



Published in final edited form as:

Zoonoses Public Health. 2014 June ; 61(4): 290–296. doi:10.1111/zph.12070.

Rabies Prevention and Management of Cats in the Context of Trap, Neuter, Vaccinate, Release Programs

Allison D. Roebing, MPH, DVM^a, Dana Johnson, DVM^b, Jesse D. Blanton, MPH^{a,*}, Michael Levin, PhD^a, Dennis Slate, PhD^c, George Fenwick, PhD^d, and Charles E. Rupprecht, VMD, PhD^a

^aCenters for Disease Control and Prevention, Atlanta, Georgia, USA

^bUniversity of Illinois, Urbana, Illinois, USA

^cUnited States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, Manchester, New Hampshire, USA

^dAmerican Bird Conservancy, The Plains, Virginia, USA

Summary

Domestic cats are an important part of many Americans' lives, but effective control of the 60–100 million feral cats living throughout the country remains problematic. Although Trap-Neuter-Vaccinate-Return (TNVR) programs are growing in popularity as alternatives to euthanizing feral cats, their ability to adequately address disease threats and population growth within managed cat colonies is dubious. Rabies transmission via feral cats is a particular concern as demonstrated by the significant proportion of rabies postexposure prophylaxis associated with exposures involving cats. Moreover, TNVR has not been shown to reliably reduce feral cat colony populations because of low implementation rates, inconsistent maintenance, and immigration of unsterilized cats into colonies. For these reasons, TNVR programs are not effective methods for reducing public health concerns or for controlling feral cat populations. Instead, responsible pet ownership, universal rabies vaccination of pets, and removal of strays remain integral components to control rabies and other diseases.

Keywords

Cat; Vaccination; TNR; Release; Trap

Introduction

The relationship between humans and domestic cats originated 10,000 years ago when modern cats diverged from wildcat ancestors to live among *Homo sapiens* in the Middle East (Southwest Asia) (Driscoll *et al.*, 2009). These cat ancestors spread throughout the Old World and eventually were brought to the Americas, where they are not native, by European settlers less than five hundred years ago (Lipinski *et al.*, 2008). Today, domestic cats persist

*Corresponding author: Jesse D. Blanton, Centers for Disease Control and Prevention, 1600 Clifton Rd, MS G33, Atlanta, GA 30333, (P) 404-639-2289, (F) 404-639-1564, Asi5@cdc.gov.

in the United States as popular and beloved pets; however, effective control of the 60–100 million feral cats living throughout the country remains problematic (Jessup, 2004). While removal of unowned (“stray”) domestic animals has been the historical approach, these animal control programs are criticized for euthanizing cats that are not, or cannot, be adopted (Alley_Cat_Allies, 2012a). Recent focus has turned to Trap-Neuter-Release (TNR), Trap-Neuter-Vaccinate-Return (TNVR), and other similarly named programs as alternatives to euthanasia. These programs involve humane trapping of feral cats, sterilization surgery, and return to the environment, often but not always with vaccination against rabies and other diseases (Alley_Cat_Allies, 2012c). Such programs generate support and enthusiasm from many animal welfare advocates, yet these managed feral cat “colonies” are not innocuous. Feral cats can cause considerable mortality to local wildlife (Jessup, 2004, Hawkins *et al.*, 1999, Baker *et al.*, 2008), act as reservoirs for feline-specific diseases (Cohn, 2011, Al-Kappany *et al.*, 2011, Nutter *et al.*, 2004a), and transmit zoonotic diseases to humans (Nutter *et al.*, 2004a, McElroy *et al.*, 2010, CDC, 1995, CDC, 2008b). Additionally, claims by TNR advocates that managed colonies can reduce feral cat populations and control rodents are contradicted by research (Hawkins *et al.*, 1999, Castillo & Clarke, 2003, Longcore *et al.*, 2009, Gunther *et al.*, 2011). As such, communities deciding how to manage feral cat overpopulation are torn between the competing interests of cats, wildlife, and public health.

