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Authors

Barredo-Barberena, J. M.
Ortiz-Alcaraz, A. A.
Hernández-Montoya, J. C.
[et al.](#)

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Getting Ready for the Next Step: The Eradication of Feral Cats on Large and Highest Priority Mexican Islands

J. M. Barredo-Barberena

Grupo de Ecología y Conservación de Islas, A.C. (GECI), Ensenada, Baja California, México

A. A. Ortiz-Alcaraz

Grupo de Ecología y Conservación de Islas, A.C. (GECI), Ensenada, Baja California, México and Centro de Investigaciones Biológicas del Noroeste, La Paz, B.C.S. México

J. C. Hernández-Montoya

Grupo de Ecología y Conservación de Islas, A.C. (GECI), Ensenada, Baja California, México

L. Luna-Mendoza

Grupo de Ecología y Conservación de Islas, A.C. (GECI), Ensenada, Baja California, México, and School of Biological Sciences, University of Auckland, Auckland, New Zealand

A. Aguirre-Muñoz

Grupo de Ecología y Conservación de Islas, A.C. (GECI), Ensenada, Baja California, México

ABSTRACT: Mexican islands' biodiversity is very rich and diverse; several reptile, bird, and mammal endemic species live on them. However, ecological and evolutionary processes have been negatively affected by invasive species. To date, more than 20 island endemics, including mammals, birds and reptiles, have gone extinct on Mexican islands. As a very opportunistic predator that adapts easily to different environments, the feral cat is one of the most lethal invasive species. Restoration of island ecosystems can be achieved effectively by the eradication of this noxious species. In Mexico, 18 islands (<400 km²) have been cleared of feral cats using traditional techniques, i.e. trapping and hunting. These techniques are still being implemented on smaller islands or on islands where populations are small. Nevertheless, on big islands with complex terrain and topography, varied habitats and climates, and with non-target species, there are challenges to overcome. This includes Socorro (130 km²), Cerralvo (135 km²), and Guadalupe (240 km²) Islands. To achieve successful cat eradications on these islands, dispersion of toxic baits will be necessary. Currently, bait trials are being developed by Grupo de Ecología y Conservación de Islas, A.C., and supported by Australian and New Zealand institutions, as part of island-specific eradication plans. To date, these studies comprise feral cat and native species ecology for Cerralvo and Socorro Islands. All data gathered is valuable for eradication planning.

KEY WORDS: Curiosity[®] bait, eradication, Eradicat[®] bait, *Felis catus*, feral cats, island restoration, Mexican islands, Mexico, non-toxic bait trials

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INTRODUCTION

Mexico has more than 1,664 insular features (i.e., islands, islets, cays, rocks, and reefs) (CANTIM 2012). Just in the northwest region, where most of the islands are located, more than 330 endemic taxa of vertebrates and plants have been recorded (Aguirre-Muñoz et al. 2011). In total, all islands provide habitat for 8% of all vertebrate and plant species in Mexico (CANTIM 2012). Invasive mammals (e.g., cats, rats, and goats) have been introduced to Mexican islands, the majority during the 19th and 20th centuries. Frequently, feral cats (*Felis catus*) have been introduced as pets or as an attempt to control rodent populations (Moran 1996, Van Aarde 1980). As a result, cats have been responsible for the extinction and extirpation of at least 10 bird and mammal species from Mexican islands (Aguirre-Muñoz et al. 2011), and at least 9 other mammals, 2 birds, and 1 lizard are under threat for the same reason (Álvarez-Castañeda and Ortega-Rubio 2003, Arnaud et al. 1993, IUCN 2011, Jehl and Parkes 1983, Mellink et al. 2002).

So far, feral cats have been eradicated from 18 Mexican islands, mainly through traditional techniques such as trapping and hunting (the most widely used), and trained dogs (Aguirre-Muñoz et al. 2011, Wood et al. 2002). Nevertheless, cats are present in at least 17 additional islands.

