

# MANAGEMENT OF INTRODUCED ANIMALS IN GALAPAGOS

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## SUMMARY

We review programmes to control or eradicate introduced vertebrates and invertebrates in Galapagos.

## RESUMEN

**El manejo de los animales introducidos en Galápagos.** Revisamos los programas de control y erradicación de vertebrados e invertebrados en Galápagos.

## INTRODUCTION

The arrival of humans in the Galapagos Islands, since their discovery in 1535, brought a series of negative impacts and, in some cases, irreversible damage, such as the extinction of endemic plants and rodents on several islands. A major cause of these impacts was the deliberate or unintentional introduction of non-native organisms. There have been substantial efforts to eradicate introduced species on the islands over the last 20 years and, in other cases when it has not been possible to eradicate a species, control activities have at least reversed negative impacts.

## INTRODUCED VERTEBRATES

As of 2007, 36 introduced vertebrate species had been recorded in Galapagos, of which 30 had become established; the other six were detected and eliminated on arrival (Jiménez-Uzcátegui *et al.* 2008). Some were brought as food for the human population and do not threaten the island ecosystem, while others were brought unintentionally, or as pets or domesticated animals that escaped to form wild populations (Jiménez-Uzcátegui *et al.* 2008). At present, efforts of the Galapagos National Park and Charles Darwin Foundation are focused on control and eradication programmes for feral Goat *Capra hircus*, Pig *Sus scrofa*, Donkey *Equus asinus*, Cat *Felis catus*, Black Rat *Rattus rattus*, Brown Rat *R. norvegicus* and House Mouse *Mus musculus*, and on promoting the recovery of native ecosystems and of endemic species affected by these introduced animals.

### Eradication of feral Goat

Many goat eradications have been carried out successfully in Galapagos (Table 1, see Campbell *et al.* 2004, Campbell & Donlan 2005). Since 2004, goat eradication projects on Santiago, Isabela and Floreana islands have used three phases: an aerial hunting phase using a helicopter, especially when there is a large number of goats; a land hunting phase using groups of hunters aided by specially

trained dogs; a monitoring phase using radio tagged "Judas goats" that associate with remaining feral animals, after the goat population has been significantly reduced by aerial and land hunting. Goat eradication projects on Isabela and Santiago islands reached the monitoring stage in 2006. At the end of 2006, a goat (and donkey) eradication program was begun on Floreana, and was thought successful by 2008. Monitoring will continue in order to ensure successful eradication.

### Eradication of feral Pig

Pigs were eradicated from Santiago at the end of 2001, after almost 25 years of work. In the early 1990s, activities were intermittent, but an injection of donated funds in 1998 made possible an intensive campaign combining various techniques, including systematic dog-aided hunting and the use of anticoagulant poisons. From the 1970s to the end of the operation, *c.* 18,800 pigs were eliminated on the island (Cruz *et al.* 2005). On Sierra Negra and Cerro Azul volcanoes of Isabela Island and on Santa Cruz Island long-term pig control is being done to reduce predation on tortoise nests.

### Eradication of feral Donkey

Donkeys were eradicated from Santiago Island, where park wardens gradually eliminated them over several decades; the last 24 individuals were shot from a helicopter in 2004, during the Isabela Project (Carrión *et al.* 2007). Donkeys were eradicated from Alcedo Volcano, northern Isabela, where *c.* 1523 individuals were exterminated between 2004 and 2005, only 99 of them with helicopter support (Carrión *et al.* 2007). During the Isabela Project, *c.* 1102 were killed on southern Isabela, where it is estimated that about 200 live animals remained at the end of 2007. Floreana's total donkey population of 302 was eradicated at the beginning of 2007.

### Eradication of feral Cat

Cats were eradicated from Baltra Island in 2004. This was possible because the island is small (2.6 km<sup>2</sup>), has a small

**Table 1.** Galapagos islands from which feral Goat has been eradicated.

Island	Area (ha)	Ngoats eliminated	Year eradicated
Plazas Sur	13	5	1961
Santa Fe	2,413	3,005	1971
Rábida	508	14	1975
Española	6,089	3,344	1978
Marchena	12,996	484	1983 and 2002
Pinta	5,910	40,000	1999
Santiago	57,728	85,000*	2006
Isabela (north)	240,000	135,000*	2006
Baltra	2,537	35	2007
Floreana	17,229	1,320	2008
<b>Total</b>	<b>345,423</b>	<b>208,207</b>	

\*Includes animals killed before the Isabela Project started in 1998.

human population, low risk of reintroduction, mainly carries sparse open vegetation which facilitates control and monitoring, and has a road network that facilitated access. Behavioural studies revealed that the cats were active both during the day and at night (Phillips *et al.* 2005). Field personnel looked for tracks in the day and set traps (Tomahawk and Victor) where they were found. Nocturnal searching was also carried out using searchlights, and cats spotted were hunted with rifles. This methodology was successful in gradually reducing the cat population until it was completely eradicated, with *c.* 250 individuals eliminated. Monitoring from late 2003 to the present revealed no traces of live individuals, but monitoring will be continued annually to detect possible reintroductions.

Cat control continues at Punta Pitt on San Cristóbal and at Bahía Cartago and on the main southern beaches of Isabela. In 2006, cat control was begun on the west coast of Isabela to prevent predation on important marine bird colonies there, especially penguin breeding colonies.

