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Essay

Critical Assessment of Claims Regarding Management of Feral Cats by Trap–Neuter–Return

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Abstract: *Many jurisdictions have adopted programs to manage feral cats by trap–neuter–return (TNR), in which cats are trapped and sterilized, then returned to the environment to be fed and cared for by volunteer caretakers. Most conservation biologists probably do not realize the extent and growth of this practice and that the goal of some leading TNR advocates is that cats ultimately be recognized and treated as "protected wildlife." We compared the arguments put forth in support of TNR by many feral cat advocates with the scientific literature. Advocates promoting TNR often claim that feral cats harm wildlife only on islands and not on continents; fill a natural or realized niche; do not contribute to the decline of native species; and are insignificant vectors or reservoirs of disease. Advocates also frequently make claims about the effectiveness of TNR, including claims that colonies of feral cats are eventually eliminated by TNR and that managed colonies resist invasion by other cats. The scientific literature contradicts each of these claims. TNR of feral cats is primarily viewed and regulated as an animal welfare issue, but it should be seen as an environmental issue, and decisions to implement it should receive formal environmental assessment. Conservation scientists have a role to play by conducting additional research on the effects of feral cats on wildlife and by communicating sound scientific information about this problem to policy makers.*

Keywords: exotic species, *Felis catus*, no kill, predation, TNR, trap–neuter–release, urban ecology

Evaluación Crítica de las Demandas Relacionadas con el Manejo de Gatos Ferales en Programas de Captura–Esterilización–Liberación

Resumen: *Muchas jurisdicciones han adoptado programas para el manejo de gatos ferales mediante la captura–esterilización–liberación (CEL), en los que los gatos son atrapados y esterilizados y devueltos al ambiente para ser alimentados y cuidados por voluntarios. La mayoría de los biólogos de la conservación probablemente no comprenden la extensión y crecimiento de esta práctica y que la meta de los defensores de CEL es que los gatos sean reconocidos y tratados como "vida silvestre protegida." Comparamos los argumentos en apoyo a CEL por muchos defensores de gatos ferales con la literatura científica. Los defensores que promueven el CEL sostienen que los gatos ferales solo dañan a la vida silvestre en islas y no en los continentes; ocupan un nicho natural o realizado; no contribuyen a la declinación de especies nativas y son vectores o reservorios de enfermedad insignificantes. Los defensores frecuentemente también sostienen que la efectividad de CEL, incluyendo argumentos que las colonias de gatos ferales eventualmente son eliminadas por CEL y que las colonias manejadas resisten la invasión de otros gatos. La literatura científica contradice cada uno de esos argumentos. CEL de gatos ferales es vista y regulada principalmente como un asunto de bienestar animal, pero debería verse como un tema ambiental, y las decisiones para su implementación deberían recibir una evaluación ambiental formal. Los científicos de la conservación tienen un papel importante al realizar investigaciones adicionales sobre los efectos de los gatos ferales sobre la vida silvestre y en la comunicación de información científica sólida a los tomadores de decisiones.*

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Palabras Clave: captura–esterilización–liberación, CEL, depredación, ecología urbana, especies exóticas, no muerte

Introduction

Exotic and subsidized predators pose a grave threat to native species (Wilcove et al. 1998; Crooks & Soulé 1999), and feral domestic cats (*Felis catus*) are particularly harmful (Nogales et al. 2004). Domestic cats are on the list of the 100 worst invasive species globally (Lowe et al. 2000). In North America, however, advocates for feral cats have gained political strength and have influenced legislation, the funding agendas of foundations, and the policies of major animal-oriented nonprofit organizations. For example, in 2008 a coalition of organizations successfully blocked federal legislation that would have funded removal of exotic species from national wildlife refuges because feral cats might be targeted. Feral cat advocates usually promote trap–neuter–return (TNR) as a management approach (Berkeley 2004). Almost universally these advocates claim that TNR is the only proven, humane method to manage feral cats (Berkeley 2004; No Kill Advocacy Center 2006*a*,*b*; Winograd 2007).

Trap–neuter–return (or any number of similarly named variants) is an approach to feral cat management in which cats are surgically sterilized and returned to the environment, usually where they were captured (Barrows 2004; Berkeley 2004; Levy & Crawford 2004). The course of action after neutering varies, although advocates promote ongoing care of the cats in managed colonies (Slater 2002; Levy & Crawford 2004). Cats may be tested and vaccinated for some diseases and an ear tip may be removed before release to identify treated cats. Managers generally feed cats daily and seek to capture and sterilize any new cats (Slater 2004).

Animal advocates have increasingly called for shelters to avoid euthanasia of any healthy animals, an approach described as "no kill" (Levy & Crawford 2004; Winograd 2007). Although the effort to reduce euthanasia is long established and has widespread appeal, the generic no kill approach has been formalized by the No Kill Advocacy Center, a leading proponent of TNR, as the so-called no kill equation, the first element of which is a TNR program for feral cats (No Kill Advocacy Center 2006*b*; Winograd 2007). The stated goal of this program is for feral cats to be recognized as "protected healthy wildlife [that] should not enter shelters in the first place." This group believes "it is inevitable that the No Kill paradigm will eventually lead to laws that make it illegal for people to trap and kill healthy feral cats" (No Kill Advocacy Center 2006*a*). TNR approaches have been adopted in at least 10 large metropolitan areas in the United States (Berkeley 2004; The Humane Society of the United States 2008).

