FERAL AND INTRODUCED CARNIVORES: ISSUES AND CHALLENGES

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Abstract: Feral and invasive carnivores have been intentionally or unintentionally introduced to many parts of the world for a variety of reasons. Once established, they have often caused significant impacts to endemic species because of their predatory nature and, in numerous cases, have altered ecosystem structure and function in important conservation areas. They can also cause competition for native predators, hybridization with native species, losses to livestock and companion animals, and disease hazards. We provide examples of the extent of introductions, resulting impacts, and efforts to control or eradicate these populations. Working with introduced or feral carnivores presents many challenges to resource managers, agencies, agriculturists, and landowners. There has been considerable success in controlling or eradicating some populations in various parts of the world, primarily using traps, shooting, and toxicants. Recent technological advances and research needs are addressed.

Key words: eradication, feral cat, feral dog, fox, introduced carnivore, invasive species, mongoose, wildlife management

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INTRODUCTION

The term feral animal, as defined by Webster, has several meanings, but for our purpose we will use the definition that feral animals are "animals that have escaped from domestication and become wild". Introduced or non-native animals are those that have become established outside their natural range. Feral and introduced carnivores include feral cats (*Felis catus*), feral dogs (*Canis familiaris*), foxes (e.g., red fox, *Vulpes vulpes*), mongooses (*Herpestes* spp.), members of the weasel family (*Mustela* spp.), raccoons (*Procyon lotor*), and many other species (Long 2003). Long (2003) lists over 45 species of carnivores that have been introduced to various parts of the world. The International Union for the conservation of Nature has included feral cats, red foxes, small Indian mongooses, and ermines (also called stoats, *Mustela erminea*) on their list of the "100 of the World's Worst Invasive Alien Species" (Lowe et al. 2004). These populations can be come established from several sources (Long 2003). Some are escaped or abandoned pets or fur-farm animals. Some have been introduced as a source of fur or for sport hunting. Some have been introduced in an attempt to control "pests" such as rats or snakes. In addition to many species of carnivores that have been accidentally or intentionally introduced, there are a number of carnivores that could be considered invasive because of natural adaptation and range expansion, especially as the result of habitat alterations and livestock/poultry production by humans

(Witmer et al. 1995). Animals such as coyotes (*Canis latrans*), red foxes, and raccoons are presently found in areas where there are no historical records to show that they formerly occurred there. Also, issues with predation are broader than the taxonomic sense, because non-carnivore species such as armadillos (*Dasypus novemcinctus*), rats (*Rattus* spp.) and feral hogs (*Sus scrofa*) can cause significant predation problems for endemic species. For the purpose of this paper, however, we will focus on four carnivore species that have a dramatic worldwide impact on humans, livestock, and wildlife: feral cats, feral dogs, introduced foxes, and introduced mongooses.

The introduction or release of non-native animals into naive ecosystems often has harmful consequences on native fauna (Witmer et al. 1996, Long 2003). This is especially true if the introduced species is a carnivore with generalist feeding habits to which the native fauna is not adapted, as is the case on many islands. At least 40% of the species extinction and endangerment are caused by introduced animals (Pimental et al. 2000). The impacts of introduced carnivores include predation on native fauna (especially ground-nesting birds), competition with native predacious species, hybridization with native fauna, reductions in biodiversity and ecosystem structure and functions, livestock and poultry losses, and disease transmission, including the considerable expense of rabies treatment, (Pimental et al. 2000). The predation levels of introduced carnivores can be exacerbated by "surplus killing" behaviors of some carnivores (Short et al. 2002a). The populations of some species of feral carnivores, especially cats and dogs, are supported in many areas by poor sanitation practices that provide food, cover, and, in some cases, support a prey base of commensal rodents (*Rattus* spp. and house mice, *Mus musculus*).

One-to-several species of feral and introduced carnivores occur and cause problems in almost all countries and on many of the world's islands. These species, as with others that have become established in previously naive areas, become permanent in ecological time unless intentionally removed. Examples of carnivore introductions around the world, the impacts caused, and their control and eradication have been presented by Long (2003), Parkes and Murphy (2002), Pimental (2002), and Witmer and Lewis (2001).

FERAL CATS

Wild populations of domesticated cats are distributed throughout the world, wherever humans are present (Long 2003). According to Van't Woudt (1990), feral or free ranging cats are more likely to be rare or absent in regions with viable predator populations. However, in areas with reduced predator populations (such as remote islands), feral cats often become the dominant predator and often exist at much higher densities than native predators. It has been estimated that there are over 30 million feral cats in the U.S. and that they kill about 465 million birds per year (Pimental et al. 2000). Pimental et al. (2000) estimated the value of those birds at $17 million. It has been estimated that the 5 million cats in the United Kingdom kill as many as 70 million wild animals per year (Churcher and Lawton 1987). The control of feral cats is a very controversial area as many members of the public and some advocacy groups are strong supporters of cats and are against the killing of feral cats. These persons and groups often prefer the trap-neuter-release approach for feral cat management. Some groups actually maintain feeding stations for feral cat colonies. Nonetheless, several groups of wildlife professionals and state and federal

agencies advocate the strict control or elimination of feral cat populations.