Some are small in size with low densities of cats, thus it is feasible to conduct successful eradications. Yet, 9 are in the range of 130-350 km², and one is bigger than 900 km², therefore imposing bigger and more complex challenges (Aguirre-Muñoz et al. 2011, Rodríguez-Malagón et al. 2012). Traditional techniques could still be implemented on small islands (e.g., Redonda, 0.23 km², Marietas Archipelago; and Cayo Centro, 5.4 km², Banco Chinchorro Archipelago) with small populations (<20 individuals). However, the challenges (e.g., bigger size, complex topography, more dense and widespread populations) require novel techniques that have been successfully used in other parts of the world. Baiting (poisoning) is the most successful method for controlling feral cats (Campbell et al. 2011, Short et al. 1997), but there are critical issues to face: adequate toxin, palatable bait, appropriate bait delivery timing, and avoiding poisoning of non-target species (Algar et al. 2007, Marks et al. 2006, Murphy et al. 2005, Short et al. 1997). The consumption of bait by non-target species resistant to toxins also has to be considered, to ensure that enough baits are available for feral cats (Algar and Brazell 2008).

Eradicat[®] bait, a sausage-type bait with 1080 (sodium fluoroacetate) injected, developed by the Western Australian Department of Environment and Conservation (John-

ston et al. 2011), is a bait that has proven to be successful (Algar et al. 2002, Algar and Burrows 2004). However, during the last decade Australia and New Zealand started to explore the use of PAPP (*para*-aminopropiophenone) as an alternative toxin for eradication of introduced mammals, including feral cats (Murphy et al. 2007), given its advantages as a humane toxin (Eason et al. 2010). Research on PAPP has focused on the delivery of the toxin to feral cats and avoidance of consumption by native species (Marks et al. 2006, Murphy et al. 2007). One approach has resulted in the use of a polymer capsule (pellet) in the Eradicator[®] bait (without 1080), called Curiosity[®] bait (Johnston et al. 2011). The bait with the toxin (or biomarkers) encapsulated has been tested on French, Christmas, and Dirk Hartog Islands, Australia to evaluate its efficacy, with encouraging results (Johnston et al. 2010a,b, 2011).

A modification of the Curiosity[®] bait has been used in preliminary trials on Mexican islands with feral cats. On Guadalupe Island, the modified bait without the pellet was tested. Feral cats consumed the bait, but so did native species such as the western gull (*Larus occidentalis*) and the endemic junco (*Junco hyemalis insularis*) (Luna-Mendoza et al. 2011). In this paper, we describe preliminary results of bait and pellet consumption trials on Cerralvo and Socorro Islands. The information gathered, combined with feral cat home range estimations and abundance indexes, will be used to formulate specific eradication plans for the eradication of feral cats from these two Mexican islands.

STUDY SITE

Socorro Island (130 km²; 1,040 masl) is located in the Pacific Ocean (18° 47'N, 110° 58'W), in the Archipiélago de Revillagigedo Biosphere Reserve, 480 km off mainland Mexico (Ortega-Rubio and Castellanos-Vera 1994). Vegetation on the island comprises scrubland, coastal halophytes, and forest. It is an arid climate, according to Köppen classification. Rainfall average is 313.8 mm per year, with most of the rain concentrated in summer months. Fauna consists of landbirds (9), seabirds (93), reptiles (1) (including 10 endemisms within all groups), and invertebrates (land crab *Johngarthia planate*), but no native mammals (Ortega-Rubio and Castellanos-Vera 1994, SEMARNAT 2004). Sheep (*Ovis aries*) and cats were introduced in the 19th and 20th centuries (Ortega-Rubio and Castellanos-Vera 1994). Fortunately, sheep eradication is currently on confirmation phase (Ortiz-Alcaraz et al. 2011). Feral cats are partially responsible for the extinction in the wild of the Socorro dove (*Zenaida macroura*) and for diminishing populations of other endemics such as the elf owl (*Micrathene whitneyi graysoni*), Socorro towhee (*Pipilo erythrophthalmus socorroensis*), Townsend's shearwater (*Puffinus auricularis*), Socorro wren (*Troglodytes sissonii*), and the Socorro blue lizard (*Urosaurus auriculatus*) (Arnaud et al. 1993, Jehl and Parkes 1982, Martínez-Gómez and Jacobsen 2004).