Rabies is a zoonotic disease of particular importance. The World Health Organization attributes more than 55,000 human deaths each year to rabies worldwide primarily in countries where canine rabies has not been controlled (WHO, 2005).. Effective rabies control programs in the United States limit human deaths attributed to rabies to just a few each year. However, up to 38,000 persons are estimated to receive rabies postexposure prophylaxis (PEP) annually due to a potential exposure (Christian *et al.*, 2009). In addition to PEP, vaccination of owned pets and removal of stray cats and dogs are also important in preventing human rabies mortality by reducing the opportunities for exposure. The interaction between cats and raccoons or other wildlife rabies reservoirs is the source of rabies infection by which cats may subsequently infect people. As a rabies vector, cats pose a disproportionate risk for potential human exposures compared to wildlife reservoir species in part because people, and especially children, are more likely to approach them. As such, potential exposures from cats of unknown vaccination history account for a substantial proportion of PEP administered annually in the U.S. (Moore *et al.*, 2000, Hensley, 1998). They also pose a considerable rabies risk to persons who are exposed but fail to recognize the need for PEP, as is sometimes the case with children (CDC, 2012). Thus, comprehensive rabies control requires continued implementation of current policies for animal vaccination and removal of strays, as well as administration of PEP following potential exposures. The policies outlined in the National Association of State Public Health Veterinarians (NASPHV) Compendium of Animal Rabies Control and Prevention specifically state that all cats be up-to-date on rabies vaccine, a daunting challenge for any caretaker with a sizable feral cat colony (National Association of State Public Health Veterinarians, 2011).

In this review, we focus on the impact of managed feral cats from a public health perspective. Special emphasis is given to rabies virus because it is often discounted as a risk by TNVR advocates (Alley_Cat_Allies, 2012b). In addition, we review scientific literature regarding the efficacy of TNVR programs to achieve rabies vaccination coverage and impact

feral cat populations. Lastly, we consider other community concerns that arise when addressing managed feral cat colonies and their impact on wildlife.

Cats and the Threat of Rabies

Throughout the world, dogs are the rabies reservoir of greatest human health concern, causing 99% of human infections (WHO, 2005). In the U.S., however, the canine rabies virus variants have been recently eliminated and, as such, dogs are now a vector species for wildlife rabies instead of a reservoir. In 2010, 303 rabid cats were reported through national surveillance, compared to only 69 dogs (Blanton *et al.*, 2011). This 4-fold difference is in sharp contrast to the pattern reported in 1946 (prior to mass vaccination of dogs), when 8,384 rabid dogs were reported compared to only 455 cats (Held *et al.*, 1967). The dramatic decline in dog rabies from over 8,000 cases a year to fewer than a hundred was accomplished through policies that promote mass vaccination coverage and control of strays, but adherence to these policies appears limited for cats (National Association of State Public Health Veterinarians, 2011, CDC, 2008a). Legislation reflects this disparity; canine rabies vaccination is required by 38 states, but only 30 states require cats to be vaccinated (Blanton *et al.*, 2010). Because control tactics for cats are less emphasized, the number of reported rabies cases in cats has not declined in the same way as it has in dogs.

PEP has been crucial to the prevention of human deaths due to rabies following contact with rabid cats, where contact is defined as an exposure that could potentially transmit rabies virus. No national reporting system exists to quantify the proportion of PEP attributable to cat exposures, but estimates indicate that 16% of PEP administration in the US is likely due to cats and may account for the majority of PEP administration in some areas (Christian *et al.*, 2009). Some regions experience much higher rates of PEP from cat exposures. A study of 67 counties in Pennsylvania found that 44% of PEP administration was due to cats, most of which (82%) were feral, stray, or unowned (Moore *et al.*, 2000). Similarly, New York state attributes more PEP administration to cat exposures (32%) than any other species (Eidson & Bingman, 2010). Most striking, a study in Montgomery County, Virginia attributed 63% of PEP recommendations to stray cat exposures compared with only 8% for wild animal contact (Hensley, 1998). In this community, the high rate of PEP due to cats resulted in part from the lack of a county animal shelter facility for cats, illustrating the need for removal of feral and stray cats as a means of rabies control and PEP reduction.

The propensity to underestimate rabies risk from cats has led to multiple large-scale rabies exposures and potentially caused a recent case of clinical rabies. In 1994, 665 persons in New Hampshire received PEP following exposures to a rabid stray kitten of unknown history, one of the largest documented mass exposure events recorded in the US (CDC, 1995); for each person, exposure status was either sufficient for transmission or could not be determined because of the young age of those exposed. Similarly, contact with a rabid stray kitten found at a South Carolina softball tournament led to 27 individuals requiring and receiving PEP in 2008 based on exposure of open wounds or mucous membranes to the kitten's saliva (CDC, 2008b). Individuals who are exposed to saliva from rabid cats in an open wound or mucous membrane and are not administered PEP are at risk of developing rabies and death. During 2011, an 8 year old girl contracted rabies because no one was

aware of an exposure; investigation showed that she had petted and been scratched by stray cats around her school weeks before developing clinical signs, but because she recalled no animal bites and none of the cats captured after her illness were rabid, the definitive source of her infection was never identified (CDC, 2012). While this was an atypical case of human rabies with the child surviving, the vast majority of rabies victims die. Historically, exposures to rabid cats resulted in human fatalities in 1960 and 1975 (Anderson *et al.*, 1984). In addition to these reported human cases associated with exposures to cats, more than 25,000 cats are submitted for rabies diagnosis each year in the US to rule-out potential human exposures (Blanton *et al.*, 2011). All of these examples illustrate both the real potential for feline rabies infection and potential for transmission to humans.

