

# Feral Goat Eradications on Islands

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**Abstract:** *Introduced mammals are major drivers of extinction. Feral goats (*Capra hircus*) are particularly devastating to island ecosystems, causing direct and indirect impacts through overgrazing, which often results in ecosystem degradation and biodiversity loss. Removing goat populations from islands is a powerful conservation tool to prevent extinctions and restore ecosystems. Goats have been eradicated successfully from 120 islands worldwide. With newly developed technology and techniques, island size is perhaps no longer a limiting factor in the successful removal of introduced goat populations. Furthermore, the use of global positioning systems, geographic information systems, aerial hunting by helicopter, specialized hunting dogs, and Judas goats has dramatically increased efficiency and significantly reduced the duration of eradication campaigns. Intensive monitoring programs are also critical for successful eradications. Because of the presence of humans with domestic goat populations on large islands, future island conservation actions will require eradication programs that involve local island inhabitants in a collaborative approach with biologists, sociologists, and educators. Given the clear biodiversity benefits, introduced goat populations should be routinely removed from islands.*

**Key Words:** *Capra hircus*, conservation action, eradication techniques, introduced species, invasive species, island restoration, nonnative species

Erradicaciones de Cabras Ferales en Islas

**Resumen:** *Los mamíferos introducidos son los principales causantes de extinción. Las cabras ferales (*Capra hircus*) son particularmente devastadoras de ecosistemas insulares, provocando impactos directos e indirectos por sobrepastoreo, que a menudo resulta en la degradación del ecosistema y la pérdida de biodiversidad. La remoción de poblaciones de cabras de las islas es una poderosa herramienta de conservación para prevenir de extinciones y restaurar ecosistemas. Se han erradicado cabras exitosamente de 120 islas a nivel mundial. Con tecnología y técnicas desarrolladas recientemente, el tamaño de la isla ya no es un factor limitante en la remoción exitosa de poblaciones introducidas de cabras. Más aun, el uso de sistemas de posicionamiento global, sistemas de información geográfica, cacería aérea desde helicóptero, perros de caza especializados y cabras Judas han incrementado la eficiencia dramáticamente y reducido la duración de las campañas de erradicación significativamente. Los programas de monitoreo intensivo también son críticos para las eradicaciones exitosas. Debido a la presencia de humanos con poblaciones de cabras domésticas en las islas grandes, las acciones de conservación en el futuro requerirán de programas de erradicación que involucren a los habitantes locales en un esfuerzo cooperativo con biólogos, sociólogos y educadores. Dados los claros beneficios para la biodiversidad, las poblaciones de cabras introducidas deberán ser removidas de las islas rutinariamente.*

**Palabras Clave:** *Capra hircus*, especies invasoras, especies introducidas, especies no nativas, restauración de islas, técnicas de erradicación

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## Introduction

Extinction over the past six centuries has been largely dominated by insular species, with non-native mammals being responsible for the majority (Diamond 1989; Groombridge et al. 1992; MacPhee & Flemming 1999). Island vertebrates and plants are vulnerable to the impacts of rats (*Rattus* spp.), feral cats (*Felis catus*), and introduced herbivores (Elton 1958; King 1985; Ebenhard 1988; Atkinson 1989; Donlan et al. 2002; Nogales et al. 2004). Feral goats (*Capra hircus*) are particularly destructive to island ecosystems. The introduction of goats to islands worldwide has resulted in widespread primary and secondary impacts via overgrazing, often leading to ecosystem degradation and biodiversity loss (Coblentz 1978; Schofield 1989; Moran 1996; Desender et al. 1999).

In response to these biodiversity threats, techniques have been developed and improved over the past 30 years to remove introduced goat populations from islands (Daly 1989; Parkes 1990a; Veitch & Clout 2002). These techniques are powerful tools for preventing extinctions and restoring ecosystems. Unfortunately many insular goat eradications remain unpublished or inaccessible, creating the perception that eradications are rare. This most 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).

We reviewed feral goat eradication campaigns on islands with the primary intent of assessing the approaches, successes, and challenges of these conservation actions to help facilitate future island conservation programs. Data cover most of the world's insular regions and were compiled using published and gray literature and personal communications with researchers and conservation practitioners. We analyzed key aspects of these eradication campaigns to identify future directions and challenges of island conservation.

## History and Impact of Goat Introductions

Goats were domesticated 10,000 years ago in the highlands of western Iran (Zeder & Hesse 2000). Physiological traits such as a low metabolism, an efficient digestion system, and low water requirements allow goats to persist in conditions unsuitable for many other herbivores (Silanikove 2000). These traits, along with a high reproductive rate and general diet, allow domestic goats to thrive on islands as feral populations (Parkes 1993). Goats have become established on countless islands worldwide, generally having been introduced by humans to serve as a food resource.

The earliest recorded goat introduction occurred shortly after 1458 on Selvagem Grande Island in the Madieras (Zino & Biscoito 1994); medieval (approximately AD

1000–1300) introductions, however, are believed to have occurred on Holy and Lundy islands in Britain (Munton 1975). During European exploration and colonization before and throughout the eighteenth and nineteenth centuries, goats were introduced onto many islands by sailors on long sea voyages. Saint Helena Island, the Juan Fernandez Islands, and Hawaii are but a few well-known examples. Intentional introductions are now relatively rare, although they sometimes still occur on islands used by fishers (e.g., San Benitos, Mexico; Pinta and Marchena Islands, Galápagos).

