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Feral donkey (*Equus asinus*) eradications in the Galápagos

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Abstract. Introduced herbivores are major drivers of ecosystem change and biodiversity loss, particularly on islands. Tools and techniques now exist to routinely remove introduced herbivores from islands, providing a powerful conservation tool. Here, we summarize the few documented feral donkey removals on islands worldwide, and report on the removal of populations from the Galápagos archipelago, Ecuador. After decades of sporadic control programs on Santiago Island and Alcedo Volcano, Isabela Island, donkey populations were removed from both areas, concurrent with a goat eradication program. Both ground and aerial hunting programs were utilized. The latter method was highly efficient; donkeys were removed from Santiago Island with less than 80 h of aerial hunting. Given the clear impacts of introduced herbivores on islands worldwide, feral donkey populations should be routinely removed from islands.

Introduction

Extinction over the last six centuries has been largely dominated by insular species, with non-native mammals being responsible for the majority (Diamond 1989; Groombridge 1992; MacPhee and Flemming 1999). Introduced herbivores are particularly devastating to islands ecosystems. Goats (*Capra hircus*), European rabbits (*Oryctolagus cuniculus*), and donkeys (*Equus asinus*) have been introduced to countless islands worldwide, resulting in primary and secondary impacts via overgrazing, often leading to extinctions and habitat destruction (Coblentz 1978; Fowler 1983; Cruz and Cruz 1987; Schofield 1989; Moran 1996; Desender et al. 1999; Donlan et al. 2002).

In response to these biodiversity threats, techniques have been developed and improved over the past 30 years to remove introduced herbivores from islands (Daly 1989; Parkes 1990; Veitch and Clout 2002; Campbell and Donlan

2005). These techniques are powerful tools in preventing extinctions and restoring ecosystems. Unfortunately many eradications remain unpublished or inaccessible, which likely inhibits progress in island conservation and contributes to the low level of importance placed on the eradication of invasive species in many conservation circles (Simberloff 2001; Donlan et al. 2003b). This is particularly true for feral donkeys. While impact studies of feral goat and European rabbits on island ecosystems and successful eradications have been reported (Coblentz 1978; Parkes 1990; Chapuis et al. 2001; Bullock et al. 2002; Donlan et al. 2002, 2003a; Campbell et al. 2004; Chapuis et al. 2004; Campbell and Donlan 2005), primary literature on insular feral donkey populations is largely limited to behavioral observations and disease ecology (Smith and Latham 1978; Fowler de Neira and Johnson 1985; Rudman 1998). Here, we briefly summarize the few feral donkey impact studies and documented removals, and report on the successful large-scale eradication of feral donkey populations from Santiago Island and Alcedo Volcano on Isabela Island in the Galápagos archipelago.

Background

Donkeys were first recorded on the Galápagos archipelago in 1834 on Floreana Island, introduced from the coast of Ecuador (Coulter 1845). Oil seekers moved donkeys around the archipelago for transporting kegs of tortoise oil to ships and settlements (van Denburgh 1914). By 1875 large numbers of donkeys roamed Santiago, and in the 1880s donkeys were recorded as numerous on Isabela, San Cristobal, Floreana and Santa Cruz Islands (Cookson 1875; Baur 1891).

Santiago Island (58,465 ha), located in the center of the Galápagos archipelago, enjoys protected status and receives little visitation by scientists and tourists (Figure 1). Some 20 endemic birds and six reptiles are present on the island, including the giant Galápagos tortoise (*Geochelone nigra*). Land iguanas (*Conolophus subcristatus*) are extinct on Santiago; while Darwin recorded them abundant, only skeletal remains were found during a California Academy of Sciences expedition in 1905 (van Denburgh and Slevin 1913; Slevin 1935). The endemic rice rat, *Nesoryzomys swarthi*, which was considered extinct since 1906, was rediscovered in 1997 (Dowler et al. 2000). Introduced goats (*Capra hircus*), rats (*Rattus rattus*), house mice (*Mus musculus*), and smooth-billed anis (*Crotophaga ani*) are present. Feral pigs (*Sus scrofa*) were recently removed, and a goat removal campaign is in its final stages (Cruz et al. 2005).