Human rabies fatalities are rare in the US thanks to the effectiveness of properly administered modern PEP, but treatment is expensive. Biologics alone cost in excess of \$2000 (Shwiff *et al.*, 2007). When mass exposure events occur, the monetary burden can be substantial; PEP for the New Hampshire mass exposure event referenced above totaled \$1.1 million (CDC, 1995). Also, while comparatively safe, it should be noted that severe adverse events have been rarely reported in association with rabies PEP (CDC, 2008a).

Public Health and TNVR Programs

The ability of TNVR programs to achieve appropriate levels of rabies vaccination coverage in feral cat populations is doubtful. The current recommendations of the American Association of Feline Practitioners (AAFP) and the European Advisory Board on Cat Diseases (ABCD) state that kittens should be vaccinated against rabies between 12–16 weeks of age, boosted at a year, and then again at the interval recommended by the manufacturer (Richards *et al.*, 2006). Unfortunately, most cats in TNVR programs will only be trapped once in their lifetimes (Richards *et al.*, 2006). While feral cats in managed colonies live far shorter lives on average than indoor cats, many can live at least six years (Levy *et al.*, 2003), and therefore one vaccine dose does not necessarily offer lifetime coverage. Additionally, annual trapping rates of less than 10% (Foley *et al.*, 2005) cannot reach a sufficient proportion of the population to establish and maintain herd immunity, even without accounting for declines in vaccine-induced immunity over time. Furthermore, the lack of consistent, verifiable documentation of vaccination for cats in TNVR programs makes it unlikely that vaccination would change practices regarding human exposure assessment and PEP. When a stray cat involved in an exposure to a human is captured, it is recommended that the animal be confined and observed for ten days or immediately euthanized and tested for rabies (CDC, 2008a). Generally, if the animal cannot be captured, persons should begin PEP. Given the challenges above, ongoing vaccination of colony cats in a TNVR campaign would not be likely to impact these recommendations or the risk assessment process.

Many other potential zoonotic and cat-specific diseases are harbored in feral cat populations in addition to rabies. Among these are bartonellosis, toxoplasmosis, plague, endo- and ectoparasites, feline immunodeficiency virus (FIV), feline leukemia virus (FeLV), and rickettsial diseases (Al-Kappany *et al.*, 2011, Nutter *et al.*, 2004b, McElroy *et al.*, 2010, Little, 2011). The feline immunosuppressive diseases (i.e. FIV and FeLV) are especially

important because they may predispose infected cats to developing additional viral, bacterial, or parasitic diseases that can be passed to humans or owned cats (Al-Kappany et al., 2011). Many of these diseases are prevalent at higher levels in feral cats compared to the owned pet population because outdoor access poses the greatest risk of infection (Little, 2011). Group-feeding of cats by colony caretakers puts cats at greater risk for contracting diseases whose transmission is augmented by increased animal density and contact rates among cats. Feline Respiratory Disease Complex (FRDC), a group of pathogens that lead to high morbidity in shelters, catteries, and colony feeding sites, is one such example (Cohn, 2011); however, other diseases are likely to be facilitated as well.

Group feeding also increases risk for contracting rabies and other wildlife diseases by enabling greater contact along the interface between cat colonies and wildlife reservoirs. A TNVR study in Florida reported that a feral cat feeding site attracted raccoons and opossums (Levy et al., 2003), and studies with rabies oral vaccine baits have shown cats sharing sites with these species as well as gray foxes (Olson *et al.*, 2000) (Figure 1). Feeding sites that attract raccoons, skunks, and foxes are particularly dangerous because these species are rabies reservoirs in the U.S (CDC, 2008a). Cross-species contact also allows feral cat populations to spread diseases to wildlife. In one study, about a third of raccoons and opossums sharing habitats with feral cats showed evidence of past infection with *Toxoplasma gondii*, a deadly zoonosis that requires felids to complete its life cycle (Fredebaugh *et al.*, 2011).