Cerralvo Island (135 km²; 700 masl) is located in the Gulf of California (24° 09'N, 109° 48'W) (Aguirre-Muñoz et al. 2011, Hernández-Ramírez 2004) 13 km off mainland Mexico. It is contained in the natural protected area "APFF Islas del Golfo de California". This desert habitat includes 20 species of reptiles (4 endemic) and 67 bird species including 3 endemic landbirds (*Picoides scalaris*

soulei, *Cardinalis cardinalis clintoni*, *Amphispiza bilineata belvedere*). There are 2 endemic rodents (*Chaetodipus arenarius siccus* and *Peromyscus eremicus avius*), and 3 introduced species: cats, goats (*Capra hircus*), and black-tailed jackrabbit (*Lepus californicus*) (Álvarez-Castañeda and Cortés-Calva 1999, Banks 1963a,b, Grismer 2002, Hernández-Ramírez 2004). Predation by feral cats has been recorded on the spiny-tailed iguana (*Ctenosaura hemilopha*), a rattlesnake (*Crotalus* sp.), the coachship snake (*Masticophis flagellum*), and other native species (Banks 1964).

Characteristics and other logistical reasons particular to each island required differences in the methods for cat monitoring and bait tests, as described below.

METHODS

Cat Surveys

The surveys were conducted during 2011: Socorro in April, and Cerralvo in March. On Socorro, the survey was conducted on the east half of the island; the effort was directed to this area based on previous studies by Arnaud et al. (1993). On Cerralvo, the survey was located on the west half of the island, mostly for logistic reasons. Eight sand plot transects were set on each island along dirt roads, cross-country, and intermittent streams to monitor cat presence. Each transect was 3 km long with 10 stations, separated every 300 m. Transects were separated by approximately 1 km. Canned tuna was used as attractant. Each plot was observed for the presence or absence of tracks. The plots were swept daily to clear evidence of previous activity. Information was recorded over 3 consecutive nights. An index of relative abundance was obtained by dividing the total cat visits between the number of total operative station-nights (Linhart and Knowlton 1975).

Bait and Trials

To evaluate the response of target and non-target species to the bait, we conducted experiments on the two islands. The baits were composed of 70% minced beef (buffered to pH ~7.5), 20% chicken fat, and 10% animal digest (natural meat flavor) and flavor enhancers (Algar and Burrows 2004). Baits were man-made using domestic sausage manufacturing equipment. Baits were stuffed in a 21-mm collagen casing; they were similar to a chipolata sausage, weighing between 15 to 20 g and 6 cm long. Baits were manually implanted with a polymer encapsulation structure (pellet), known as the 'Hard Shell Delivery Vehicle' (HSDV) (Johnston et al. 2011). During this study, no toxins were used. Instead, pellets contained Rhodamine B (a non-toxic biomarker) to track bait consumption without risking native fauna.

Bait Field Trials

Socorro Island. Trials were conducted in November 2011. Baits were presented on four 1.2-km transects, each with 4 stations separated 400 m. Two baits with pellet were placed on each station. To evaluate the interaction of feral cats and native species, one remote camera (Bushnell Trophy Cam, Overland Park, KS) was installed on each station. Transects were run during 3 consecutive nights with 2 baits per station. Transects were placed at coastal,

forest, and 2 distinct scrubland habitats.

Cerralvo Island. Trials were conducted in January 2012. Five 3-km transects were implemented, 4 on canyons, and one along the coastline. Each transect had 10 stations, and a remote camera was installed per station. One bait with pellet was placed on each station. Transects were run for 1 night with baits laid at midafternoon and checked early in the morning. Cat differentiation was based in coat color.

Cage Trials with Target Species

Feral cats were trapped as part of an ongoing control campaign on both islands. Cats were housed in 100 × 70 × 85-cm cages for the bait trials. On Socorro, remote cameras were used to monitor cat activity without human disruption. Cameras were triggered by a motion detector system recording 30-second videos each occasion. For the trials for Cerralvo, a technician recorded videos of the cats when they showed some interest on baits during the trial. After the trial finished, cats were humanely euthanized.

Socorro Island. In November-December 2011, 6 cats were captured and trials conducted on site; consequently, cats had a short acclimation period. They were fed once a day and had access to water *ad libitum*. On the third day of captivity, 2 baits with pellets were offered.

Cerralvo Island. In January 2012, 8 cats were removed alive from the island and taken to a facility at La Paz, B.C.S. Cats were fed once a day and had free access to water. After a 7-day period for acclimation, 4 baits without a pellet were offered; 3 days later 2 baits with a pellet were offered again.

Cage Trials with Non-Target Species

Captivity trials with the endemic Socorro blue lizard and the native land crab were conducted only on Socorro Island in November 2011. Single individuals were housed in plastic 60 × 40 × 40-cm containers for 1 night; 1 bait was offered per individual. Lizards were monitored for 5 minutes every 2 hours during daylight hours; land crabs were left alone during night, and results were recorded at morning.