Approximately 377 vascular plant species are present on Santiago Island, including six extant single-island endemics, 107 Galápagos endemics, 48 non-natives (A. Tye, personal communication). Goats and donkeys were the main threat to this plant diversity, including the Galápagos shrub snapdragon (*Galvezia leucantha porphyrantha*), *Scalesia atractyloides*, and *S. stewartii* – all of which are threatened (Tye 2000, 2003; Tye and Jäger 2000). Goats and

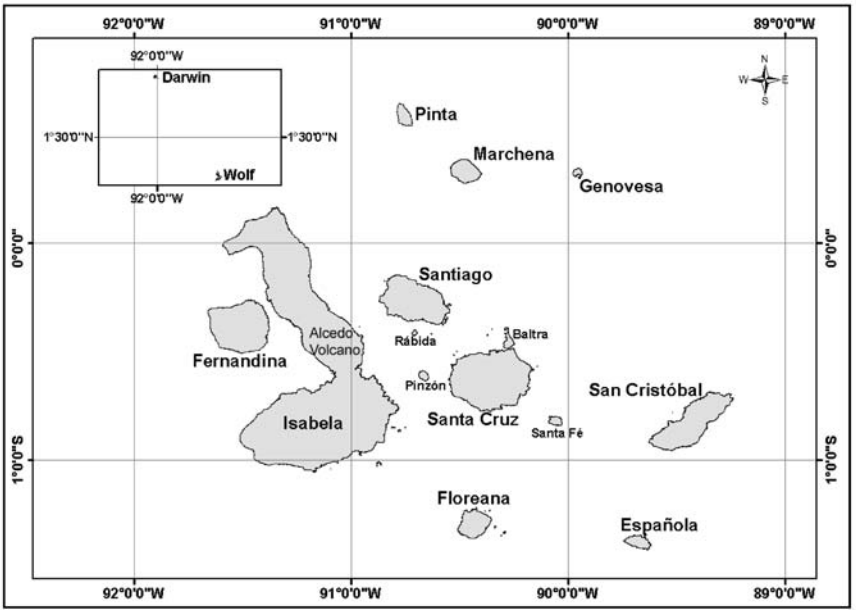

Figure 1. The Galápagos Archipelago.

donkeys may be responsible for the extinction of the Santiago endemic *Blutaparon rigidum*; last seen in 1906, this is one of only three Galápagos plants thought to be extinct (Tye 2003).

Alcedo Volcano (74,103 ha) is one of the six volcanoes of Isabela Island (458,812 ha), the largest and most diverse island in the Galápagos. Alcedo holds a significant population of tortoises (*G. n. vandenburghi*), while Santiago's population (*G. n. darwini*) is recovering from human depredation with the aid of captive breeding and repatriation programs (Fritts et al. 2000). Two species of native rats (*Nesoryzomys* sp.; *Megaoryzomys* sp.) were once present on Isabela Island, and are thought to be extinct (Steadman and Ray 1982; Steadman et al. 1991). Alcedo supports approximately 220 plant species (180 native), including the Isabela island endemic *Froelichia juncea juncea*, and a species of shrub restricted to Alcedo, *Hyptis gymnocaulos*, which has not been recorded for the last 20 years (A. Tye, personal communication). Introduced rats, house mice, and cats (*Felis catus*) are present, and goats are currently being removed from Alcedo and the rest of northern Isabela Island.

Throughout the archipelago, donkeys have impacts on Galápagos plant species, including endemic *Opuntia* species on Alcedo (*O. insularis*) and Santiago (*O. galapageia*) (van der Werff 1983; Hicks and Mauchamp 1995). Donkeys impact tortoise and land iguana populations by trampling nests, and perhaps through an overlap in diet (Fowler de Neira and Roe 1984; Hoeck 1984; Snell et al. 1984; Fowler de Neira and Johnson 1985). Feral donkey

populations still exist on Santa Cruz, Floreana and San Cristobal Islands, as well as Sierra Negra Volcano on southern Isabela Island. South of Alcedo, a lava isthmus (approximately 14 km by 5 km) appears to limit distributions of donkeys on Alcedo and Sierra Negra volcanoes.

Methods and results

On Santiago, donkeys were hunted opportunistically during pig (1970s–2001) and goat (2001–present) eradication campaigns (Cruz et al. 2005). On Alcedo, donkeys were hunted sporadically in the 1970s, while hunting ceased during the 1980s. Between 1991 and 2000, hunters targeting goats on Alcedo hunted donkeys opportunistically. Ground hunters used a variety of rifles on Santiago and Alcedo (pre-1995: 0.22, 0.222 and 0.243 calibers; 1995–2000: 0.22 magnum, 0.223 and 0.243 calibers). In 2004, aerial hunting operations began on Santiago and northern Isabela Islands with the goal of removing goats and donkeys. McDonnell & Douglas 500D/E model helicopters were used with pilots and shooters highly experienced in aerial hunting. Helicopter-based shooters used semi-automatic AR15 0.223 caliber rifles on Alcedo and 12 gauge pump-action shotguns with 00 magnum buck shot on Santiago, with the former outperforming the latter.