Effectiveness of TNVR Programs

Other disease risks notwithstanding, maintaining adequate rabies vaccination coverage in feral cat populations is impractical, if not impossible. Therefore, these populations must be reduced and eliminated to manage the public health risk of rabies transmission. Traditional animal control policies have stressed stray animal control and removal since the 1940s (Held et al., 1967, Anderson et al., 1984), and such policies were a major factor in the decline of canine rabies in the US. In contrast, less emphasis on control and removal of stray cats is likely the cause of increased numbers of rabid cats compared to dogs (CDC, 2008a). TNVR programs claim to reduce stray cat populations over time, but evidence indicates that current implementations are unlikely to achieve declines in populations (Longcore et al., 2009). A study of 103 local colonies in Rome, Italy, found that while half of the colonies reported population decreases, virtually the same number were stable or showed increases (Natoli *et al.*, 2006) in spite of an active sterilization campaign and the adoption of most of the kittens being born in colonies. A Tel Aviv, Israel study similarly showed that two colony populations continued to grow even at 73–75% sterilization, mostly due to immigration from surrounding cat populations (Gunther et al., 2011). Likewise, managed cat colonies in two Florida parks increased in size despite TNR programs (Castillo & Clarke, 2003). These failures can be attributed in part to inadequate levels of sterilization. One model estimates that the percent sterilization needed to reduce feral cat populations is between 71% and 94%, levels that are rarely reached in real-world scenarios (Foley et al., 2005). Similarly, another study concluded that 90% sterilization is necessary to reduce feral cat populations (Jones & Downs, 2011).

Evidence from other model-based analyses of TNR programs showed that while TNVR may be useful if broadly implemented in closed populations when no animals can immigrate into colonies (e.g. island settings), it is ineffective in open populations that more closely resemble most cat colonies in the U.S. (Schmidt *et al.*, 2009). Facing these challenges, many TNVR programs only show positive results at temporarily reducing cat numbers when heavily subsidized by adoptions and assisted by colony cat emigration to other areas (Levy *et al.*, 2003). Moreover, while emigrants do technically reduce the number of cats living in a particular colony, they should not be interpreted as reducing the overall feral cat population. Thus, unless sterilization is nearly universal and unneutered cats are prevented from immigrating, colony populations do not decrease and eventually disappear with time, and may increase in response to supplemental feeding.

Feral Cats and Wildlife

Exotic feral cats can have profound ecological effects on native species. As an obligate predator, this invasive species often preys on native wildlife. A study comparing an area with supplemental feral cat feeding to one without it found that the area with feeding had reduced abundance of native rodent and bird populations, illustrating that supplemental feeding attracts cats without substantially decreasing their hunting behavior (Hawkins *et al.*, 1999). When the quantitative effects of cat predation have been estimated, results are striking. One study in the United Kingdom observed sites where the estimated number of birds killed was greater than the number fledged for multiple passerine species (Baker *et al.*, 2008). Despite their ability to affect native bird and mammal populations, cats do not appear to significantly decrease populations of synanthropic pest species. Feeding sites do not show decreased populations of house mice, as access to a constant food source may increase their populations (Hawkins *et al.*, 1999). The difference in the effects of cats on native fauna compared to exotic rodents may be due to their coevolution with foreign pest species, which made pests better adapted to evasion of cats (Jessup, 2004). In addition to the risks posed by feral cats to biodiversity and ecosystems, several wildlife veterinarians and scientists question the logic of prioritizing feral cat welfare over the welfare of native prey animals (Jessup, 2004).

Discussion

Rabies remains an important cause of human mortality throughout the world, but the effectiveness of control programs in the U.S. may subdue the collective memory of the significance of rabies. Despite the presence of enzootic rabies in nearly every state, only a few human deaths are reported each year in the U.S. This accomplishment is entirely the result of practical, effective public health policy and education in tandem with appropriate animal vaccines and vaccination schedules, use of PEP, and stray animal management.

Unfortunately, most current applications of TNVR programs do not provide effective rabies vaccination coverage or cat population control. Current NASPHV rabies recommendations stipulate that all cats, dogs, and ferrets be current on rabies vaccinations. Within feral cat colonies, even those with TNVR programs, compliance with national vaccination recommendations or laws that uphold them are likely to be impractical. Although most

caretakers provide food for colonies, adequate domestic animal care also requires prevention of disease and unmitigated breeding. Feeding of feral cat colonies sustains their populations, and it likely subjects them to increased disease transmission by increasing cat densities and contact rates at feeding sites (Jessup, 2004, Hawkins et al., 1999, Cohn, 2011). TNVR does not adequately meet feral cat population control needs that public health and animal welfare necessitate.