The diet of feral and free-ranging cats varies depending on availability, abundance, and geographic location. Foods may be naturally occurring, but also include those made available by people, whether intentional or unintentional (Long 2003). In a survey of New Zealand scientific literature, Fitzgerald (1990) concluded that prey selection of feral and free-ranging cats is dependent on availability. The author found that cats on mainland situations fed most heavily on mammals; whereas, cats on islands fed almost exclusively on birds (particularly seabirds). Feral and free-ranging cats are known to prey on birds as large as mallard ducks (Figley and VanDruff 1982) and young brown pelicans (Anderson et al. 1989) and mammals as large as hares and rabbits. Many of these cat populations rely heavily on humans, either for handouts or waste food stuffs, especially when prey populations are low.

Effects of predation on native species by feral cat populations are widespread and significant (Whittaker 1998). Cats have been one of the most important biological factors (excluding humans) causing the depletion or extinction of both island and mainland bird species (Nogales et al. 2004). In isolated environments such as islands, feral cats are directly responsible for a number of extinctions and extirpations worldwide and across multiple taxa (Towns et al. 1990, Veitch 2001, Long 2003). Jackson (1978) reports cats as the most significant factor, next to habitat destruction, contributing to the extinction of bird species. He reports that at least 33 species have become extinct as a result of cat predation, most of these are on islands.

If feral cats are so destructive to wildlife, especially on islands, why is there not a greater effort to control feral cat populations? Nogales et. al. (2004) identified 48 successful eradication efforts on islands. The most commonly used methods were trapping and shooting, although some countries also use toxic baits. Most of these eradication efforts were on small islands where seabirds can form extremely dense nesting colonies. The recovery of endemic or protected wildlife species can be rapid once feral cats are controlled or eliminated as was the case with the endangered Key Largo woodrat (*Neotoma floridana smalli*) in Florida (B. Constantin, unpubl. data).

Another significant problem created by cats is that they are reservoirs and transmitters of various diseases and parasites to both domestic and wild animal species and to humans. Cats serve as reservoirs or hosts for cat scratch fever, distemper, histoplasmosis, leptospirosis, mumps, plague, rabies, ringworm, salmonellosis, toxoplasmosis, tularemia, and various endo- and ecto-parasities (Fitzwater 1994). In a survey of pet cats and dogs on U.S. Air Force bases, the most frequent zoonoses were hookworms, roundworms, tapeworms, and fleas. In human reported cases on the bases, dermatomycoses, fleas, scabies, Gram-positive bacterial infections, and rabies are the most important zoonotic threats (Warner 1984). All of these are associated with cats.

FERAL DOGS

Like feral cats, humans have transported feral dogs to most parts of the world (Long 2003). Feral dogs probably exist in all states of the U.S., often with 50,000 or more per state, and may total over 33 million in the U.S. (Long 2003). These dogs often run in packs and may kill deer, small- and medium-sized mammals, livestock (cattle, sheep, goats, poultry) and pets (Pimental et al. 2000). Pimental et al. (2000) estimated that feral dogs may cause

$5 million per year in damages of these types. It is important, however, to distinguish predation from feral dogs from that of native carnivores, especially coyotes (*Canis latrans*; Green and Gipson 1994). Feral dogs also can be reservoirs of various diseases, notably canine distemper and rabies, which can affect humans, livestock, pets, and native fauna. Additionally, an estimated 4.7 million persons in the U.S. are bitten by feral or unrestrained dogs each year with 800,000 cases requiring medical treatment (Pimental et al. 2000). CDC estimates that these dog bites, the rabies treatment associated them, and lost work time, cost the U.S. $250 million per year (Pimental et al. 2000). About 10-15 persons, usually small children, are killed by dogs in the U.S. each year (Pimental et al. 2000). Feral dogs in Australia also cause substantial impacts to livestock production and native fauna (Fleming 2000, Bomford and Hart 2002). Here, agricultural losses are estimated to be at least $20 million per year with another $15 million per year being spent on dog control and maintenance of the 5,614 km wild dog control fence (Bomford and Hart 2002).