RESULTS

Cat Surveys

On Socorro Island, the relative abundance index was 0.323 ± 0.145; while on Cerralvo it was 0.081 ± 0.075.

Bait and Trials

Field Trials

Socorro Island. From 48 station-nights, only 40 were considered active (i.e., with remote cameras working properly). In total, baits were displaced or consumed from 78% of stations. Partial consumption was recorded on 8 stations, mostly by insects; pellets in those baits were in good condition and complete. Land crabs took baits from 30% of stations. One house mouse (*Mus musculus*) was recorded gnawing the bait by the remote camera but posterior examination of the bait showed that pellet was intact. A Socorro blue lizard was recorded approaching a bait, tasted it, and departed the station. Feral cats were recorded on 3 occasions: one inspected a station where baits were already removed, while the other two sniffed

the bait and moved along. Birds were not recorded approaching baits.

Cerralvo Island. Total active station-nights were 47. Baits were totally consumed or removed in 28% of the stations and partially consumed in 19%. Partial consumption was done by insects and hermit crabs (*Coenobita compressus*), but in all cases pellets were intact. Only 1 cat was recorded consuming the bait; in that station, there were no signs of the bait or the pellet. Common ravens (*Corvus corax*) removed baits from 10 stations. One camera recorded a raven tearing the bait, but the pellet was found at the station undamaged; the other 9 baits (and pellets) were not found. At one station an endemic mouse, *C. a. siccus*, inspected a bait, smelled it, and went away. No reptiles or any other birds were recorded approaching the stations.

Cage Trials with Target Species

Socorro Island. Of 6 cats held in captivity, 3 consumed both baits, but one cat only swallowed 1 of 2 pellets. The other 3 did not consume any baits, and one of the cats died during the test (Table 1).

Cerralvo Island. One cat died before baits were offered. Total consumption was recorded for both trials (baits with and without pellet) with the 7 cats. One cat even licked and swallowed a pellet from the cage floor that had fallen apart from the bait (Table 1).

Cage Trials with Non-Target Species

Only 3 Socorro blue lizards were captured; none paid any attention to the bait. Three out of 4 land crabs consumed the bait but not the pellet.

Table 1. Morphological details and bait consumption by cats during cage trials.

| Cat ID | Sex (M/F) | Weight (kg) | BCS | Bait ingestion | Pellet ingestion | Notes |
|--------|-----------|-------------|-----|----------------|------------------|-------|
| So1 | M | 3.3 | 3 | 2/2 | 2/2 | e |
| So2 | M | 3.0 | 3 | 2/2 | 2/2 | e |
| So3 | M | 2.8 | 3 | 0/2 | - | e |
| So4 | M | 2.3 | 2 | 0/2 | - | e |
| So5 | M | 2.4 | 2 | 0/2 | - | d |
| So6 | F | 2.1 | 3 | 2/2 | 1/2 | e, a |
| Ce1 | F | 2.4 | 3 | 6/6 | 2/2 | e |
| Ce2 | M | 2.1 | 2 | - | - | d |
| Ce3 | M | 2.6 | 3 | 6/6 | 2/2 | e |
| Ce4 | F | 1.6 | 2 | 6/6 | 2/2 | e |
| Ce5 | M | 3.3 | 3 | 6/6 | 2/2 | e |
| Ce6 | F | 1.7 | 2 | 6/6 | 2/2 | e, b |
| Ce7 | M | 3.6 | 3 | 6/6 | 2/2 | e |
| Ce8 | F | 1.9 | 2 | 6/6 | 2/2 | e |

So = Socorro Island

Ce = Cerralvo Island

BCS = Body condition score (Kronfeld et al. 1994)