In most cases, biotas of oceanic islands have evolved in the absence of large herbivores. Although equivocal, some evidence suggests that island floras lack adaptations to mammalian herbivory (Carlquist 1974; Bowen & Van Vuren 1997). Nonetheless, it is clear that introduced goats are responsible for wholesale impacts on island floras, including altering the structure and composition of plant communities, causing extinction, and accelerating soil erosion (Spatz & Mueller-Dombois 1973; Coblentz 1978; Parkes 1984; Brennan 1986; Coblentz & Van Vuren 1987; Cronk 1989; Walker 1991; Moran 1996; Desender et al. 1999). Goats remain a serious threat today. The World Conservation Union (IUCN) identified goats as the primary threat to 26% of threatened insular plant species (Lucas & Syngé 1978). Further, more recent data indicate that 31% of extinct plant species and 18% of threatened plant species are from island nations (analysis by authors with data from Walter & Gillett 1998, IUCN classification). Secondary impacts are commonplace, such as habitat degradation via overgrazing leading to extirpation of native fauna (Gibbons 1984; King 1985; Desender et al. 1999). Goats are sometimes the exclusive cause of island extinctions (Moran 1996); in other cases they are a contributing factor along with other anthropogenic forces (Maunder et al. 1995; Shimizu 1995; Tye 2000). Biodiversity and ecosystem impacts from introduced goats have been discussed in detail elsewhere (Coblentz 1978; Ebenhard 1988; Courchamp et al. 2003).

Island recovery after the removal of goat populations is often swift and dramatic, even with long-standing goat populations. On Pinta and Santiago islands (Galápagos), native vegetation recovered rapidly despite it having been heavily affected by goats over many decades (Hamann 1979, 1993; A. Tye, personal communication). Seedbanks or small populations inaccessible to goats appear capable of preventing insular plant extinctions, and insular plant species often recover demographically once goats have been eradicated (Mueller-Dombois & Spatz 1975; Shimizu 1995).

## Island Goat Eradications

Goats have been eradicated from at least 120 islands (Fig. 1; Appendix 1). Areas of islands from which goats have

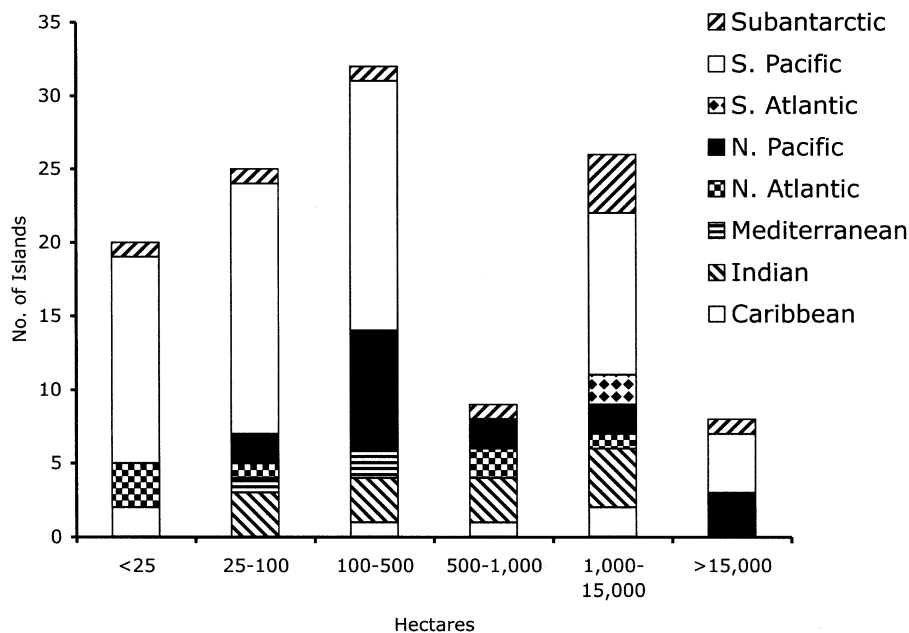


Figure 1. Size and location of islands (ocean basin) where introduced goat populations have been eradicated.

been eradicated range from 1 to 132,867 ha (Fig. 1). On the majority of larger islands (>20,000 ha), small numbers of goats have been removed from distinct areas. For example, on Flinders Island, Australia (132,867 ha), only 30 goats were present when they were removed in 1994. Similar situations occurred on Auckland Island (45,975 ha), New Zealand, and King (110,075 ha) and Bruny (36,735 ha) islands, Australia (<150 goats were removed [Appendix 1]). In terms of island size and number of goats removed (Appendix 1), the four largest goat eradication attempts completed to date are from the islands of Lana'i

(Hawaii, 36,100 ha), San Clemente (United States 14,800 ha), Pinta (Galápagos 5,940 ha), and Raoul (New Zealand, 2,943 ha). A number of unsuccessful eradications have also been documented (Table 1). These campaigns failed primarily because of a lack of political support, inappropriate methods, lack of effort, or the failure to detect the final goats at low densities.

Invasive mammals can be eradicated by trapping, hunting, poisoning, biocontrol, or some combination of these (Veitch & Clout 2002). The most common method used in goat eradication campaigns is hunting, although

Table 1. Unsuccessful goat eradication attempts on islands.

Island	Country <sup>a</sup>	Area (ha)	Introduction year	Eradication attempt	Reason failed	Ref <sup>b</sup>
Great Barrier	NZ	28,510		1986-1989	denied access to private land	1
St. Helena	UK	12,100	~1513	1950s-1970s	failure to remove final goats at low densities	2
Grande Terre (Aldabra)	SEY	11,000	<1906	1997	eradication halted due to politics	3
Pinta (Galápagos)	ECU	5,940	1959	1985, 1990	failure to detect/remove final goats at low densities <sup>c</sup>	4
Másatierra (Juan Fernández)	Chile	4,711	1574	1686, 1996	inappropriate method and lack of effort	5
South Percy	AUS	1,280	1880s	1981-2003	lack of effort	6
Lord Howe	AUS	1,455		1970s, 1999	lack of support from local inhabitants; insufficient funds	7
Aguigan	NMI-USA	715		1990	political, change in governance	8
La Plata	ECU	575		1991	lack of political support	9
Holy (Arran)	UK	250	~1000	1963	inappropriate method	10

<sup>a</sup>Abbreviations: NZ, New Zealand; SEY, Seychelles; ECU, Ecuador; AUS, Australia; NMI-USA, Northern Mariana Islands, United States of America; ECU, Ecuador; UK, United Kingdom.