#### Eradication of rats

Black Rat and House Mouse probably arrived to the Galapagos on ships at the end of the 18th century, and the Brown Rat in the 1980s. These species are currently spread over several islands and affect endemic species including iguanas, nesting tortoises and birds (Cruz & Cruz 1987a, 1987b). The long-term Black Rat control program began in 1982 in the nesting zones of Dark-rumped Petrel *Pterodroma phaeopygia* on Floreana and was later extended to Santa Cruz, San Cristóbal and Santiago islands. The petrel population on Floreana was soon on the path to recovery (Cruz & Cruz 1987a, 1987b).

A workshop was held in early 2007 in Galapagos, with the participation of international experts in rat management on oceanic islands. This resulted in the first draft of a long-term rat management plan for the archipelago. The first step was an eradication project on

North Seymour Island. After three applications of Klerat (anticoagulant in wax bait blocks) spread manually over the entire island using equidistant point distribution, monitoring suggests that rats have been eradicated.

#### Eradication of Rock Dove *Columba livia*

The Rock Dove was introduced to San Cristóbal, Floreana and Isabela Islands around 1972–3 (F. Cruz pers. comm.), and reported on Santa Cruz for the first time in 1983. These birds are carriers of at least 40 diseases that can affect humans, wild fauna and poultry, including *Tricomonas gallinae*, a disease that affects the endemic Galapagos Dove *Zenaida galapagoensis* (Santiago-Alarcón *et al.* 2006) and domestic poultry. While Rock Doves are themselves resistant to many of these diseases, they become points of infection for transmission to other birds.

After joint efforts by various local organizations, the Rock Dove was eradicated from the urban and rural areas of Santa Cruz in 2002, with 429 individuals eliminated in *c.* 18 months. The eradication operation on San Cristóbal began in 2002 at Puerto Baquerizo Moreno and in the agricultural zone and 816 pigeons were eliminated using the same methods as on Santa Cruz. In 2004, an eradication project was launched on Isabela in both urban and agricultural zones, and *c.* 400 individuals were eliminated on this island. Regular monitoring continues, to detect and prevent reintroduction of this species.

#### INTRODUCED INVERTEBRATES

According to the latest data (Causton & Sevilla 2008), 499 identified insect species and 53 other terrestrial invertebrates have been introduced into the Galapagos Islands. Many more remain to be identified and, despite the introduction of the Galapagos inspection and quarantine system, new species continue to arrive and escape detection at control points. The most aggressive of the identified invertebrate species include two fire ants and one scale insect (discussed below), with an additional 58 identified as actually or potentially damaging (Causton & Sevilla 2008).

#### Eradication of fire ants

An eradication programme for the Little Red Fire Ant *Wasmannia auropunctata* was begun in a 26-ha area on Marchena Island in 2000. The method involved first surveying the relative abundance and distribution of *Wasmannia* and other ants, using sausage, peanut butter, sweet biscuits and canned tuna fish as baits, along with pitfall traps and Berlese funnels. Then monitoring visits were undertaken, with AMDRO (commercially sold as Siege Pro) insecticide bait (hydramethylnon 0.73 g/kg) dispersed over the infested area at the end of each trip. In the last six monitoring visits, since 2002, no *Wasmannia* were found in and adjacent to the treated area, and native ant communities had stabilized (Causton *et al.* 2005). The methodology was thus proved effective and may be used

on other islands. However, during a recent goat monitoring trip to Marchena, ant traps were set in other places outside the treated area and *Wasmannia* was detected at two sites. We urgently need to delimit these infested areas and immediately proceed to eliminate the insects.

On southern Isabela, campaigns to control *Wasmannia* are currently being carried out in the tortoise nesting sites on Cinco Cerros and at the Sulphur Mine in the Sierra Negra crater.

The Black Fire Ant *Solenopsis geminata* was detected on Champion Islet in early 2007 and monitoring was begun to determine the extent of the infestation. Subsequent applications of Siege Pro bait seem to have been sufficient to eradicate this species, which is however common on some of the larger Galapagos islands.

#### Control of the Cottony Cushion Scale *Icerya purchasi*

*Icerya purchasi* has invaded some 80 countries, damaging more than 2000 plant species. It was reported for the first time in Galapagos in 1982, where it attacks at least 62 endemic and native plant species and some crops, especially citrus. Infestations were killing mangroves and many threatened endemic plants. Control of *Icerya* was the first scientific use of a biological control agent in Galapagos, with the first individuals of the Australian ladybird *Rodolia cardinalis* released in January 2002, simultaneously on Santa Cruz, San Cristóbal, southern Isabela and Floreana islands. Later, it was released on northern Isabela and uninhabited islands including Marchena, Pinta, Pinzón, Rábida, Genovesa, Santiago and Fernandina. Monitoring on Santa Cruz showed the ladybird's great ability to disperse, with insects found up to 40 km from release points, such as at Baltra, North Seymour and Eden islets. They were observed feeding on *Icerya* on a variety of plants and have brought it under control sufficiently to allow recovery of many severely damaged plant populations.

#### MANAGEMENT PRIORITIES AND STRATEGIES

There are two alternatives for managing invasive species that are already established in the Galapagos Islands. The preferred option, eradication, involves removing them completely from the islands where they are found, while the second, control and mitigation, involves reducing the damage they cause to levels that do not alter natural ecosystem processes and biological diversity significantly. Eradication is the preferred option, provided it is feasible, as it is more cost-effective in the long term than continuous control. It is increasingly viable because of developments in technology and expertise.

The choice between eradication and control is based on eradication feasibility assessment, and on scientific knowledge of the targeted and non-target species, of the impact of the methods used and of the impact of the introduced species. A fundamental tool to facilitate such decisions will be a prediction system currently under test, which takes into account factors such as the population dynamics and dispersal ability of the introduced species, its impact on the ecosystem, habitats or species, and the costs and resources required for management.

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