Unfortunately, TNR does not eliminate feral cat colonies under prevailing conditions (Jessup 2004; Winter 2004, 2006) and many false claims used to support the approach go unchallenged. Published research has been distorted by TNR proponents with little response from the scientific community, perhaps in part because TNR has been approached largely as an animal welfare issue instead of being recognized as a broad environmental issue with a range of impacts on species conservation, the physical environment, and human health. Conservation scientists and advocates must properly identify the environmental implications of feral cat management and actively engage this issue to bring scientific information to the attention of policy makers.

Environmental Effects of Feral and Free-Roaming Cats

Trap–neuter–return advocates use a series of arguments to justify the return of cats to places where they have adverse environmental consequences. Conservation scientists should be aware of these arguments because they are often presented to jurisdictions considering actions pertaining to feral cats.

Claim: Feral Cats Harm Wildlife Only on Islands and Not on Continents

Trap–neuter–return advocates argue that studies showing adverse effects of feral cats on islands do not apply to continents (Gorman & Levy 2004; Alley Cat Allies 2005). Cats are implicated in species declines and extinctions on islands (Nogales et al. 2004). The Stephens Island Wren (*Traversia lyalli*) was infamously driven to extinction by predation from feral cats, although not by a single cat as often reported (Galbreath & Brown 2004). Feral and free-roaming cats also affect wildlife on continents (Soulé et al. 1988; Hawkins 1998; Crooks & Soulé 1999; Jessup 2004). In urban and suburban areas, natural habitats resemble islands, where fragments are surrounded by an inhospitable matrix, but unlike on islands, the inhospitable areas serve as an ongoing source of subsidized predators (Walter 2004). In California, for example, increased predation is likely to occur in fragments <1.4 km^2, where probability of cat presence is higher. Larger areas are likely to have fewer cats because of the presence of larger predators (Soulé et al. 1988; Crooks 2002). Urban and suburban habitats, including yards, serve as valuable habitat for migratory and resident birds

(Pennington et al. 2008; Seewagen & Slayton 2008) and support local and regional biodiversity (Angold et al. 2006; Tratalos et al. 2007), so concerns about predation by feral cats should extend to these environments.

Claim: Feral Cats Fill a Natural or Realized Niche

Feral cats are exotic and do not fill an existing niche, but TNR advocates often argue that their long presence in ecosystems diminishes their impact (Gorman & Levy 2004). The sheer abundance of feral cats subsidized by humans, however, makes them an unnatural element of any ecosystem. Feral cats are generally found at densities 10–100 times higher than similarly sized native predators (Nowell & Jackson 1996; Liberg et al. 2000).

Cats managed in TNR colonies can continue to prey on species whose populations have declined to such levels that they would not support native predators (Soulé et al. 1988). This is a form of hyperpredation, similar to what occurs on oceanic islands where an exotic prey species (e.g., rats) supports an exotic predator (e.g., cats) that then devastates native prey (Courchamp et al. 2000; Woods et al. 2003). Owned cats also threaten native prey populations when they are allowed to roam outdoors, although this effect decreases (as it does for feral cats) with the presence of larger predators and harsh weather (Crooks & Soulé 1999; Kays & DeWan 2004). Feeding by humans reduces the average range size of free-roaming cats, but increases densities, concentrating predation on wildlife where feeding occurs (Schmidt et al. 2007).

Contrary to claims that well-fed cats pose little threat to wildlife, hunting and hunger are not linked in domestic cats (Adamec 1976). Even well-fed cats hunt and kill lizards, small mammals, birds, and insects (Liberg 1984; Castillo & Clarke 2003; Hutchings 2003). A classic study documented continuous kills by the same 3 well-fed house cats over 4 years (George 1974).

Claim: Feral Cats Do Not Contribute to the Declines of Native Species

Trap–neuter–return advocates frequently imply that because cats are not singled out in reviews of the causes of bird declines, cats must have no influence on bird populations (Alley Cat Allies 2005). Habitat loss and resulting fragmentation are indeed leading causes of species decline, but this does not mean that sources of direct mortality are not important to species dynamics. Furthermore, one of the adverse effects of fragmentation is increased predation by cats supported by humans (Wilcove 1985; Askins 1995) and evidence indicates that cats can play an important role in fluctuations of bird populations (Lepczyk et al. 2003; Woods et al. 2003).

Trap–neuter–return advocates cite the work of John Terborgh as vindicating cats as a cause of decline of North American birds because he did not specifically mention them in his paper on the decline of American songbirds (Terborgh 1992; Alley Cat Allies 2005). When informed of this by telephone, Terborgh said that this argument is "a preposterous extrapolation and grotesque distortion of something I didn't say" (personal communication). Nevertheless, variations on the claim that the decline of bird species is due to other factors and, by implication, not by cats, has been proffered by cat advocacy groups and has appeared in peer-reviewed veterinary journals (Slater 2004).