<sup>b</sup>References: 1, Parkes 1990a; 2, Maunder et al. 1995, Melville 1979, Holdgate and Wace 1961, R. Cairns-Wicks, personal communication; 3, Rainbolt & Coblenz 1999, B. Coblenz, personal communication; 4, Campbell et al. 2004; 5, Wester 1991; 6, Brennan 1986, A. Griffiths, personal communication; 7, Recher and Clarke 1974, Parkes et al. 2002, N. MacDonal, personal communication; 8, Rice 1991; 9, F. Cruz, personal communication; 10, Munton 1975.

<sup>c</sup>Goats eradicated from island in 1999.

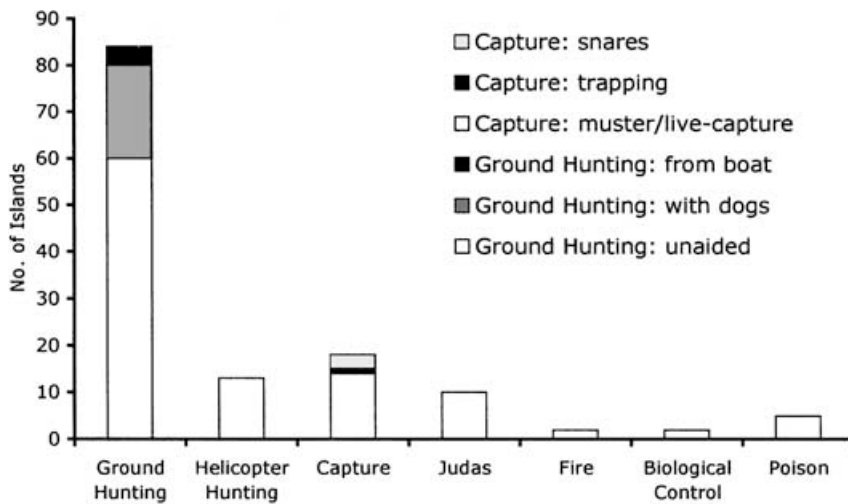


Figure 2. Methods used in eradication of introduced goats from islands. For many of the 120 documented goat removals the methods were not recorded.

poisoning, trapping, biocontrol (releasing dogs or dingos [*Canis lupus dingo*]), and habitat alteration via fire have also been used (Fig. 2, Appendix 1). Hunting includes the use of hunting dogs, Judas goats (described below), and shooting from a helicopter. Live removal has been conducted on nine islands. Usually, only one method has been used in eradication attempts (mean number of methods used  $\pm$  SD:  $1.5 \pm 0.9$ ,  $n = 69$ ) and the majority of campaigns have not used specialized hunting techniques. Although often not critical for successful eradication on smaller islands, multiple methods—some implemented simultaneously, others sequentially—and specialized eradication methods are requisites for success on larger islands with large populations (Cruz et al. 2005). Workers involved in recent campaigns on larger islands (e.g., Isabela and Santiago islands, Galápagos) have improved and developed specialized eradication techniques, including (1) aerial hunting by helicopter, (2) use of specially trained hunting dogs, (3) the integration of GPS (global positioning system) and GIS (geographic information system) technology with eradication methods, and (4) Judas goat techniques (Taylor & Katahira 1988; Isabela Project 1997; Prohunt New Zealand 1997; Campbell 2002; Campbell et al. 2004; Cruz et al. 2005). These techniques rely heavily on technology and highly skilled staff and allow for goat eradications on larger islands within a shorter time period and with increased cost-effectiveness (Caley & Ottley 1995; Campbell et al. 2004).

Hunting dogs and helicopters were exploited in 20 and 13 eradication campaigns, respectively. The use of specially trained goat-hunting dogs increases the ability to detect and kill goats at low densities and in areas of heavy vegetation (Caley & Ottley 1995; Isabela Project 2001). Aversion training eliminates impacts on native fauna from hunting dogs (Tortora 1982; Prohunt New Zealand 1997; Isabela Project 2001). Although it is expensive and requires specialist personnel, aerial hunting is highly effective when removing goats at high densities where open

canopy exists and appears critical for eradications on larger islands with established populations.

A common reason for unsuccessful eradication attempts is the failure to remove the final animals at low densities, because of either the inability to detect them or the selection of inappropriate hunting methods (Table 1). By exploiting the gregarious nature of goats, the Judas goat method is a vital tool for detecting goats at low densities and a monitoring tool to confirm eradication (Taylor & Katahira 1988; Campbell et al. 2004). Radiotelemetry collars are fitted to select goats, which are released and allowed to seek out other goats. Judas goats are then radio tracked, either on foot or by helicopter, and accompanying goats are shot. Judas goats are then allowed to escape to seek out other goats and are then rechecked at a later date. This approach allows the last individuals to be removed (Rainbolt & Coblenz 1999).