On Santiago, 339 donkeys were removed over three decades during different control/eradication campaigns (Table 1). Increased hunting effort during the pig eradication campaign during 1995–1996 resulted in larger numbers of donkeys being removed (Cruz et al. 2005). The last 25 animals were removed by aerial hunting concurrent with a goat eradication campaign, which involved an intensive effort. Donkeys were removed from Santiago within 80 h of aerial hunting; 334 h of aerial goat hunting and 1762 hunter days since serves as monitoring to confirm their eradication. On Alcedo, ground hunting between 1974 and 2000 under a donkey/goat control program removed 1424 donkeys (Table 1). An aerial hunting goat eradication campaign starting in 2004 removed the last 99 donkeys (Table 1). Donkey eradication on Alcedo was confirmed with 517 h of aerial hunting and 361 hunter days.

Discussion

Santiago Island and Alcedo Volcano are now free of donkeys for the first time in over 120 years. There is hope that Alcedo's endemic shrub, *Hyptis gymnocaulos*, will reappear after 20 years of not being recorded, saved by the seedbank as has been observed on other islands when introduced herbivores were removed (Campbell and Donlan 2005). Donkeys likely fed on this endemic, since they frequently fed on the non-native congener *Hyptis rhomboidea* (Fowler de Neira and Johnson 1985).

Table 1. Feral donkey removal from Santiago Island and Alcedo Volcano, Isabela Island from 1974 to 2005.

Year	Donkeys removed	Method	Concurrent program
Santiago			
1976–1978	76	Ground hunting	Non-native mammal control
1980s	3	Ground hunting	Non-native mammal control
1990s	153	Ground hunting	Pig eradication
2000–2003	83	Ground hunting	Pig monitoring/goat eradication
2004	25	Aerial hunting	Goat eradication
Total	340		
Alcedo			
1974–1975	200	Ground hunting	Non-native mammal control
1991–1999	1208	Ground hunting	Non-native mammal control
2000	16	Ground hunting	Non-native mammal control
2004	95	Aerial hunting	Goat eradication
2005	4	Aerial hunting	Goat eradication
Total	1523		

Feral donkeys have also been eradicated from at least five other islands, as well as large mainland areas in western Australia. A regional island conservation program in northwest Mexico, that includes non-native removal and environmental education, has removed free-roaming donkeys from four islands: San Benito West Island (350 ha), Coronado South (227 ha), Guadalupe (26,470 ha), and Todos Santos North (62 ha) (B. Keitt, personal communication; Donlan et al. 2000; Tershy et al. 2002). Feral donkeys were removed from San Miguel Island, California (3865 ha) in the mid 1970s by the U.S. National Park Service (K. Faulkner, personal communication). Large-scale feral donkey and horse control programs have been underway in western Australia since the 1970s; in the Northern Territory, feral horse and donkey populations are being controlled on a massive spatial scale with aerial hunting, notably funded by private landowners rather than the Australian government (Johnson 1999; Saafeld 2005). Contraceptive vaccines have been effective on donkeys, and may be a useful control technique; however, it is unlikely to result in eradication unless the population is intensively managed over a long period (Turner et al. 1996; Turner and Kirkpatrick 2002). Aerial hunting is highly efficient at removing donkeys in areas with open canopy; their size and behavioral traits, such as a lack of hiding behavior, make them particularly vulnerable. If donkeys were the primary target on Santiago Island, their removal and confirmation could have been conducted within 20 h of aerial hunting.

The donkey removals on Santiago and Isabela islands are part of a massive unprecedented island conservation program. Pigs have been successfully removed from Santiago, the largest island from which they have been removed (Cruz et al. 2005). In addition to feral donkey removal, goats are currently being removed from both Santiago and Isabela. If successful, Isabela will

become the largest island where goats have been removed by over an order of magnitude while doubling the total area of restored island habitat via feral goat removal to over 1 million hectares (Campbell and Donlan 2005). In the past decade great strides have been made worldwide toward preventing extinctions on islands with the removal of introduced mammals (Veitch and Clout 2002; Donlan et al. 2003b). Given non-native herbivores, including feral donkeys, are major drivers of ecosystem change and degradation, they should be routinely eradicated from islands.

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