Comparative field studies and population measurements illustrate the adverse effects of feral and free-roaming cats on birds and other wildlife. In canyons in San Diego native bird diversity declined significantly with density of domestic cats (Crooks & Soulé 1999). In a comparative study in Alameda County, California, a site with a colony of feral cats had significantly fewer resident birds, fewer migrant birds, and fewer breeding birds than a control site without cats (Hawkins 1998). Ground-foraging species, notably California Quail (*Calipepla californica*) and California Thrashers (*Toxostoma redivivum*), were present at the control site but never observed at the site with cats. Native rodent density was drastically reduced at the site with cats, whereas exotic house mice (*Mus musculus*) were more common (Hawkins 1998). In Bristol, United Kingdom Baker et al. (2005) calculated that the predation rates by cats on 3 bird species in an urban area is high relative to annual productivity, which led the authors to suggest that the area under study may be a habitat sink. The fear of cats exhibited by birds can result in population declines even if predation is low or absent (Beckerman et al. 2007).

Most discussion of the effects of feral cats on wildlife concentrates on birds. Cat advocates correctly argue that birds are secondary prey items for cats under most (but not all) circumstances (Gillies & Clout 2003; Hutchings 2003). But even as a secondary prey item, the number of birds killed is vast, and evaluation of the importance of such mortality requires species-by-species consideration (Baker et al. 2005). Cat predation on mammals (Hawkins 1998; Baker et al. 2003; Meckstroth et al. 2007), reptiles (Iverson 1978), and even invertebrates (Gillies & Clout 2003) is also cause for concern because of direct impacts to native species and competition with native predators (George 1974). Rare and endangered species of birds, mammals, and reptiles are documented victims of feral cats (Winter 2004, 2006).

Feral and free-roaming cats are efficient predators, and their abundance results in substantial annual mortality of wildlife. Churcher and Lawton (1987) concluded that cats were responsible for 30% of the mortality of House Sparrows (*Passer domesticus*) in an English village. May (1988) extrapolated their results to an estimated 100 million birds and small mammals killed per year in England. Although this extrapolation is often criticized for the limited geographic scope and number of cats studied, Woods et al. (2003) confirmed and refined this result with a

larger sample size and geographic area that included England, Scotland, and Wales. From a survey of cat owners that documented prey returned by 696 cats, Woods et al. (2003) estimated that the 9 million cats in Britain kill at least 52–63 million mammals, 25–29 million birds, and 4–6 million reptiles each summer. In North America Coleman and Temple (1996) developed estimates of cat densities in Wisconsin and associated mortality of 8–217 million birds per year.

The focus in discussions of predation by feral cats on birds is usually whether the predation is significant at the population level (Lepczyk et al. 2003; Woods et al. 2003; Baker et al. 2005). We argue that it is philosophically inappropriate for population-level impacts to be the only criteria by which the effects of cats are judged. People who notice and care about birds are just as attuned to the loss of an individual bird in a backyard, or the decline of local populations of birds, as are feral cat advocates to the loss of individual feral cats. We see no justification for valuing birds and other wildlife only as populations while valuing cats as individuals.

Claim: Feral Cats Are Not Vectors or Reservoirs of Disease

Cats in TNR programs have infection rates of 5–12% for either feline leukemia virus (FeLV) or feline immunodeficiency virus (FIV) or both (Gibson et al. 2002; Lee et al. 2002; Wallace & Levy 2006). Only 2 of 7 TNR programs surveyed in the United States test for FeLV or FIV before releasing cats, and these tests are optional (Wallace & Levy 2006). Some programs vaccinate for these diseases without testing (Wallace & Levy 2006), but the vaccine is ineffective on infected animals. These diseases can be transmitted to owned domestic cats and to wildlife (Jessup et al. 1993; Roelke et al. 1993).

High densities of feral cats increase the prevalence of ectoparasites in the environment. For example, at a site in Florida, 93% of feral cats had fleas and 37% had ear mites (Akucewich et al. 2002). Fleas transmit disease-causing bacteria such as *Bartonella*, *Ricksettia*, and *Coxiella* between animals and humans (Chomel et al. 1996; Shaw et al. 2001), and arthropod vectors cause a high rate of disease transfer between feral cats (Chomel et al. 1996). A study of feral cats in Florida shows that 75% were infected with hookworms (Anderson et al. 2003). Cats infected with hookworms or roundworms shed the eggs of the parasite, which then accumulate in the soil where they can be transmitted to humans and wildlife (Uga et al. 1996). In backyards with feral cats in Prague, prevalence of roundworm eggs in soil reached 45% of all samples (Dubná et al. 2007). Anderson et al. (2003) conclude that feral cats may be reservoirs of hookworm infection for wild canids and felids in Florida.