Judas goats have been used successfully in a number of eradications: San Clemente and Santa Catalina islands (California, U.S.A.); Kaho'olawe Island (Hawaii, U.S.A.), Ile Malabar and Ile Picard (Republic of Seychelles), Woody Island (Australia), and Pinta Island (Galápagos, Ecuador; Allen 1991; Kaho'olawe Island Conveyance Commission 1993; Keegan et al. 1994; Rainbolt & Coblenz 1999; Schuyler et al. 2002; Campbell et al. 2004). On San Clemente Island, where more than 29,000 goats were removed, trapping and helicopter shooting in combination failed to remove the remnant population. The use of Judas goats finally removed the last 263 individuals (Keegan et al. 1994). Recently developed methods involve hormone therapy and sterilization techniques that should improve the efficacy of Judas goats (Campbell 2002). The use of Judas goats should be standard in most goat eradication campaigns to detect the last individuals and as a cost-effective monitoring tool to confirm eradication.

Of the 120 successful goat eradications, 60% (72) were published, 14% (17) are in the gray literature (unpublished reports), and 26% (31) remain unpublished. Although

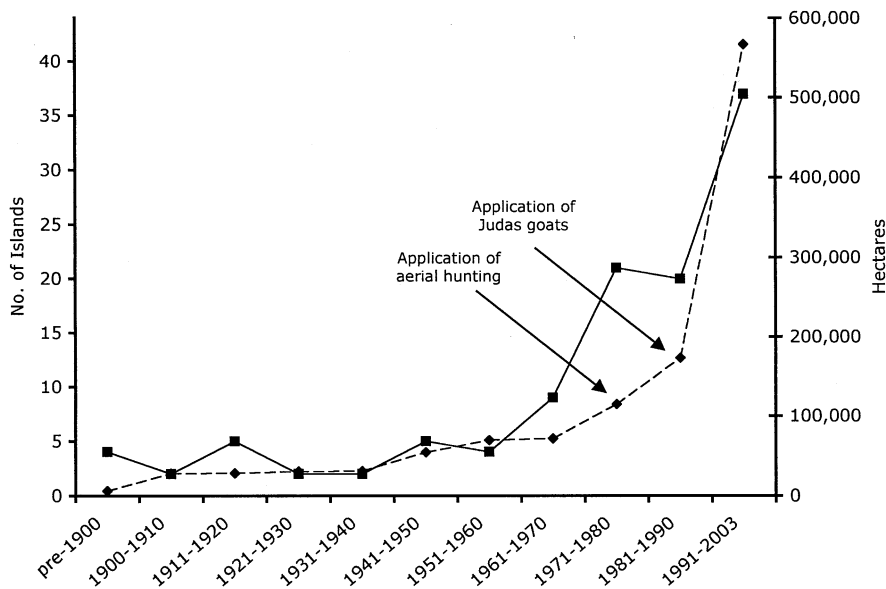


Figure 3. Frequency of successful introduced goat eradications throughout the twentieth century. Solid line shows the number of islands and dashed line shows the cumulative area of islands where goats were removed.

it is encouraging that more than half of known goat eradications are published, 84% of both published and gray literature papers lack sufficient detail to assess the eradication (e.g., methods, timing, or number of goats removed). Thus they are of little use in future island conservation efforts. Data on costs of eradication programs are completely absent. Incorporating economics into unpublished reports and publications would prove useful. Publishing detailed accounts of both successful and failed goat eradication attempts will help facilitate future efforts (Simberloff 2001; Donlan et al. 2003b).

Approximately 70% of all known goat eradications took place between 1960 and 2003, with the number doubling in the past two decades (Fig. 3). Worldwide, insular goat populations have been eradicated from approximately 567,000 ha (Fig. 3). Because of the relative ease with which goats can be eradicated with recently developed techniques and the clear conservation benefits of eradications, we expect the number of successful eradications to continue to increase in the coming decades.

## Challenges and Recommendations

The successful eradication of introduced mammals from islands is no longer a rare event. This is true not only for goats but also for other introduced species such as cats and rats (Townes & Broome 2003; Nogales et al. 2004). Highly skilled specialists and special equipment should be involved in larger or more complex eradications to provide cost efficiency, whereas smaller eradications can be undertaken effectively without specialized personnel and equipment. Goats can be easily removed from most islands of < 500 ha. Large islands, which generally house

more biodiversity, are as feasible but require detailed planning and the use of technology (GPS and GIS systems) and multiple techniques (e.g., aerial hunting, hunting dogs, Judas goats).

Recent island conservation actions demonstrate the feasibility of removing large, established goat populations from large islands. More than 10,000 goats were removed from Raoul Island, New Zealand (2,943 ha, Parkes 1990a). On San Clemente Island, United States (14,800 ha), approximately 29,000 goats were removed (Keegan et al. 1994). With both of these campaigns, multiple techniques were used, including ground hunting, aerial hunting, specialty hunting dogs, and Judas goats. Although each eradication campaign will have unique circumstances, these techniques make up the tool chest of any goat eradication campaign on large islands because they allow for successful removals in years rather than decades. For example, on Pinta Island, Galápagos (5,940 ha), it took 30 years to remove 41,000 goats. This was due to lack of continuous effort and limited eradication techniques (Campbell et al. 2004). In contrast, ground hunters removed over 66,000 goats from Santiago Island, Galápagos (58,465 ha), in < 3 years (K.C. and C.J.D., unpublished data) because they were aided by extensive planning, integration of GPS and GIS technology, and multiple eradication techniques (i.e., mustering, ground hunting, hunting dogs). Santiago Island should be free of goats by 2006 (a 5-year campaign). With the application of these new techniques and careful planning, funding rather than island size is now the limiting factor in island goat eradications.