On some islands, such as the Galapagos Islands, feral dogs have been significant predators of endemic and rare fauna such as iguanas, tortoises, marine mammals, and seabirds (Long 2003). Because of this, there have been substantial efforts to control the feral dogs of the Galapagos using toxicants and fertility control (Barnett 1986). In the U.S., feral dogs hybridize with native wolves (*Canis lupus* and *C. rufus*) and coyotes (Long 2003).

Although feral dogs inhabit rural and wilderness communities and cause damage to livestock and wild fauna, they are often found in greatest numbers in low-income areas of cities. While some feral dogs are born on the streets, most are domesticated pet dogs that have been abandoned or free-ranging household dogs that have joined packs and become feral. These feral dogs usually join packs of other dogs and survive by scavenging garbage or, in more rural areas, killing and eating wildlife and livestock. In the U.S., because most feral dogs are found in highly urbanized areas, they have a better chance of being rescued and placed back into domestic life. In less developed countries, feral dogs tend to form large packs and live on the edge of domestication where they subsist on whatever garbage they can find and in whatever shelters are available

Various methods are used to control or eliminate feral dogs, including traps, snares, and shooting (Green and Gipson 1994). Some countries, but not the U.S., use toxic baits (Fleming 2000). In San Juan, Puerto Rico, federal wildlife specialists have eliminated several feral dog populations that were endangering humans and killing local pets (B. Constantin, unpubl. data). One area was a Commonwealth governmental office complex that had jogging/biking trails and other outdoor athletic and social facilities. The dogs were chasing and biting joggers and bikers and intimidating people using the other facilities. Once the packs were located, they were removed through trapping (mostly walk-in cage traps) and snaring. One hundred twenty-six dogs were removed from the complex and no other dogs were seen. A similar situation occurred at Fort Buchanan in San Juan. In that case, feral dogs were coming out of a large wooded area around the military base and killing pets, chasing people, and scattering garbage. Federal wildlife specialists removed most of the feral dogs by trapping and snaring, and then trained designated military personnel so that they could continue control efforts as needed.

FOXES

Native to most of the northern hemisphere, the red fox has perhaps the largest geographic range of any terrestrial carnivore with the possible exception of the domestic (and feral) cat (Lariviere and Pasitschniak-Arts 1996, Witmer and Lewis 2001). They (along with arctic foxes, *Alopex lagopus*) were introduced historically to a large number of islands, primarily for fur production (Long 2003). Although native to North America, the range of the red fox on that continent has been expanded by human introductions to new areas (Witmer and Lewis 2001). The largest introduction and range expansion, however, has occurred on the Australian mainland where they were introduced by hunt clubs in the 1850s (Long 2003). That huge range expansion was facilitated by the previously introduced European rabbit (*Oryctolagus cuniculus*) which had spread over most of the Australian continent and provided a large prey base for foxes (Long 2003). Foxes are very efficient predators and are also omnivorous, feeding on a wide array of vertebrate and invertebrate prey as well as fruit and vegetable materials (Long 2003, Witmer and Lewis 2001). Consequently, there can be significant impacts by foxes to livestock (lambs, poultry) and crop production, important game bird populations, native non-game birds, and protected species. They also are significant reservoirs of various diseases, especially rabies ((Lariviere and Pasitschniak-Arts 1996). The impacts of introduced foxes to livestock and native wildlife are particularly severe in Australia where damage and control efforts cost about $50 million per year (Saunders et al. 1995, Pimental et al. 2000).

Foxes (both red and arctic) were introduced to many of the Aleutian Islands by the Russian fur industry as early as the 1750s (Ebbert 2000, Long 2003). Ironically, arctic ground squirrels (*Spermophilus parryii*) were introduced to some of the islands as a prey base for the foxes, especially once the seabird populations declined dramatically from fox predation (Ebbert and Byrd 2002). The foxes had severe impacts on nesting seabirds and nearly caused the extinction of the Aleutian Canada goose (*Branta canadensis leucopareia*; Ebbert 2000, Ebbert and Byrd 2002). Fox eradication efforts on the Alaska Maritime National Wildlife Refuge began in 1949 and since then, foxes have been removed from 39 islands with success nearly at hand on several other islands (Ebbert and Byrd 2002). Traps, shooting, and toxicants have been used in this effort, although the use of toxicants dropped off after Presidential Executive Order 11643 was issued in 1972 (Ebbert 2000). Most seabird populations have shown dramatic increases within 10 years of fox removal (Ebbert and Byrd 2002) and the Aleutian Canada goose has been delisted.