a = cat only ingested one of two pellets

b = cat licked pellet from cage floor

d = died

e = euthanized

DISCUSSION

Our results are the first for bait trials, field and cage, with specific target delivery system (HSDV) targeting feral cats in Mexico. Although target species' response during field trials on Socorro was not encouraging, the trials did provide important information concerning cat eradication planning. A lack of planning (inappropriate timing and faulty methods) is one of the primary causes responsible for cat eradication failure (Campbell et al. 2011). During the November trial, Socorro Island was very humid, and land crabs were present on most parts of the area where baits were laid. The experiment showed that land crabs represent an important competitor for feral cats regarding bait availability. Bait consumption by non-target species is a recurrent issue when targeting invasive species with toxins (Algar et al. 2007, Wegmann 2008). Although bait was attractive to land crabs, preliminary results showed that the use of pellets to reduce toxic intake could be effective against this species. Similar results were obtained with coconut crabs (*Birgus latro*) and hermit crabs (*Coenobita brevipennis*) with acetaminophen-mouse baits in a study conducted on Guam; crabs consumed the mouse tissue and avoided the acetaminophen tablets (Johnston et al. 2002). In the case of Cerralvo, being a desert island, it is probable that hermit crabs, found only at sandy beaches, will not cause serious interference with bait availability; the pellet would work as mitigation instrument.

Another subject to consider is that feral cats on Socorro were not food stressed, as cats trapped had an average body condition score (BCS) of 2.5 ($n = 18$, GEI unpubl. data, 2011). BCS was determined by an experience technician palpating subcutaneous fat and muscle along the cat's body; a score of 1 = cachectic, 2 = underweight, 3 = optimal, 4 = overweight, and 5 = obese (Kronfeld et al. 1994). It will be important to replicate a similar experiment in Socorro during late winter-early spring (i.e., the dry season) when land crabs could be found in low numbers and feral cats will probably be food stressed. This would allow the Socorro feral cat eradication program to be timed for a period of minimal prey availability combined with low crab abundance. Baseline information about feral cats and native species is necessary to properly implement eradication efforts. Regular cat surveys are essential to gather data while pre-eradication preparations take place (i.e., toxicant registration and fund-raising).

Birds on Socorro were not recorded interacting with the baits. This could be explained by feeding habits, since there are not scavenging birds on the island and because of this, it is possible that most of native bird species are out of risk of toxic ingestion (J. Martínez-Gómez, pers. commun.). Nevertheless, there are some birds of prey like the endemic Socorro red-tailed hawk (*Buteo jamaicensis socorrensis*) and for those further trials in different seasons are needed in order to discard risk to this species. In relation to reptile species on both islands, results on Socorro showed that the Socorro blue lizard does not appear to be interested in the bait presented. However, complementary trials are needed, given that this endemic species is listed as endangered and exhibits a decreasing population trend (IUCN 2011). Field trials on Cerralvo did not record any lizard or snake interacting with the bait. As on Socorro, further tests are needed to understand reptile response to

the bait. Murphy et al. (2011) suggest that reptiles, as a group, can be vulnerable to PAPP effects. The use of the pellet as target delivery system appears to reduce the possibility of ingestion by this particular group.

Cage trials results on Cerralvo with cats were encouraging, given the high consumption rate of baits and pellets, even though only one cat consumed the bait during field trials. The former might be explained by the low cat abundance on the island, from 525 trap-nights during 2 field trips in 2011, we obtained a 2.28% capture success (Ortiz-Alcaraz et al. 2012). Surveys indicate that the cat population's size and distribution is similar all over the island. Bait consumption results during cage trials on Cerralvo suggest that the bait tested could be a useful tool for targeting feral cats and obtain a high percentage knock-down rate. Complementary methods will be required to achieve cat eradication (Campbell et al. 2011).

Concerning bait consumption by common ravens, it will be necessary to conduct cage trials to assess pellet intake to support the data recorded on Cerralvo. It will be useful to replicate Avery et al. (2001); they offered acetaminophen-mouse baits to fish crows (*Corvus ossifragus*) to evaluate their response to treated baits. Their research showed that crows consumed the mouse tissue but avoided ingesting the tablet; a similar result was recorded on the field trials at Cerralvo. Before baits can be aerially dispersed, mitigation actions would need to be in place to prevent non-target species' consumption of toxic pellets.

Even though native rodents did not consume baits on Cerralvo, we can assume that in case of consumption, the pellet will not represent a risk for this group, given that rodents nibble their food, as showed on the trials at Socorro where the bait was gnawed by a house mouse but the pellet was intact. It is necessary to assure there would be no negative impacts, given that *C. a. siccus* and *P. e. avius* are considered threatened under the Mexican regulation (SEMARNAT 2010). Rodent abundance needs to be considered for both islands when implementing the cat eradication plan, given that rodents can compete for bait availability, as was noted by Luna-Mendoza et al. (2011) on Guadalupe Island.

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