Appropriate methods and their cost-effectiveness will vary with animal density, wariness to certain methods, vegetation, and topography (Rainbolt & Coblentz 1999). In an effort to avoid educating animals, a systematic approach is needed in which each method (or combination

of methods) employed removes nearly 100% of the animals that are encountered. Goats rapidly become wary of each method (e.g., finding refuge in caves during aerial shooting), and the use of multiple methods applied sequentially and simultaneously puts educated animals at risk. Switching methods should be based on cost per kill, animal wariness, and timing. For example, it may initially cost more per goat to use helicopter hunting than ground hunting; the use of multiple techniques, however, is likely to significantly shorten the time to eradication.

Once a limiting factor, the problem of failing to detect remnant goats has been solved with Judas goat techniques (Taylor & Katahira 1988). These techniques can be scaled to large islands. On Pinta Island, Galapagos (5,940 ha), 28 Judas goats were used and on Isabela Island, Galapagos (458,812 ha), 600 goats will be deployed (Rainbolt & Coblenz 1999; Campbell 2002; Campbell et al. 2004). Where there is a risk of goat reintroduction (e.g., Galápagos; Appendix 1), a long-term Judas goat program allows for detection and removal of reintroduced goats. The threat of reintroductions highlights the need for a long-term conservation perspective with eradication campaigns and the integration of locally based environmental education programs (Donlan & Keitt 1999; Ter-shy et al. 2002). Of the islands reviewed, only three goat eradication campaigns mention a community outreach or environmental education component.

Judas goat programs could potentially be used on large continental areas. With helicopter-based hunting, introduced herbivores have been removed from large areas in New Zealand (Nugent et al. 2001a, 2001b). Nonetheless, preventing immigration from some distant source (e.g., farms) is considered a requisite for eradication to be a solid management strategy (Parkes 1990b; Bomford & O'Brien 1992). Extensive, long-term Judas goat programs may be a feasible and cost-effective approach to manage immigration and reintroductions. Although large mainland areas may never be completely free of goats, a single intensive hunting effort followed by a long-term Judas goat program could eradicate goats from an ecological perspective.

Goat eradications should be undertaken with an ecosystem perspective because this facilitates additional introduced mammal eradications, if needed, and prevents unexpected changes to other ecosystem components (Zavaleta et al. 2001). Goat removal can have a dramatic effect on vegetation; thus, recovery of vegetation can interfere with completing the goat eradication itself and the eradication of other introduced species. Therefore, to maximize the efficiency of eradications campaigns, goats should be removed as swiftly as possible (Parkes 1990a) and, in many cases, goats should be eradicated after other introduced species. For example, feral pigs (*Sus scrofa*) were removed from Santiago Island, Galápagos, before goats. Simultaneous campaigns, or the reverse or-

der, would have drastically increased the costs of the eradications (Cruz et al. 2005).

Conservation practitioners should take plant and herbivore interactions into account in goat eradication programs (Donlan et al. 2003a). Although benefits to native flora from introduced herbivore eradications have been documented widely (Hamann 1979, 1993; North et al. 1994; Donlan et al. 2002), increases in non-native plants because of herbivore release have also been recognized (Eckhardt 1972; Scowcroft & Conrad 1982; Laughrin et al. 1994; Kessler 2002). Vegetation monitoring and assessments before eradication, particularly on islands dominated by non-native plants, can help avoid unexpected negative consequences of introduced herbivore removal. For example, on Guadalupe Island, Mexico, goat exclosures were constructed to assess the non-native plant response from herbivore release before the eradication campaign. Integrating eradication campaigns with a holistic ecosystem restoration framework will help increase the efficiency of eradications and prevent potential adverse secondary effects of introduced mammal removals from islands (Zavaleta et al. 2001; Donlan et al. 2003a).

Removing introduced species from islands is one of our most powerful conservation tools. Thanks to improved technologies and techniques, removing feral goats from islands small and large is now feasible. One hundred twenty islands, totaling more than 567,000 ha, have been freed from introduced goats and their detrimental effects; more eradications are being planned or are under way. These include new precedents in island size and number of goats removed: Santiago and Isabela islands, Galápagos (58,465 and 458,812 ha), Guadalupe Island, Mexico (26,500 ha), and Great Barrier Island, New Zealand (28,510 ha) (B. Ter-shy, personal communication; J. Parkes personal communication). Research challenges revolve around detecting and removing goats at low densities, including improving existing techniques (e.g., Judas goats), applying existing technologies (e.g., FLIR, forward-looking infrared), and developing new technologies and techniques. Island size may no longer be a limiting factor in eradication success; rather, sociological factors and funding will prove important in future island conservation actions. Many large islands with goat populations are also inhabited by people who use goats for economic gain, subsistence, or recreation (e.g., Hawaiian and Australian islands). Designing successful eradication programs for multitenure islands will take collaborative approaches involving biologists, sociologists, educators, and local inhabitants—along with a strong political will. This challenge will require substantial financial backing but will ultimately result in tremendous conservation gains. Given the unequivocal evidence of biodiversity loss and ecosystem degradation caused by introduced goats, they should be routinely eradicated from islands.

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Appendix 1. Characteristics of islands where introduced goat populations have been eradicated.