Felids, including free-roaming and feral cats, are vectors of the protozoan *Toxoplasma gondii* (Dubey 1973), which can infect other wildlife and humans through contact with oocysts in soil, vegetation, or water (Afonso et al. 2006). Feral cats are vectors for transmission of rabies to humans (Patronek 1998). Over 80% of the prophylactic treatments administered to humans in the United States for possible exposure to rabies resulted from contact with stray or feral cats (Moore et al. 2000). Laboratory studies show that cats exposed to avian flu (H5N1) contract the disease and shed the virus extensively, raising concerns about cats as vectors for a pandemic (Rimmelzwaan et al. 2006).

Some TNR advocates argue that feral cats are infected with a variety of pathogens at the same rate as free-roaming owned cats (Levy & Crawford 2004; Luria et al. 2004). The correct comparison should be with indoor-only cats, which are healthier and live longer (Barrows 2004). Even so, other studies show elevated infection rates of disease-causing pathogens in stray and feral cats compared with owned cats as a whole, including those that roam (Dubey 1973; Nutter et al. 2004; Norris et al. 2007).

Fecal matter from feral and free-roaming cats degrades water quality (Dabritz et al. 2006). In an urban watershed in Michigan, Ram et al. (2007) showed that cats and dogs contribute more to fecal coliform bacteria contamination than other sources and that cats are 2 times more likely than dogs to be the source of bacteria. Runoff contaminated by cat feces also threatens sea mammals. Felids, including feral and free-roaming cats, shed *Toxoplasma* oocysts that infect southern sea otters (*Enhydra lutris nereis*) (Miller et al. 2002; Conrad et al. 2005), Pacific harbor seals (*Phoca vitulina richardsi*), and California sea lions (*Zalophus californianus*) (Conrad et al. 2005). The large quantity of waste from feral and free-roaming cats containing *Toxoplasma* oocysts (Dabritz et al. 2006, 2007) and the correlation between freshwater runoff and toxoplasmosis in marine mammals (Miller et al. 2002) has led researchers to suspect domestic cats as the source of the infections, although further research is needed to determine the relative importance of native versus exotic felids as sources of this parasite (Miller et al. 2008).

In terrestrial ecosystems *Toxoplasma* oocysts accumulate in the soil (Dabritz et al. 2007), where they can infect other species. For example, feral cats are implicated in *T. gondii* infection in the endangered island fox (*Urocyon littoralis*) on the California Channel Islands (Clifford et al. 2006).

Efficacy of TNR

Feral cat advocates regularly assert that TNR "works" and is proven effective. They support this claim with anecdotes of success and reference to selected peer-reviewed studies (Zaunbrecher & Smith 1993; Centonze & Levy 2002; Hughes & Slater 2002; Levy et al. 2003).

Nevertheless, the definition of a successful TNR program for feral cat advocates is almost always different from what a conservation biologist or policy maker might view as a successful feral cat management program. Reduced adverse effects on wildlife and rapid colony elimination are almost never included in the definition of success used by advocates (e.g., No Kill Advocacy Center 2006*a*). For many TNR advocates, success is not defined by elimination of feral cats in an area, but rather by the welfare of the cats. For example, one study concluded, "The effectiveness of the program was demonstrated by the low turnover and improved health of the colony over the 3-year period," but the colony size only decreased from 40 to 36 (Zaunbrecher & Smith 1993). Another seminal study used to support the notion that TNR works was based on the assumption that feral cats were desired at a location, in which case TNR would produce a "stable, healthy, and manageable colony" (Neville 1983). Similarly, a Florida county implemented TNR "to decrease the number of healthy cats euthanized, decrease the costs to the county, and decrease complaints" (Hughes et al. 2002). In contrast, conservation scientists and wildlife veterinarians measure success of a feral cat management program by the decline and elimination of free-roaming cats (e.g., Jessup 2004; Nogales et al. 2004).

Claim: Trap–Neuter–Return Eliminates Colonies under Prevailing Conditions

Supporters of TNR assert that managed colonies slowly shrink through attrition. Mathematical models of feral cat populations indicate that 71–94% of a population must be neutered for the population to decline, assuming there is no immigration (Andersen et al. 2004; Foley et al. 2005). This level of neutering and exclusion of additional cats has not been consistently documented in practice. A study of TNR implemented countywide in San Diego showed that feral cat populations had not decreased after 10 years, and a similar result was found after 7 years in Alachua County, Florida, where feral cat populations increased (Foley et al. 2005). Four years of TNR at a colony in London saw the population fluctuate between 19 and 17 with no indication of further decline (Neville 1989). Ten years of TNR in Rome showed a 16–32% decrease in population size across 103 colonies but concluded that TNR was "a waste of time, energy, and money" if abandonment of owned cats could not be stopped (Natoli et al. 2006). Two colonies subject to TNR in Florida were tracked for over a year and population size of both colonies increased owing to the influx of new cats dumped at the highly visible sites (Castillo & Clarke 2003).