MONGOOSES

The small Indian mongoose (*Herpestes auropunctatus* or *H. javanicus*) is indigenous to southern Asia, but has been introduced into South America, Hawaii, Puerto Rico, and many other islands around the world (Nellis and Everard 1983, Long 2003). Other species have been introduced to other parts of the world (Long 2003). Mongoose were usually introduced in an effort to control pests such as rodents and snakes. The mongoose was introduced to the Caribbean Islands in 1872 and to the Hawaiian Islands in 1883 in an attempt to control introduced rats on sugar cane plantations (Pimental et al. 2000). While they may kill some rodents, mongooses are mainly diurnal whereas rats are mainly nocturnal. Hence, mongooses are basically useless as a means of rodent damage control. Mongooses use many habitats (usually semi-

arid open grasslands, shrublands, savannah, and the edges of villages and towns) and feed on a wide variety of vertebrate, invertebrate, and plant foods (Long 2003). It has long been considered responsible for the extirpation and extinction of many terrestrial vertebrate species on islands around the world (Seaman and Randall 1962, Long 2003). They also cause significant losses to poultry production on islands (Long 2003). The successful re-introduction of some endangered species (such as the St. Croix ground lizard, *Ameiva polops*) is dependent on eradication of mongooses on select islands (Nellis et al. 1978). Additionally, the mongoose is a major vector and reservoir of rabies and leptospirosis on Puerto Rico and other islands (Pimental et al. 2000). Pimental et al. (2000) estimated that the mongoose causes about $50 million in damages each year in Hawaii and Puerto Rico. Trapping and toxic baits placed in bait stations are the main methods used for control and eradication of mongoose, although success has usually been marginal (Roy et al. 2002, Quinn and Whisson 2004). Over the last several decades, the mongoose has emerged as the main vector and reservoir for rabies on several Caribbean islands (Quinn and Whisson 2004). Development of an oral rabies vaccine for mongoose is also considered an important research goal (Quinn and Whisson 2004).

METHODS OF CONTROL

Methods available to remove or eradicate introduced and feral carnivores include monitoring and surveillance methods and control methods. For effective control or eradication, the use of multiple methods is generally required (Ebbert 2000, Wood et al. 2002, Fleming 2000). Methods currently available to remove introduced and feral carnivores were summarized by Fitzwater (1994), Green and Gipson (1994), Nogales et al. (2004), Phillips and Schmidt (1994), and Saunders et al. (1995). Of course, the costs and effectiveness vary considerably among the methods (Saunders et al. 1995, Allen and Sparkes 2001). The application of benefit-cost analyses can help in deciding on which method(s) to use and whether or not control is warranted (Shwiff 2004). Research continues to improve existing methods and to develop new methods.

Monitoring and Surveillance

Monitoring and surveillance are important components of an effective introduced or feral carnivore management program and a variety of methods are available (Saunders et al. 1995, Engeman and Witmer 2000). Monitoring and surveillance are necessary to establish locations used by target species, develop baseline populations for target species, and measure efficacy of carnivore removal efforts.

A conundrum of monitoring and surveillance is detecting remnant survivors after control or newly-arrived individuals. Surviving populations tend to be low in relative abundance, dispersed, and wary. Several methods have been used to detect remnant populations including aerial surveys by helicopter, spot-light searches, use of detecter dogs, scent and track stations, snow or sand tracking, scat searches, cameras at bait stations, howling responses, and systematic sweeps of areas.

Traps and Snares

Trapping and snaring have always been important tools for carnivore capture (e.g., Phillips and Schmidt 1994, Short et al. 2002b, Wood et al. 2002, Nogales et al. 2004). The use of traps and snares, however, can be logistically difficult and will usually not lead to eradication when not combined with other methods because some

animals will be "trap-shy" and elude capture (Wood et al. 2002). A wide variety of single-animal capture traps and snares are available and some may perform better than others under certain conditions or with certain "types" of animals (Short et al. 2002b). Recently, a multiple-capture trap has been used to capture packs of feral dogs (Johnson 2002). Some traps and snares are set as "blind sets" along trials, fencelines, etc. Other sets involve the use of lures or food baits (Clapperton et al. 1994, Edwards et al. 1997). Food baits are generally meat or fish-based. Lures may be commercially-available lures or merely predator odors (e.g., cat feces). The use of radio-transmitters on remote traps can improve efficiency by allowing personnel to determine, from a distance, that a trap has been triggered (Johnson 2002, Hess et al. 2004, McCann et al. 2004). For the most part, carnivores are very wary animals and the importance of using experienced trappers is often noted (e.g., Wood et al. 2002). A new cat calling machine has been developed to aid in getting cats to trap sets (Coast-to-Coast Vermin Traps, Baldivis, Western Australia; website: home.primus.com.au/CTCVT).