Island (group)	Country <sup>a</sup>	Area (ha)	Introduction year	Eradicated year	No. goats removed	Eradication methods	Reference
Flinders (Tasmania) <sup>b</sup>	AUS	132,867		1994	~30	unknown	Howell & Atkinson 1994; G. Atkinson pers. comm.; I. Skira pers. comm.
King (Tasmania) <sup>b</sup>	AUS	110,075	<1860s	1997	120 (1996-1997)	unknown	G. Atkinson pers. comm.; I. Skira pers. comm.
Auckland <sup>c</sup>	NZL	45,975	1865	1992	105 (1992)	hunting, hunting w/dogs?, helicopter as support, poisoning	Chimera et al. 1995
Bruny (Tasmania) <sup>b</sup>	AUS	36,735		1996	32 (1995-1996)	unknown	G. Atkinson pers. comm.; I. Skira pers. comm.
Lana`i (Hawai`i)	USA	36,100	early 1800s	1981		hunting, hunting w/helicopter, helicopter as support	Hobby 1993; R. Bartlett pers. comm.
Santa Catalina (Channel)	USA	19,400	1827	2002	8500 (1990-2002)	hunting, hunting w/helicopter, Judas goats, live capture	Schuyler et al. 2002; P. Schuyler pers. comm.
Ni`ihau (Hawai`i)	USA	18,900	1778, 1779	1779, 1910 <sup>d</sup>		unknown	Tomich 1986; Beattie 1994; R. Bartlett pers. comm.
Saltspring (British Columbia)	CAN	18,600		1980		unknown	D. Shackleton pers. comm.
San Clemente (Channel)	USA	14,800	<1827	1993	29,266 (1972-1993)	hunting, hunting w/helicopter, Judas goats, trapping, live capture	Keegan et al. 1994
Marchena (Galápagos)	ECU	12,996	c.1967, 1999, 2002, 2003	1979 <sup>d</sup> , 2000, 2002, 2003	484	hunting, hunting w/dogs	Hoeck 1984; K.C. unpublished data
Macquarie (Tasmania)	AUS	12,785	1878, 1948	1957	~9000	unknown	Selkirk et al. 1990
Kaho`olawe (Hawai`i)	USA	11,600	1793	1990		hunting?, hunting w/helicopter?, Judas goats	Kaho`olawe Island Conveyance Commission 1993
Ascension	UK	9,700	<1700	1945		unknown	Ashmole et al. 1994
Tristan da Cunha (Tristan-Gough)	UK	9,500	<1790, 1942	1951	12 (1950-1951)	hunting	Holdgate & Wace 1961; Wace & Holdgate 1976; Daly & Goriup 1987
Townshend (Queensland)	AUS	7,000	c.1967	1997	2000-3000 (1993-1997)	hunting w/helicopter, biocontrol	Allen et al. 1998; L. Allen pers. comm.
Española (Galápagos)	ECU	6,048	<1905	1978	3344 (1968-1978)	hunting, hunting w/dogs, boat as support?	Hoeck 1984
Pinta (Galápagos)	ECU	5,940	c.1957	2000	41,682 (1971-1999)	hunting, hunting w/dogs, support, Judas goats	Campbell et al. 2004
Amsterdam	FRA	5,500	1823	1957		unknown	Clark & Dingswall 1985; Jouventin 1994
Isla de la Blanquilla	VEN	5,220	c.1500	?		unknown	http://www.sibv.org.ve/Aspectos._Comunes/Especies_exoticas/Especies_situacion.asp
Faure (Shark Bay) <sup>b</sup>	AUS	5,148	c.1900	1994		unknown	Parkes et al. 1996
Bernier (Shark Bay)	AUS	4,267	1899	1984	>690 (1962-1984)	hunting, hunting w/helicopter, mustering	Morris 1989
Norfolk <sup>b</sup>	AUS	3,450	>1774	1856		hunting	Daly & Goriup 1987; L. Rodgers pers. comm.
Grand Jason (Falklands)	UK	3,000	1870	?		unknown	Croxall et al. 1984; Armstrong 1994
Raoul (Kermadec)	NZL	2,943	<1836	1984	>10,000 (1956-1984)	hunting, hunting w/dogs, hunting w/helicopter, Judas goats, snares, poisoning, mustering	Parkes 1990a
Malabar (Seychelles)	ROS	2,640	<1967	1994	80 (1987-1994)	hunting, Judas goats	Rainbolt & Coblentz 1999
Woody (Queensland)	AUS	2,600	1880	1991	340 (1987-1991)	hunting w/dogs, Judas goats, mustering	Allen 1991

continued

Appendix 1. (continued)