Peer-reviewed reports of TNR decreasing the size of feral colonies (e.g., Levy et al. 2003) derive in part from intensive efforts to remove cats for adoption as part of the TNR program. In a TNR program on a Florida university campus, 73 of 155 cats (47%) were removed for adoption during the study period (Levy et al. 2003). In another program, during 2–3 years of TNR, 270 of 814 cats (33%) were captured and adopted, without which the number of cats at the 64 sites would have increased as a result of 87 cats joining the colonies while 50 died (Stull 2007). If adoption is sufficiently high, it may offset immigration to colonies and even reach the 50% removal threshold necessary for population decline (Andersen et al. 2004). Documented examples of dramatic population declines at TNR sites are from programs in limited geographic areas that were implemented with participation of the researchers themselves (e.g., Hughes & Slater 2002; Levy et al. 2003). Programs implemented by researchers are likely to be much more thorough than programs implemented exclusively by volunteers (see also examples in Jessup 2004).

Assertions of colony declines often are supported only by reference to Web sites, even in peer-reviewed articles (Gibson et al. 2002). Few published scientific studies document the actual disappearance of a colony through TNR and then only after many years of constant effort (e.g., Levy et al. 2003; Stoskopf & Nutter 2004).

Claim: Trap–Neuter–Return Colonies Resist Invasion

Feral cat advocates usually argue that managed colonies are stable and resist invasion by cats from surrounding areas (Berkeley 2004), but this assertion is not consistent with scientific literature or reports from TNR colonies (Stull 2007). For example, Levy et al. (2003) documented cats moving between identified colonies and to and from the surrounding woods. Cats do not defend territories when a constant food source is available (Levy & Crawford 2004) and can therefore reach high densities (Liberg et al. 2000; Schmidt et al. 2007). Populations can be limited by lack of shelter from the environment (Calhoon & Haspel 1989). Advocates also refer to a so-called vacuum effect in which new cats are said to immigrate to a location after removal programs (Patronek 1998; Gibson et al. 2002), but fail to provide evidence that such a phenomenon does not also occur when TNR colonies decrease in size.

Conclusions

Management of feral cats is usually governed by laws about pets and domestic animals, which vary by the patchwork of jurisdictions that control land uses. Although some entities in the U.S. federal government have banned TNR, most notably the U.S. Navy (Jessup 2004), it is largely local jurisdictions that are adopting TNR policies (The Humane Society of the United States 2008). These local policies typically do not receive the formal environmental review that projects with potential adverse

environmental effects normally require (Glasson et al. 1999). This probably results from the perception of TNR as an animal welfare, rather than environmental, measure.

The lack of formal environmental review of TNR makes it difficult for scientists, trustee agencies, and conservationists to give input. We urge greater engagement from conservation scientists at local to national levels to communicate that management of feral cats is not just an animal welfare issue. Scientists and conservationists have an important role to play by conducting research on feral cats and providing credible scientific information to resource managers, funding agencies, foundations, and policy makers about the adverse ecological consequences of condoning the indefinite maintenance of feral cat colonies through adoption of TNR as a preferred management scheme.

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Literature Cited

Adamec, R. E. 1976. The interaction of hunger and preying in the domestic cat (*Felis catus*): an adaptive hierarchy? Behavioral Biology **18:**263–272.

Afonso, E., P. Thulliez, and E. Gilot-Fromont. 2006. Transmission of *Toxoplasma gondii* in an urban population of domestic cats (*Felis catus*). International Journal for Parasitology **36:**1373–1382.

Akucewich, L. H., K. Philman, A. Clark, J. Gillespie, G. Kunkle, C. F. Nicklin, and E. C. Greiner. 2002. Prevalence of ectoparasites in a population of feral cats from north central Florida during the summer. Veterinary Parasitology **109:**129–139.

Alley Cat Allies. 2005. Understanding cats and predation. Alley Cat Allies, Bethesda, Maryland.

Andersen, M. C., B. J. Martin, and G. W. Roemer. 2004. Use of matrix population models to estimate the efficacy of euthanasia versus trap-neuter-return for management of free-roaming cats. Journal of the American Veterinary Medical Association **225:**1871–1876.

Anderson, T. C., G. W. Foster, and D. J. Forrester. 2003. Hookworms of feral cats in Florida. Veterinary Parasitology **115:**19–24.

Angold, P. G., et al. 2006. Biodiversity in urban habitat patches. Science of the Total Environment **360:**196–204.

Askins, R. A. 1995. Hostile landscapes and the decline of migratory songbirds. Science **267:**1956–1957.

Baker, P. J., R. J. Ansell, P. A. A. Dodds, C. E. Webber, and S. Harris. 2003. Factors affecting the distribution of small mammals in an urban area. Mammal Review **33:**95–100.

Baker, P. J., A. J. Bentley, R. J. Ansell, and S. Harris. 2005. Impact of predation by domestic cats *Felis catus* in an urban area. Mammal Review **35:**302–312.

Barrows, P. L. 2004. Professional, ethical, and legal dilemmas of trap-neuter-release. Journal of the American Veterinary Medical Association **225:**1365–1369.

Beckerman, A. P., M. Boots, and K. J. Gaston. 2007. Urban bird declines and the fear of cats. Animal Conservation **10:**320–325.

Berkeley, E. P. 2004. TNR past present and future: a history of the trap-neuter-return movement. Alley Cat Allies, Washington, D.C.