Shooting

Shooting from the ground has proven to be a very effective technique (Green and Gipson 1994, Fitzwater 1994, Phillips and Schmidt 1994, Nogales et al. 2004). Both day (opportunistic) and night shooting can be used, but spot-light shooting at night is probably more effective. Usually a small caliber (0.22 rimfire) rifle is used, although shotguns can be used if short range opportunities present themselves. Carnivores can be called in with a commercial predator call or the recording of an injured rabbit or they can be lured by using a carcass as bait. Shooting from the ground may be more effective with the use of dogs to locate the target animals, especially when the target animal numbers are low (Wood et al. 2002).

Shooting from helicopters can be an effective and rapid method of population control (Green and Gipson 1994, Phillips and Schmidt 1994). However, it is very expensive and animals may learn to recognize the sound of the helicopter and hide (McCann et al. 2004). Helicopters are also valuable for transporting equipment and traps, getting personnel into remote locations, and for surveying areas for introduced or feral animals (McCann et al. 2004).

It should be noted that bounties were used as a method of predator control in some countries in the past, but are very rare today (Allen and Sparkes 2001). In this system, participants would use any of a variety of methods (e.g., traps, snares, shooting) to take the animals and then would bring in the carcass or some part of it for payment. The system formerly used in Australia for fox control was discussed by Saunders et al. (1995).

Denning

Predator populations can be reduced by finding dens and destroying the young in them, although considerable effort may be required to find many dens (Green and Gipson 1994, Phillips and Schmidt 1994, Saunders et al. 1995). In some places and situations, fumigants may be used in dens to kill the occupants (Phillips and Schmidt 1994, Saunders et al. 1995).

Toxicants

The use of toxicants is highly regulated and they can only be used for predator control in limited and specific situations (Jacobs 1994, Phillips and Schmidt 1994, Saunders et al. 1995). They have been mostly used for cat eradication on islands (Nogales et al. 2004), fox control in

the Aleutian Islands (Ebbert 2000) and for fox (Saunders et al. 1995) and wild dog (Fleming 2000,) control in Australia. Aerial distribution of Compound 1080 (sodium monofluoroacetate) baits is commonly used in Australia and New Zealand for the control of introduced, invasive species (Fleming 2000, Veitch 2001). In the U.S., the surface use of predator toxicants was greatly restricted in 1972 (Ebbert 2000). The main uses now are the M-44 device which ejects sodium cyanide into the mouth of the predator that tugs at the device with its teeth (Green and Gipson 1994, Ebbert and Byrd 2002). These devices are also being tested for fox control in Australia (Petel et al. 2004). We have already mentioned that den fumigants are used in some situations.

A rather novel approach for using toxicants is the loading of prey species so that the predator is killed by secondary poisoning after consuming the poisoned prey (Risbey et al. 1997, Short et al. 1997).

Biological Control

Biological control has rarely been used in the control or eradication of introduced or feral carnivores, but there are a few interesting examples. The viral disease agent, feline panleucopaenia, was used to eradicate cats from a few islands (Nogales et al. 2004). Pech (2000) discussed the many issues involved with the use of disease agents. In the second example, sterile red foxes were placed on two Aleutian Islands with introduced arctic foxes and the larger red foxes apparently killed off the smaller arctic foxes (Bailey 1992). Presumably, the sterile red foxes would die off over time, leaving no foxes on the islands.

Sterilization

Sterilization is rarely used as a management tool for introduced or feral carnivores with the exception of feral cats. Unfortunately, trap-neuter-release programs do not eliminate feral cat colonies nor do they greatly reduce predation on native wildlife (Castillo and Clark 2003). Consequently, some wildlife conservation organizations such as the American Bird Conservancy are opposed to "managed" feral cat colony programs (website: www.abcbirds.org).

The issues and challenges of fertility control of free-ranging wildlife were reviewed by Fagerstone et al. (2002). Research has identified several materials that could effectively sterilize feral dogs and cats (Miller et al. 2004). Efficient delivery methods remain a major challenge with this method. A modeling effort concluded that a virus-vectored immuno-contraceptive approach could effectively control feral cat populations while minimizing non-target hazards (Courchamp and Cornell 2000).

Fencing

Predator-proof fencing can be used to protect nesting colonies of endangered species (Witmer et al. 1996) and highly-valued game bird populations (Jimenez et al. 2001). Materials and installation, however, are very expensive and regular maintenance it is required. Australia has undertaken the most extensive wild dog-proof fencing project reported, extending 5,614 km (Fleming 2000). The fence is considered very effective in reducing livestock losses to wild dogs, but at about $10 million per year, is quite expensive to maintain (Bomford and Hart 2002).

