reported.

Baltra Island

Baltra Island (0º30′ S, 90º01′ W) in the Galápagos Islands is a raised basaltic island reaching 60 m a.s.l with a generally flat topography. The island has ship rats and mice (Harper & Carrion 2011). The island has a permanent naval base and the main airport for the Galápagos Islands. Feral cats were eradicated between 2001 and 2003 (Phillips et al. 2005).

Table 4. Effort and known numbers of cats removed from Little Barrier Island, 1977–1980 (after Veitch 2001).

Year	Cage traps		Leghold traps		Total cats known to be killed	Total person-days
	Effort (trap-nights)	No. cats killed	Effort (trap-nights)	No. cats killed		
1977	3637	26	0	0	32	182
1978	0	0	37 332	73	77	1497
1979	0	0	5459	37	37	1008
1980	0	0	32 615	5	5	1372
Totals	3637	26	75 406	115	151	4059

Initial population reduction: After some live-capture trials in early 2001, about 350 bait stations were pre-baited with non-toxic fish followed by two applications of 1080 fish baits during September–October 2001. Bait-take fell rapidly from 80% on the first day, to 18% on the second day, to a maximum of 8% during the second period of baiting. Cage traps were also deployed around residential areas and where cats had been seen (Phillips et al. 2005). This rapid reduction was confirmed by pre- and post-poisoning spotlight counts, which fell from 1.62 cats per kilometre before poisoning to 0 per kilometre after poisoning.

Removing the last animals: Cage and leghold traps were deployed, supplemented by spotlight shooting as trapping became less effective. Between the end of the poisoning campaign in late 2001 and July 2003 a further 61 cats (including recruits) were trapped or shot in nine control events during 504 person-days' effort. This included systematic spotlight searches from a vehicle and on-foot searches in areas not accessible by vehicle, and daytime searches for tracks and other cat sign.

Validating success: Four searches of the island in July 2003 and November 2004 found no cats.

Discussion

Effect of cat biology on control effort

Three aspects of cat biology are relevant in any phased eradication project: the intrinsic rate of population increase, home range, and behavioural response to control methods. Feral cats generally have litters of up to five kittens and can breed several times a year when resources are not limiting, resulting in observed rates of increase of between 0.23 (van Aarde 1979) and an intrinsic rate of 1.0 based on allometric models (Sinclair 1996). An intrinsic rate of increase of 1.0 means a cat population could double every 8 months, which is a good reason to set short deadlines to achieve eradication, especially during the initial population reduction phase. The initial phase is also best achieved using methods that teach survivors least, i.e. to avoid having wary (e.g. bait- or trap-shy) animals left at the end of the phase. Initial reduction is best applied simultaneously over the whole population, but if this is impractical a 'rolling front' strategy over sub-areas has to be used. The size and shape of management sub-areas need to take account of potential natural or artificial boundaries to cats' movements and the likely largest home ranges of cats for the particular island, e.g. an mean of 510 ± 354 ha for male cats on Guadalupe Island (Luna-Mendoza et al. 2011) compared with 2083 ± 457 ha for males on Stewart Island, New Zealand (Harper 2007). A 'rolling front' strategy carries a higher risk than treating the whole population as a unit because it also needs to manage the problem of cats reinvading already cleared sub-areas. Another option for pest eradication on large islands is to fence it into manageable areas, as was done for the feral pig eradication on Santa Cruz Island (Parkes et al. 2010). Bode at al. (2013) have modelled fencing as an option for the proposed cat eradication on Dirk Hartog Island and found only marginal reductions in cost but more substantial benefits by reducing the risk of failure.

Sequences of cat removal methods that work

Clearly there is yet no standard process to eradicate cats, as every project seems to have developed empirically and independently, often with a period of trial and error before the final commitment to attempt eradication (Table 5). One strategy is to use toxins first, and for projects where the bait coverage can be complete (i.e. all cats potentially at risk) to hope all cats will be killed. Only three of 25 projects that started with baiting (two aerial and one ground-based baiting) achieved this outcome (Campbell et al. 2011), but nothing was common between the islands with respect to the baits, toxins and methods of application. One project, Rangitoto/Motutapu Island in New Zealand, targeted multiple mammal species (rodents, stoats, hedgehogs, rabbits and cats), using aerial brodifacoum baiting with the expectation that all rodents would be killed but that a mop-up phase would be required for the remaining species (Griffiths & Towns 2008, Griffiths 2010). Thus, if rodents are present on an island and their eradication by baiting is feasible, this can present a way to achieve an initial reduction in cat populations through secondary poisoning. If rodents are not present or cannot be eradicated by baiting, then targeting the cats with cat-specific baits may provide the next-best solution. If any toxic baiting is not possible the only general rule from our case studies seems to be the increasing use of leghold traps towards the end of the project (Table 5).

Estimating the effort required

The effort taken to remove cats in each phase from these case-study islands provides an indication of the likely effort required for future island eradications. No standard measure of effort was used across the case studies. Therefore, we have converted the data provided in the reports, with some assumptions about conversion rates, to a unit of field-days per 1000 ha over the actual time it took for each phase of a project for the six islands (Table 6).

Table 5. Sequence of control methods in different phases of cat eradication on six islands.