Calhoon, R. E., and C. Haspel. 1989. Urban cat populations compared by season, subhabitat and supplemental feeding. Journal of Animal Ecology **58:**321–328.

Castillo, D., and A. L. Clarke. 2003. Trap/neuter/release methods ineffective in controlling domestic cat "colonies" on public lands. Natural Areas Journal **23:**247–253.

Centonze, L. A., and J. K. Levy. 2002. Characteristics of free-roaming cats and their caretakers. Journal of the American Veterinary Medical Association **220:**1627–1633.

Chomel, B. B., R. W. Kasten, K. Floyd-Hawkins, B. Chi, K. Yamamoto, J. Roberts-Wilson, A. N. Gurfield, R. C. Abbott, N. C. Pedersen, and J. E. Koehler. 1996. Experimental transmission of *Bartonella henselae* by the cat flea. Journal of Clinical Microbiology **34:**1952–1956.

Churcher, P. B., and J. H. Lawton. 1987. Predation by domestic cats in an English village. Journal of Zoology, London **212:**439–455.

Clifford, D. L., J. A. K. Mazet, E. J. Dubovi, D. K. Garcelon, T. J. Coonan, P. A. Conrad, and L. Munson. 2006. Pathogen exposure in endangered island fox (*Urocyon littoralis*) populations: implications for conservation management. Biological Conservation **131:**230–243.

Coleman, J. S., and S. A. Temple. 1996. On the prowl. Wisconsin Natural Resources **20:**4–8.

Conrad, P. A., M. A. Miller, C. Kreuder, E. R. James, J. Mazet, H. Dabritz, D. A. Jessup, F. Gulland, and M. E. Grigg. 2005. Transmission of *Toxoplasma*: clues from the study of sea otters as sentinels of *Toxoplasma gondii* flow into the marine environment. International Journal for Parasitology **35:**1155–1168.

Courchamp, F., M. Langlais, and G. Sugihara. 2000. Rabbits killing birds: modelling the hyperpredation process. Journal of Animal Ecology **69:**154–164.

Crooks, K. R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology **16:**488–502.

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature **400:**563–566.

Dabritz, H. A., E. R. Atwill, I. A. Gardner, M. A. Miller, and P. A. Conrad. 2006. Outdoor fecal deposition by free-roaming cats and attitudes of cat owners and nonowners toward stray pets, wildlife, and water pollution. Journal of the American Veterinary Medical Association **229:**74–81.

Dabritz, H. A., M. A. Miller, E. R. Atwill, I. A. Gardner, C. M. Leutenegger, A. C. Melli, and P. A. Conrad. 2007. Detection of *Toxoplasma gondii*-like oocysts in cat feces and estimates of the environmental oocyst burden. Journal of the American Veterinary Medical Association **231:**1676–1684.

Dubey, J. P. 1973. Feline toxoplasmosis and coccidiosis: a survey of domiciled and stray cats. Journal of the American Veterinary Medical Association **162:**873–877.

Dubná, S., I. Langrová, I. Jankovská, J. Vadlejch, S. Pekár, J. Nápravník, and J. Fechtner. 2007. Contamination of soil with *Toxocara* eggs in urban (Prague) and rural areas in the Czech Republic. Veterinary Parasitology **144:**81–86.

Foley, P., J. E. Foley, J. K. Levy, and T. Paik. 2005. Analysis of the impact of trap-neuter-return programs on populations of feral cats. Journal of the American Veterinary Medical Association **227:**1775–1781.

Galbreath, R., and D. Brown. 2004. The tale of the lighthouse-keeper's cat: discovery and extinction of the Stephens Island wren (*Traversia lyalli*). Notornis **51:**193–200.

George, W. G. 1974. Domestic cats as predators and factors in winter shortages of raptor prey. Wilson Bulletin **86:**384–396.

Gibson, K. L., K. Keizer, and C. Golding. 2002. A trap, neuter, and release program for feral cats on Prince Edward Island. Canadian Veterinary Journal **43:**695–698.

Gillies, C., and M. Clout. 2003. The prey of domestic cats (*Felis catus*) in two suburbs of Auckland City, New Zealand. Journal of Zoology, London **259:**309–315.

Glasson, J., R. Therivel, and A. Chadwick. 1999. Introduction to environmental impact assessment: principles and procedures, process, practice and prospects. UCL Press, London.

Gorman, S., and J. Levy. 2004. A public policy toward the management of feral cats. Pierce Law Review **2:**157–181.

Hawkins, C. C. 1998. Impact of a subsidized exotic predator on native biota: effect of house cats (*Felis catus*) on California birds and rodents. Ph.D. dissertation. Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas.

Hughes, K. L., and M. R. Slater. 2002. Implementation of a feral cat management program on a university campus. Journal of Applied Animal Welfare Science **5:**15–28.

Hughes, K. L., M. R. Slater, and L. Haller. 2002. The effects of implementing a feral cat spay/neuter program in a Florida county animal control service. Journal of Applied Animal Welfare Science **5:**285–298.

Hutchings, S. 2003. The diet of feral house cats (*Felis catus*) at a regional rubbish tip, Victoria. Wildlife Research **30:**103–110.