Island (group)	Country <sup>a</sup>	Area (ha)	Introduction year	Eradicated year	No. goats removed	Eradication methods	Reference
Koolan (Western Australia)	AUS	2,580	1920s-30s	1993		unknown	M. Everett pers. comm.
Selvagem Grande (Salvagens)	POR	2,500		1900		unknown	Zino & Biscoito 1994
Santa Fé (Galápagos)	ECU	2,413	<1905, >1972	1972 <sup>d</sup> , 1974	3003 (1964-1972)	hunting, hunting w/dogs	Hoeck 1984
Kapiti <sup>e</sup>	NZL	1,970	c.1830	1928		hunting, hunting w/dogs?	Veitch & Bell 1990
Inaccessible (Tristan-Gough)	UK	1,800	1820s	1872		hunting	Wace & Holdgate 1976
Flinders (Queensland)	AUS	1,480		1990		unknown	K. McDonald pers. comm.
Sunday (Victoria)	AUS	1,034	1928	1950		biocontrol	Abbott & Burbidge 1995
Wedge (Gambier)	AUS	947	<1914	1963	~2000	hunting	Robinson et al. 1996; R. Henzell pers. comm.
Picard (Seychelles)	ROS	930	<1878	1994	21	hunting, Judas goats	Rainbolt & Coblenz 1999
Shackleford Banks (Outer Banks)	USA	923	c.1800	1998	~150	unknown	M. Rikard pers. comm.
Koufonisi (Lefki) (Crete)	GRE	900		1976		unknown	http://www.crete-today.com/s-koufonisi.htm
Natividad (Baja California)	MEX	720		1999		live-capture	Tershy et al. 2002
Sainte-Paul	FRA	700	1800s	1874		unknown	Holdgate & Wace 1961; Clark & Dingwall 1985
Klein Bonaire	NA	690	c.1868	1990	<1834	hunting, live-capture, biocontrol	G. van Hoorn pers. comm. (from E. Domacasse and B. Bowker)
Lindeman (Whitsunday)	AUS	610		1993		hunting, hunting w/dogs, helicopter as support	K. McDonald pers. comm.; A. Griffiths pers. comm.
Sidney (British Columbia)	CAN	570		?		unknown	D. Shackleton pers. comm.
Sarigan	NMI-USA	500	c.1900, 1999	1999	908 (1998-1999)	hunting, hunting w/dogs, hunting w/helicopter, fire, boat as support	Kessler 2002
Rábida (Galápagos)	ECU	499	c.1971 & >1971	1971, 1977 <sup>d</sup>	4 (1971), 10 (1975, 1977)	hunting	Hoeck 1984
North Keppel (Keppel)	AUS	436	1880s	1975	>800	hunting	Brennan 1986; D. Crossman pers. comm.
Brampton (Whitsunday)	AUS	433	1920's	1985	~1000 (1962-1985)	hunting	Rees 1981; Brennan 1986
Wild Duck (Northumberland)	AUS	416		1985		unknown	C. Maple pers. comm.
Jarvis (Line)	USA	414		1935		unknown	Rauzon 1985
Great (Three Kings)	NZL	408	1889	1946	393 (1946)	hunting, hunting w/dogs	Turbott 1948
South Molle (Whitsunday)	AUS	380		1990		hunting, helicopter as support, boat as support, fire	K. McDonald pers. comm.; A. Jacobson pers. comm.; Abbott & Burbidge 1995
San Benitos West (Baja California)	MEX	350	1989	1998	7 (1998)	hunting	Tershy et al. 2002
Macaulay (Kermadec)	NZL	324	<1836	1970	3200	hunting	Williams & Rudge 1969; Merlin & Juvik 1992
Hayman (Whitsunday)	AUS	321		2001		hunting	K. McDonald pers. comm. (from B. Nolan); A. Griffiths pers. comm.
Sloping (Tasmania)	AUS	312		1997	6 (1997)	unknown	G. Atkinson pers. comm.; I. Skira pers. comm.
Guana (Virgin)	UK	297	1990	1991	2 (1991)	hunting w/boat	F. Kraus pers. comm.
Dragonera (Balearic)	SPA	280		1975		unknown	M. Pascal pers. comm. (Mayol pers. comm. in data collected by Lorvelec and Pascal)
San Francisco (Gulf of California)	MEX	261		1999		hunting	Tershy et al. 2002
Mukojima (Mukojima-retto)	JAP	257	1945	2002		unknown	Shimizu 2003
Philip	AUS	250	~1795	1870		unknown	Coyne 1981
Nukuwaiata (Chetwodes)	NZL	242		?		unknown	Atkinson & Taylor 1991

continued

## Appendix 1. (continued)

Island (group)	Country <sup>a</sup>	Area (ha)	Introduction year	Eradicated year	No. goats removed	Eradication methods	Reference
Santa Clara (Juan Fernández)	CHI	223	1574	2000		hunting	CONAF Rangers pers. comm.
North Mollie (Whitsunday)	AUS	219		1990		hunting, helicopter as support, boat as support	K. McDonald pers. comm.; A. Jacobson pers. comm.
Rangitira (Chatham Islands) <sup>e</sup>	NZL	219	<1900	1916		unknown	J. Parkes pers. comm.
North East (Percy)	AUS	217	late 1880s	1995		hunting, helicopter as support, boat as support	R. Henzell pers. comm.; A. Jacobson pers. comm.
Cuvier	NZL	181	1890s	1961	469 (1959-1961)	hunting, hunting w/dogs	Merton 1970
Atalandi (Atalanti)	GRE	180	1953	1979	350	unknown	Sfougari et al. 1996
Coronado South (Baja California)	MEX	180	<1950	1999		hunting	Tershy et al. 2002
Round	MAU	151	1844	1979	10	hunting	Bullock & North 1985; Merton et al. 1989;
Mokoia (Lake Rotorua)	NZL	143	1987	1989		hunting, hunting w/dogs	Parkes 1990a; Veitch & Bell 1990
Whale (Motuhora)	NZL	143	c.1890	1977	>1015	hunting	Parkes 1990a; Veitch & Bell 1990; J. Parkes pers. comm.
Nakoudojima (Mukojima-retto)	JAP	137	1945	1999	417 (1997-1999)	live capture	Shimuzu 2003
Klein Curaçao	NA	130	1915	1996	20	live capture	G. van Hoorn pers. comm. (from A. Debrof)
Mangere	NZL	113		?		unknown	Atkinson 1988
Grassy (Whitsunday)	AUS	111	1930	1989		hunting	K. McDonald pers. comm.; A. Jacobson pers. comm.; Abbott & Burbidge 1995
Minamijima (Bonin)	JAP	111		1972		hunting	Shimuzu 1995, 2003
South Neptune (Neptune)	AUS	98		1968		unknown	Robinson et al. 1996
Althorpes (York Peninsula) <sup>e</sup>	AUS	96	1880s	1980		hunting	Robinson et al. 1996; R. Henzell pers. comm.
Montague (New South Wales)	AUS	82	<1967	1988	60	unknown	Smith & Dodkin 1989; NSW National Parks and Wildlife Service 1995
Goose (Tasmania)	AUS	81		1930		unknown	I. Skira pers. comm.
Yomejima (Mukojima-retto)	JAP	81	1945	2000		unknown	Shimuzu 2003
Aride	ROS	72		1920		unknown	Warman & Todd 1984
Long (Tasmania)	AUS	70	<1977	1996	109 (1996)	unknown	G. Atkinson pers. comm.; I. Skira pers. comm.
East Repulse (Whitsunday)	AUS	67		1990		hunting	K. McDonald pers. comm. (from B. Nolan); Abbott & Burbidge 1995
Lavezzi (Lavezzi)	FRA	66		1993		hunting, live capture	Daycard & Thibault 1990; M. Pascal pers. comm.
North Islet (Gambier)	AUS	64	1820s	1916		unknown	Robinson et al. 1996
South Repulse (Whitsunday)	AUS	61		1990		hunting	K. McDonald pers. comm. (from B. Nolan); A. Jacobson pers. comm.; Abbott & Burbidge 1995
Humpy (Keppel)	AUS	60		1986		unknown	Brennan 1986
Motuoruhi	NZL	57		?		unknown	Atkinson & Taylor 1991
Saddleback (Whitsunday)	AUS	53		1988		hunting	Abbott & Burbidge 1995; K. McDonald pers. comm.; A. Jacobson pers. comm.
Burgess (Mokohinau)	NZL	52		1973		hunting	Veitch & Bell 1990
Pourewa	NZL	42	< 1950	1993	83	hunting	D. Veitch pers. comm. (from A. Basset)
Middle (Keppel)	AUS	41		1986		unknown	Brennan 1986
Horse (Roaringwater Bay) <sup>e</sup>	IRE	40		1994		unknown	http://homepage.eircom.net/~sherkinmarine/islands.html
Henning (Whitsunday)	AUS	38		1989		hunting	Abbott & Burbidge 1995; K. McDonald pers. comm.; A. Jacobson pers. comm.
Lady Elliot (Capricorn Bunker)	AUS	37	c.1860	1969		hunting	Ogilvie 1992; D. Crossman pers. comm.