Recent Technological Advances and Research Areas

There have been technological advances in equipment that are useful in introduced and feral carnivore control and eradication. The use of forward-looking infrared (FLIR) thermal imagers, night vision goggles, and suppressed rifles are

examples of technological advances that improve efficacy of removal programs. FLIR units, which can be used from the ground, from vehicles, and from helicopters, allow a much greater portion of animals to be seen at night during monitoring or shooting operations. Suppressors reduce the muzzle flash and report of the rifle when a bullet is discharged. The reduction in report appears to reduce the likelihood of animals fleeing. The reduced noise is also beneficial when conducting operations near inhabited areas. Suppressors are regulated by the Federal Bureau of Alcohol, Tobacco, and Firearms and their availability is greatly restricted by statute. State and federal wildlife agencies are able to acquire necessary federal permits to use suppressors. States may also have restrictive regulatory requirements on the use of suppressors.

Research continues on improving lures to be used with toxic baits or traps (e.g., Eason et al. 1992, Edwards et al. 1997). Research also continues in the area of fertility control (Miller et al. 2004).

CONCLUSIONS

Introduced and feral carnivores pose a significant threat to native wildlife as well as people and their livestock and companion animals. Populations can be controlled, and in some cases eradicated, with careful planning, adequate resources, and a sustained effort. There have been numerous successes worldwide, especially with cats and foxes on islands. Usually several methods are incorporated into a strategy, including shooting, traps, and toxicants. The use of experienced shooters, trappers, and trackers increase the chance of success as does the use of trained dogs. Periodic monitoring of an area or island cleared of invasive carnivores is recommended in case some were missed or the area is re-invaded. Prevention and rapid response to introductions are important elements of invasive species management and eradication.

When planning a control or eradication project, it is important to include contingency plans and to "expect the unexpected." There can be many ecological consequences of control efforts. For example, controlling introduced carnivores may "release" populations of introduced rats or rabbits unless they are controlled earlier or simultaneously. Also, controlling populations of introduced canids (foxes, dogs) may result in increased populations of feral cats.

Public and agency support are essential for any carnivore control program to be successful. We must realize that carnivores are a high profile issue with the public and with agencies, hence it is important to have adequate information on the situation, species involved, damages occurring, advantages and disadvantages of methods to be used, and the potential for environmental and non-target harm. Adequate monitoring and measures of success are necessary. A variety of control tools must be available as some individual animals will always be resistant to—or wary of—a particular method, be it a trap type or a bait/lure type. Stricter regulations regarding the release of carnivores and enforcing the neutering of pets would reduce the magnitude and incidence of introduced and feral carnivore situations. Research to improve existing methods and to develop new methods to monitor, capture, contracept, control, and eradicate introduced and feral carnivore populations should continue.

LITERATURE CITED

ALLEN, L., AND E. SPARKES. 2001. The effect of dingo control on sheep and beef cattle in Queensland. Journal of Applied Ecology 38:76-87.

ANDERSON, D.W., J.O. KEITH, G.R. TRAPP, F. GRESS, AND L.A. MORENO. 1989.

Introduced small ground predators in California brown pelican colonies. Colonial Waterbirds 12: 98-103.

BAILEY, E. 1992. Red foxes as biological control agents for introduced arctic foxes on Alaska Islands. Canadian Field-Naturalist 106:200-205.

BARNETT, B. 1986. Eradication and control of feral and free-ranging dogs in the Galapagos Islands. Proceedings of the Vertebrate Pest Conference 12:358-368.

BOMFORD, M., AND Q. HART. 2002. Non-indigenous vertebrates in Australia. Pages 25-44 *in* D. Pimental, editor. Biological invasions. CRC Press, Boca Raton, FL, USA.

CASTILLO, D., AND A. CLARKE. 2003. Trap-neuter-release methods ineffective in controlling domestic cat "colonies" on public lands. Natural Areas Journal 23:247-253.

CHURCHER, P., AND J. LAWTON. 1987. Predation by domestic cats in an English village. Journal of Zoology (London) 212:493-455.

CLAPPERTON, B., C. EASON, R. WESTON, A. WOOLHOUSE, AND D. MORGAN. 1994. Development and testing of attractants for feral cats. Wildlife Research 21:389-399.

COURCHAMP, F., AND S. CORNELL. 2000. Virus-vectored immunocontraception to control feral cats on islands: A mathematical model. Journal of Applied Ecology 37:903-913.

EASON, C., D. MORGAN, AND B. CLAPPERTON. 1992. Toxic bait and baiting strategies for feral cats. Proceedings of the Vertebrate Pest Conference 15:371-376.

EBBERT, S. 2000. Successful eradication of introduced arctic foxes from large Aleutian Islands. Proceedings of the Vertebrate Pest Conference 19:127-132.