Iverson, J. B. 1978. The impact of feral cats and dogs on populations of the West Indian rock iguana, *Cyclura carinata*. Biological Conservation **14:**63–73.

Jessup, D. A. 2004. The welfare of feral cats and wildlife. Journal of the American Veterinary Medical Association **225:**1377–1383.

Jessup, D. A., K. C. Pettan, L. J. Lowenstine, and N. C. Pedersen. 1993. Feline leukemia virus infection and renal spirochetosis in free-ranging cougar (*Felis concolor*). Journal of Zoo and Wildlife Medicine **24:**73–79.

Kays, R. W., and A. A. DeWan. 2004. Ecological impact of inside/outside house cats around a suburban nature preserve. Animal Conservation **7:**273–283.

Lee, I. T., J. K. Levy, S. P. Gorman, P. C. Crawford, and M. R. Slater. 2002. Prevalence of feline leukemia virus infection and serum antibodies against feline immunodeficiency virus in unowned free-roaming cats. Journal of the American Veterinary Medical Association **220:**620–622.

Lepczyk, C. A., A. G. Mertig, and J. Liu. 2003. Landowners and cat predation across rural-to-urban landscapes. Biological Conservation **115:**191–201.

Levy, J. K., and P. C. Crawford. 2004. Humane strategies for controlling feral cat populations. Journal of the American Veterinary Medical Association **225:**1354–1360.

Levy, J. K., D. W. Gale, and L. A. Gale. 2003. Evaluation of the effect of a long-term trap-neuter-return and adoption program on a free-roaming cat population. Journal of the American Veterinary Medical Association **222:**42–46.

Liberg, O. 1984. Food habits and prey impact by feral and house-based domestic cats in a rural area in southern Sweden. Journal of Mammalogy **65:**424–432.

Liberg, O., M. Sandell, D. Pontier, and E. Natoli. 2000. Density, spatial organisation and reproductive tactics in the domestic cat and other felids. Pages 119–147 in D. C. Turner and P. Bateson, editors. The domestic cat: the biology of its behaviour. Cambridge University Press, Cambridge, United Kingdom.

Lowe, S., M. Browne, and S. Boudjelas. 2000. 100 of the world's worst invasive alien species: a selection from the global invasive species database. Invasive Species Specialist Group, International Union for Conservation of Nature, Auckland, New Zealand.

Luria, B. J., J. K. Levy, M. R. Lappin, E. B. Breitschwerdt, A. M. Legendre, J. A. Hernandez, S. P. Gorman, and I. T. Lee. 2004. Prevalence of infectious diseases in feral cats in Northern Florida. Journal of Feline Medicine and Surgery **6:**287–296.

May, R. M. 1988. Control of feline delinquency. Nature **332:**392–393.

Meckstroth, A. M., A. K. Miles, and S. Chandra. 2007. Diets of introduced predators using stable isotopes and stomach contents. Journal of Wildlife Management **71:**2387–2392.

Miller, M. A., et al. 2002. Coastal freshwater runoff is a risk factor for *Toxoplasma gondii* infection of southern sea otters (*Enhydra lutris nereis*). International Journal for Parasitology **32:**997–1006.

Miller, M. A., et al. 2008. Type X *Toxoplasma gondii* in a wild mussel and terrestrial carnivores from coastal California: new linkages between terrestrial mammals, runoff and toxoplasmosis of sea otters. International Journal for Parasitology **38:**1319–1328.

Moore, D. A., W. M. Sischo, A. Hunter, and T. Miles. 2000. Animal bite epidemiology and surveillance for rabies postexposure prophylaxis. Journal of the American Veterinary Medical Association **217:**190–194.

Natoli, E., L. Maragliano, G. Cariola, A. Faini, R. Bonanni, S. Cafazzo, and C. Fantini. 2006. Management of feral domestic cats in the urban environment of Rome (Italy). Preventive Veterinary Medicine **77:**180–185.

Neville, P. 1983. Humane control of an urban cat colony. International Pest Control **25:**144–145, 152.

Neville, P. N. 1989. Feral cats: management of urban populations and pest problems by neutering. Pages 261–268 in R. J. Putman, editor. Mammals as pests. Kluwer, London.

No Kill Advocacy Center. 2006*a*. A model feral cat policy. No Kill Sheltering November/December:10–12.

No Kill Advocacy Center. 2006*b*. The no kill equation. No Kill Sheltering July/August:7–11.

Nogales, M., A. Martín, 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.

Norris, J. M., E. T. Bell, L. Hales, J. A. Toribio, J. D. White, D. I. Wigney, R. M. Baral, and R. Malik. 2007. Prevalence of feline immunodeficiency virus infection in domesticated and feral cats in eastern Australia. Journal of Feline Medicine and Surgery **9:**300–308.

Nowell, K., and P. Jackson, editors. 1996. Status survey and conservation action plan: wild cats. IUCN, Gland, Switzerland, and Cambridge, United Kingdom.