continued

Appendix 1. (continued)

Island (group)	Country <sup>a</sup>	Area (ha)	Introduction year	Eradicated year	No. goats removed	Eradication methods	Reference
Mahurangi	NZL	32	1800s	1915		unknown	J. Parkes pers. comm.
Fairfax [eastern] (Capricorn Bunker)	AUS	28	1898	1974	~100 (1972)	hunting	Gribb 1986; Rees 1981; D. Crossman pers. comm.; D. Arnold pers. comm.
Herekopare (Titi) <sup>e</sup>	NZL	28	1973	1976		hunting	Parkes 1990a; Veitch & Bell 1990
Ile aux Aigrettes	MAU	27	>1945	1987		unknown	J. Mauremootoo pers. comm.
Ernest (Stewart) <sup>e</sup>	NZL	25	<1948	1980		unknown	Parkes 1990a
Bono (Septre-Iles)	FRA	21		1993		live capture	M. Pascal pers. comm.
Hoskyn [western] (Capricorn Bunker)	AUS	20		?		hunting	Rees 1981; D. Arnold pers. comm.
Big (Five Islands)	AUS	19	1888	1917		unknown	Smith & Dodkin 1989; Abbott & Burbidge 1995
Trielen (Molene)	FRA	17		1998		live capture	M. Pascal pers. comm.
North Repulse (Whitsunday)	AUS	16		1990	~1200	hunting	Abbott & Burbidge 1995; K. McDonald pers. comm.; A. Jacobson pers. comm.
Allports	NZL	16		?		unknown	Atkinson & Taylor 1991
Aihau <sup>e</sup>	NZL	16		1940		unknown	J. Parkes pers. comm.
East	NZL	13	1906	1960		hunting	Parkes 1990a; Veitch & Bell 1990
Nukutaunga (Cavalli)	NZL	13		1972		hunting	Parkes 1990a; Veitch & Bell 1990
Plaza Sur (Galapagos)	ECU	12		1961	5 (1961)	hunting	Hoeck 1984; O. Chapi pers. comm.
Harbour (Tasmania)	AUS	10		1995	34 (1995)	unknown	G. Atkinson pers. comm.; I. Skira pers. comm.
Lady Musgrave (Capricorn Bunker)	AUS	9	1898	1974	~300	hunting?	Walker 1991; D. Arnold pers. comm.
Ile aux Moines (Septre-Iles)	FRA	9		1993		live capture	M. Pascal pers. comm.
Nonsuch (Castle Harbour)	BER	6	c.1953	1962	9	hunting, mustering	Wingate 1985
Hoskyn (Queensland)	AUS	5		1970		unknown	Abbott & Burbidge 1995
Ocean (Auckland)	NZL	5	1865	1942	~14 (1941-1942)	hunting	Rudge & Campbell 1977
Rurima	NZL	5		1960		unknown	Atkinson & Taylor 1991
Fairfax [western] (Capricorn Bunker)	AUS	4		1971		hunting	Gribb 1986; D. Arnold pers. comm.
Burt's (Hamilton Harbour)	BER	2	c.1964	1969	~10 (1972)	unknown	D. Wingate pers. comm.
Mariclas Sur (Galapagos)	ECU	1	c.1990	1991	5	hunting	F. Cruz pers. comm.

<sup>a</sup> Country abbreviations: AUS, Australia; BER, Bermuda; CAN, Canada; CHI, Chile; ECU, Ecuador; FRA, France; GRE, Greece; IRE, Ireland; JAP, Japan; MAU, Mauritius; MEX, Mexico; NA, Netherlands Antilles; NZL, New Zealand; NMI, Northern Mariana Islands; POR, Portugal; ROS, Republic of Seychelles; SPA, Spain; UK, United Kingdom; USA, United States of America; VEN, Venezuela.

<sup>b</sup> Domestic goats now present.

<sup>c</sup> Occupied only 4000 ha.

<sup>d</sup> Largest population eradicated.

<sup>e</sup> Semi-feral goats eradicated.