Island	Preliminary trials	Initial reduction	Removing survivors	Validating success
Marion	Biocontrol, trapping, poisoning hunting (1977–1985)	Spotlight hunting and leghold traps	Leghold traps and 1080 baiting	Hunting and trapping
Macquarie	Shooting, trapping, fumigation, 1080 baiting	Cage traps	Leghold traps, spotlight shooting	Searches with dogs and by people
Ascension	None	1080 baiting, cage traps	Leghold traps	Tracking sand pads
San Nicolas	Trapping to test non-target risks	Leghold traps	Leghold traps	Searches with dogs and camera traps
Little Barrier	Biocontrol, trapping	Cage traps, leghold traps, hunting with dogs, 1080 baiting	Trapping	Searches by people
Baltra	Cage traps	1080 baiting, cage traps	Cage and leghold traps, spotlight shooting	Searches by people

Table 6. Effort (per 1000 ha) to eradicate cats from large islands. Those islands in bold font also used 1080 baiting, but this was additional to the trapping effort and did not appear to affect the trapping effort expended.

Island	Estimated no. cats per 1000 ha	Effort = total person days per 1000 ha (years required for the phase)		
		Phase 1	Phase 2	Phase 3
Marion	117	241 (3.5)	118 (2.5)	? (2)
Macquarie	60	165 (3)	192 (2)	134 (2)
Ascension	61	220 (1)	113 (2)	213 (4)
San Nicolas	10	c.70 (1)	c. 70 (1)	? (?)
Little Barrier	51+	954 (3)	487 (1)	8 (1)
Baltra	44 – 59	? (1)	192 (2.5)	85 (2)

Precedence from our case studies shows a mean effort of 543 ± 341 (95% CL) person-days per 1000 ha of island over 5.2 ± 1.6 years will be required, at a minimum, to remove cats and validate success. The initial reduction phase (excluding the time assessing feasibility or testing methods) took an average of 330 person-days per 1000 ha, the mop-up phase took a mean effort of 195 person-days per 1000 ha, while the validation phase took 110 person-days per 1000 ha. Each phase took about 2 years to complete.

The implications can be worked out for islands being mooted for cat eradication, and there is no shortage of these. Nogales et al. (2013) have listed 12 islands as international priorities for cat eradication against feasible criteria, i.e. for islands smaller than the largest successful eradication on Marion Island. These islands range in size from 350 ha (Pine Cay in the Turks and Caicos Islands) up to 25 400 ha (Guadalupe Island in Mexico). No New Zealand or Australian islands make their list, because the key islands were considered too large and eradication not feasible using their rule. However, feral cats in New Zealand are key threats to, for example, the taiko (*Pterodroma magenta*) on Chatham Island (90 650 ha) and were the main reason why kākāpō (*Strigops habroptilus*) were removed from Stewart Island (173 500 ha). The question of island size and eradication feasibility is therefore relevant to our analysis. For example, there is a proposal to eradicate some introduced mammals from Stewart Island (Bell & Bramley 2013). Assuming the initial population reduction of cats would be achieved by an aerial baiting campaign aimed at rats but this would not eradicate the cats, then mop-up and validation phases using ground-based methods would be required. Precedents suggest 195 person-days effort per 1000 ha or 33 800 person-days would be required to eradicate the cats from Stewart Island. In a scoping plan for pest eradication (rodents, possums and cats) on Stewart Island, Bell and Bramley (2013) noted that a trained detector dog and handler could cover 50–60 ha in a day, suggesting that only 2880 days would be required to cover the whole island by this method. They noted that not all the island could be accessed by dogs and their handlers so this method alone would be insufficient to achieve and validate cat eradication. It is also unclear whether a single search by a dog would result in all cats present being killed or even detected as no one to our knowledge has measured the detection probabilities of dogs searching for cats. Trained dogs searching for brown tree snakes (*Boiga irregularis*) on Guam found 35% of those known to be present (Savidge et al. 2011), while trained dogs searching for red fox (*Vulpes vulpes*) scats in Tasmania found up to 40% of the scats known to be present within 100-ha sampling areas (Parkes & Anderson 2011). Thus, 2880 days of effort might locate areas with cats but is clearly an underestimate of the effort required to eradicate the cats.

However, the 33 800 person-days extrapolated from our case studies is probably an overestimate even if ground-based methods alone are deployed for the mop-up phase. This review of precedents suggests there is room for improved

efficiencies. For example, the most recent cat eradication (San Nicolas Island) took only 10% of the effort required for earlier projects. In future it may be possible to maximise the initial cat population reduction if aerial baiting targets rodents with a cereal bait with a concomitant secondary poisoning of cats, or by targeting cats alone with meat-based bait, or both. Aerial baiting saves time over trapping or ground-hunting methods in the initial reduction phase, but whether it saves money is unclear. Bell and Bramley (2013) noted it would take 4240 t of rodenticide baits and 5300 flying-hours to cover Stewart Island. Ignoring the rodents and targeting the cats with meat-based baits might be cheaper once such baits are developed and registered for use (see table 1 in Campbell et al. 2011) but of course does not target the other pest species when their eradication is also desirable. Aerial baiting with cat-specific baits is currently being trialled in Australia (Johnston et al. 2011) and it will be interesting to see if it will kill all cats or at least provide a more efficient way to achieve the initial population-reduction phase of eradication.

We have synthesised data from independent studies of cat eradications so there are gaps and inconsistencies in the way the effort expended in each was collected or reported. Nevertheless, we believe our estimates will be of use to those planning large-scale eradication of feral cat populations (Parkes et al. 2012, unpubl.; Nogales et al. 2013) if only to avoid a current serious problem where underestimates of the costs and time frames in planning stages of eradication projects lead to abandoned or failed projects. This is particularly the case for cat eradications where application of a sequence of control events is certain to be required but where there are few consistent recipes among the successful precedents.

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