Nutter, F. B., J. P. Dubey, J. F. Levine, E. B. Breitschwerdt, R. B. Ford, and M. K. Stoskopf. 2004. Seroprevalences of antibodies against *Bartonella henselae* and *Toxoplasma gondii* and fecal shedding of *Cryptosporidium* spp, *Giardia* spp, and *Toxocara cati* in feral and pet domestic cats. Journal of the American Veterinary Medical Association **225:**1394–1398.

Patronek, G. J. 1998. Free-roaming and feral cats—their impact on wildlife and human beings. Journal of the American Veterinary Medical Association **212:**218–226.

Pennington, D. N., J. Hansel, and R. B. Blair. 2008. The conservation value of urban riparian areas for landbirds during spring migration: land cover, scale, and vegetation effects. Biological Conservation **141:**1235–1248.

Ram, J. L., B. Thompson, C. Turner, J. M. Nechvatal, H. Sheehan, and J. Bobrin. 2007. Identification of pets and raccoons as sources of bacterial contamination of urban storm sewers using a sequence-based bacterial source tracking method. Water Research **41:**3605–3614.

Rimmelzwaan, G. F., D. van Riel, M. Baars, T. M. Bestebroer, G. van Amerongen, R. A. M. Fouchier, A. D. M. E. Osterhaus, and T. Kuiken. 2006. Influenza A virus (H5N1) infection in cats causes systemic disease with potential novel routes of virus spread within and between hosts. American Journal of Pathology **168:**176–183.

Roelke, M. E., D. J. Forrester, E. R. Jacobson, G. V. Kollias, F. W. Scott, M. C. Barr, J. F. Evermann, and E. C. Pirtle. 1993. Seroprevalence of infectious disease agents in free-ranging Florida panthers (*Felis concolor coryi*). Journal of Wildlife Diseases **29:**36–49.

Schmidt, P. M., R. R. Lopez, and B. A. Collier. 2007. Survival, fecundity, and movements of free-roaming cats. Journal of Wildlife Management **71:**915–919.

Seewagen, C. L., and E. J. Slayton. 2008. Mass changes of migratory landbirds during stopovers in a New York City park. Wilson Journal of Ornithology **120:**296–303.

Shaw, S. E., R. J. Birtles, and M. J. Day. 2001. Arthropod-transmitted infectious diseases of cats. Journal of Feline Medicine and Surgery **3:**193–209.

Slater, M. R. 2002. Community approaches to feral cats: problems, alternatives, and recommendations. Humane Society Press, Washington, D.C.

Slater, M. R. 2004. Understanding issues and solutions for unowned, free-roaming cat populations. Journal of the American Veterinary Medical Association **225:**1350–1354.

Soulé, M. E., D. T. Bolger, A. C. Alberts, J. Wright, M. Sorice, and S. Hill. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conservation Biology **2:**75–92.

Stoskopf, M. K., and F. B. Nutter. 2004. Analyzing approaches to feral cat management—one size does not fit all. Journal of the American Veterinary Medical Association **225:**1361–1364.

Stull, G. B. 2007. Burlington County Feral Cat Initiative census/progress report 2007. Burlington County Feral Cat Initiative, Vincentown, New Jersey.

Terborgh, J. 1992. Why American songbirds are vanishing. Scientific American **266:**98–104.

The Humane Society of the United States. 2008. Resources for helping feral cats. Washington, D.C. Available from http://www.hsus.org/pets/issues_affecting_our_pets/feral_cats/feral_cat_resources.html (accessed October 2008).

Tratalos, J., R. A. Fuller, P. H. Warren, R. G. Davies, and K. J. Gaston. 2007. Urban form, biodiversity potential and ecosystem services. Landscape and Urban Planning **83:**308–317.

Uga, S., T. Minami, and K. Nagata. 1996. Defecation habits of cats and dogs and contamination by *Toxocara* eggs in public park sand pits. American Journal of Tropical Medicine **54:**122–126.

Wallace, J. L., and J. K. Levy. 2006. Population characteristics of feral cats admitted to seven trap-neuter-return programs in the United States. Journal of Feline Medicine and Surgery **8:**279–284.

Walter, H. S. 2004. The mismeasure of islands: implications for biogeographical theory and the conservation of nature. Journal of Biogeography **31:**177–197.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology **66:**1211–1214.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience **48:**607–615.

Winograd, N. J. 2007. Redemption: the myth of pet overpopulation and the no kill revolution in America. Almaden Books, Los Angeles.

Winter, L. 2004. Trap–neuter–release programs: the reality and the impacts. Journal of the American Veterinary Medical Association **225:**1369–1376.

Winter, L. 2006. Impacts of feral and free-ranging cats on bird species of conservation concern: a five-state review of New York, New Jersey, Florida, California, and Hawaii. American Bird Conservancy, The Plains, Virginia.

Woods, M., R. A. McDonald, and S. Harris. 2003. Predation of wildlife by domestic cats *Felis catus* in Great Britain. Mammal Review **33:**174–188.

Zaunbrecher, K. I., and R. E. Smith. 1993. Neutering of feral cats as an alternative to eradication programs. Journal of the American Veterinary Medical Association **203:**449–452.