_____, AND G. Byrd. 2002. Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. Pages 102-109 *in* C. Veitch and M. Clout, editors. Turning the tide: The eradication of invasive species. World Conservation Union (IUCN), Gland, Switzerland.

EDWARDS, G., K. PIDDINGTON, AND R. PALRIDGE. 1997. Field evaluation of olfactory lures for feral cats in central Australia. Wildlife Research 24:173-183.

ENGEMAN, R., AND G. WITMER. 2000. IPM strategies: Indexing difficult to monitor populations of pest species. Proceedings of the Vertebrate Pest Conference 19:183-189.

FAGERSTONE, K., M. COFFEY, P. CURTIS, R. DOLBEER, G. KILLIAN, L. MILLER, AND L. WILMOT. 2002. Wildlife fertility control. Wildlife Society Technical Review 02-2. The Wildlife Society, Bethesda, MD, USA.

FIGLEY, W.K., AND L.W. VANDRUFF. 1982. The ecology of urban mallards. Wildlife Monograph No. 82. The Wildlife Society, Bethesda, MD, USA.

FITZGERALD, B.M. 1990. House cat. Pages 330-348 *in* C.M. King, editor. The handbook of New Zealand mammals. Oxford University Press, Aukland, New Zealand.

FITZWATER, W. 1994. House cats (feral). Pages C-45 – C-49 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and control of wildlife damage. University of Nebraska Cooperative Extension Service, Lincoln, NE, USA.

FLEMING, P. 2000. Wild dogs and their manipulation to prevent livestock predation in Australia. Proceedings of the Vertebrate Pest Conference 19:277-283.

GREEN, J., AND P. GIPSON. 1994. Feral dogs. Pages C-77 – C-81 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and control of wildlife damage. University of Nebraska Cooperative Extension Service, Lincoln, NE, USA.

HESS, S., P. BANKO, D. GOLTZ, R. DANNER, AND K. BRINCK. 2004. Strategies for reducing feral cat threats to endangered Hawaiian birds. Proceedings of the Vertebrate Pest Conference 21:21-26.

JACKSON, J.A. 1978. Alleviating problems of competition, predation, parasitism, and

disease in endangered birds. Pages 75-84 *in* S. Temple, editor. Endangered birds: Management techniques for preserving threatened species. Proceeding of the Symposium on Management Techniques for Preserving Endangered Birds. University of Wisconsin Press, Madison, WI, USA.

JACOBS, W. 1994. Pesticides federally registered for control of terrestrial vertebrate pests. Pages G-1 – G-22 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and control of wildlife damage. University of Nebraska Cooperative Extension Service, Lincoln, NE, USA.

JIMENEZ, J., M. CONOVER, AND T. MESSMER. 2001. Exclusionary methods to reduce predation on ground-nesting birds and their nests. Berryman Institute Publication Number 20. Jack H. Berryman Institute, Utah State University, Logan, UT, USA.

JOHNSON, M. 2002. A new capture pen for Carribean feral dog packs. Intermountain Journal of Science 8:255.

LARIVIERE, S., AND M. PASITSCHNIAK-ARTS. 1996. Vulpes vulpes. Mammalian Species No. 537. American Society of Mammalogists. Allen Press, Inc., Lawrence, KS, USA.

LONG, J. 2003. Introduced mammals of the world. CSIRO Publishing, Collingwood, Victoria, Australia.

LOWE, S., M. BROWNE, S. BOUDJELAS, AND M. DEPORTER. 2004. 100 of the world's worst invasive alien species. World Conservation Union (IUCN), Gland, Switzerland.

MCCANN, B., K. RYAN, AND D. GARCELON. 2004. Techniques and approaches for the removal of feral pigs from island and mainland ecosystems. Proceedings of the Vertebrate Pest Conference 21:42-46.

MILLER, L., J. RHYAN, AND G. KILLIAN. 2004. GonaCon, a versatile GnRH contraceptive for a large variety of pest animal problems. Proceedings of the Vertebrate Pest Conference 21:269-273.

NELLIS, D.W., AND C.O.R. EVERARD. 1983. The biology of the mongoose in the Caribbean Islands. Studies on the Fauna of Curacao and other Caribbean Islands 64:1-162.

_____, N. EICHHOLZ, T. REGAN, AND C. FEINSTEIN. 1978. Mongoose in Florida. Wildlife Society Bulletin 6:249-250.

NOGALES, N., A. MARTIN, B.R. TERSHY, C.J. DONLAN, D. VEITCH, N. PUERTA, B. WOOD, AND J. ALONSO. 2004. A review of feral cat eradication on islands. Conservation Biology 18:310-319.

PARKES, J., AND E. MURPHY. 2002. Management of introduced mammals in New Zealand. New Zealand Journal of Zoology 30:335-359.

PECH, R. 2000. Biological control of vertebrate pests. Proceedings of the Vertebrate Pest Conference 19:206-211.

PETEL, A., R. KIRKWOOD, F. GIGLIOTTI AND C. MARKS. 2004. Adaptation and assessment of M-44 ejectors in a fox-control program on Phillip Island, Victoria. Wildlife Research 31:143-147.

PHILLIPS, R., AND R. SCHMIDT. 1994. Foxes. Pages C-83 – C-88 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and control of wildlife damage. University of Nebraska Cooperative Extension Service, Lincoln, NE, USA.

PIMENTAL, D., L. LECH, R. ZUNIGA, AND D. MORRISON. 2000. Environmental and economic costs associated with non-indigenous species in the United States. BioScience 50:53-65.

_____, EDITOR. 2002. Biological invasions: Economic and environmental costs of alien plant, animal, and microbe species. CRC Press, Boca Raton, FL, USA.

QUINN, J., AND D. WHISSON. 2004. The mongoose in the Carribean: Past management and future challenges. Proceedings of the Vertebrate Pest Conference 21:31-36.

RISBEY, D., M. CALVER, AND J. SHORT. 1997. Control of feral cats for nature

conservation: Field tests of four baiting methods. Wildlife Research 24:319-326.

ROY, S., C. JONES, AND S. HARRIS. 2002. An ecological basis for control of the mongoose in Mauritius: Is eradication possible? Pages 266-273 *in* C. Veitch and M. Clout, editors. Turning the tide: The eradication of invasive species. World Conservation Union (IUCN), Gland, Switzerland.

SAUNDERS, G., B. COMAN, J. KINNEAR, AND M. BRAYSCHER. 1995. Managing vertebrate pests: Foxes. Australian Government Publishing Service, Canberra, Australia.

SEAMAN, G., AND J. RANDALL. 1962. The mongoose as a predator in the Virgin Islands. Journal of Mammalogy 43:544-546.

SHORT, J., J. KINNEAR, AND A. ROBLEY. 2002a. Surplus killing by introduced predators in Australia—evidence for ineffective anti-predator adaptations in native prey species? Biological Conservation 103:283-301

_____, B. TURNER, AND D. RISBEY. 2002b. Control of feral cats for nature conservation. Wildlife Research 29:475-487.

_____, _____, _____, AND R. CARHAMAH. 1997. Control of feral cats for nature conservation: Population reduction by poisoning. Wildlife Research 24:703-714.

SHWIFF, S. 2004. Economics in wildlife damage management studies: Common problems and some solutions. Proceedings of the Vertebrate Pest Conference 21:346-349.

TOWNS, D.R., C.H. DAUGHERTY AND I.A.E. ATKINSON, editors. 1990. Ecological restoration of New Zealand's "islands." Conservation Sciences Publication Number 2. Department of Conservation, Wellington, New Zealand.

VAN'T WOUDT, B.D. 1990. Roaming, stray, and feral domestic cats and dogs as wildlife problems. Proceedings of the Vertebrate Pest Conference 14:291-295.

VEITCH, C.R. 2001. The eradication of feral cats (*Felis catus*) from Little Barrier Island, New Zealand. New Zealand Journal of Zoology 28:1-12.

WARNER, R.D. 1984. Occurrence and impact of zoonoses in pet dogs and cats at US Air Force bases. American Journal of Public Health 74:1239-1243.

WHITTAKER, R.J. 1998. Island biogeography: Ecology, evolution and conservation. Oxford University Press, Oxford, United Kingdom.

WITMER, G., M. RODRIGUEZ, AND C. VAUGHAN. 1995. Aspects of felid predator control and conservation in Costa Rica. Pages 398-401 *in* J. Bissonette and P. Krausman, editors. Integrating people and wildlife for a sustainable future. Proceedings of the First International Wildlife Management Congress, The Wildlife Society, Bethesda, MD, USA.

_____, J. BUCKNALL, T. FRITTS, AND D. MORENO. 1996. Predator management to protect endangered avian species. Transactions of the North American Wildlife and Natural Resource Conference 61:102-108.

_____, AND J. LEWIS. 2001. Introduced wildlife of Oregon and Washington. Pages 423-443 *in* D. Johnson and T. O'Neil, editors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR, USA.

WOOD, B., B. TERSHY, M. HERMOSILLO, C. DONLAN, J. SANCHEZ, B. KEITT, D. CROLL, G. HOWALD, AND N. BIAVASCHI. 2002. Removing cats from islands in north-west Mexico. Pages 374-380 *in* C. Veitch and M. Clout, editors. Turning the tide: The eradication of invasive species. World Conservation Union (IUCN), Gland, Switzerland.