Feral cat population control should be conducted with the input of all invested stakeholders such that an effective and ethically acceptable method for controlling feral cats and their associated potential public health concerns can be achieved. One recent study, which modeled costs and benefits for TNVR as compared to trap and euthanize programs, found that in all scenarios trap and euthanize programs were cheaper to conduct and had a higher economic benefit (Lohr et al., 2012). However, that study found that the relative difference in benefits between both programs was reduced as the abandonment rate of cats in the community increased.

Domestic cats are an important part of American culture and provide companionship for millions of people. As such, it is important for public health institutions to take a science-based stance for effective and humane management of feral cat populations. While TNVR programs may be a component in controlling small populations of cats (particularly in closed population settings) it should not be endorsed as an effective approach by itself or as a method for mitigating health concerns related to feral cat colonies. Any stance should include objectives that are shown to reduce the disease burden on both the feral and owned populations of cats and to lessen the risk of zoonotic diseases, including rabies, to humans. Most importantly, any program focused on reducing feral cat populations should include components to reduce abandonment rates of cats. It is critical to educate cat owners on responsible pet ownership including the importance of maintaining a regular vaccination schedule, keeping records of these vaccinations for their cats, restricting their cats from roaming freely, and spaying and neutering to prevent unwanted kittens that will be abandoned rather than adopted to responsible homes. Furthermore, state and local governments will need to enact or enforce existing animal control laws to uphold these public health recommendations. In particular, requirements for rabies vaccination, requirements or incentives to spay or neuter, and prohibitions against free-roaming should be applied to cats as they are generally applied to dogs; they reflect standards of ownership that are appropriate for all domestic companion animals. By following these steps, feral cat populations and associated zoonotic diseases such as rabies can be better controlled. However, continued research to establish best practices for developing and effectively implementing comprehensive cat population control programs is warranted.

Acknowledgments

The authors would like to thank Ben Beard, Marta Guerra, Barbara Knust, Robert Massung, Andrea McCollum, Jennifer McQuiston, and Susan Montgomery at the Centers for Disease Control and Prevention and Steve Holmer at the American Bird Conservancy for their review and input during the writing of the manuscript. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention. Allison Roebing is a recent graduate of the University of Georgia's dual DVM/MPH program. Her studies focus on zoonotic infectious diseases including rabies and leishmaniasis.

References

- Al-Kappany YM, Lappin MR, Kwok OCH, Abu-Elwafa SA, Hilali M, Dubey JP. Seroprevalence of *Toxoplasma Gondii* and Concurrent *Bartonella Spp.*, Feline Immunodeficiency Virus, Feline Leukemia Virus, and *Dirofilaria Immitis* Infections in Egyptian Cats. *Journal of Parasitology*. 2011; 97:256–258. [PubMed: 21506874]
- Alley_Cat_Allies. Cat Fatalities and Secrecy in U.S. Pounds and Shelters. Alley Cat Allies; 2012a.
- Alley_Cat_Allies. Feral Cat Health Analysis: Living Health Lives Outdoors. Alley Cat Allies; 2012b.
- Allies, AC., editor. Alley_Cat_Allies. How to Conduct Trap-Neuter-Return. 2012c.
- Anderson LJ, Nicholson KG, Tauxe RV, Winkler WG. Human rabies in the United States, 1960 to 1979: epidemiology, diagnosis, and prevention. *Ann Intern Med*. 1984; 100:728–735. [PubMed: 6712036]
- Baker PJ, Molony SE, Stone E, Cuthill IC, Harris S. Cats about town: is predation by free-ranging pet cats *Felis catus* likely to affect urban bird populations? *Ibis*. 2008; 150:86–99.
- Blanton JD, Palmer D, Dyer J, Rupprecht CE. Rabies surveillance in the United States during 2010. *J Am Vet Med Assoc*. 2011; 239:773–783. [PubMed: 21916759]
- Blanton JD, Palmer D, Rupprecht CE. Rabies surveillance in the United States during 2009. *J Am Vet Med Assoc*. 2010; 237:646–657. [PubMed: 20839985]
- Castillo D, Clarke AL. Trap/neuter/release methods ineffective in controlling domestic cat “colonies” on public lands. *Nat Area J*. 2003; 23:247–253.
- CDC. Mass treatment of humans exposed to rabies--New Hampshire, 1994. *MMWR Morb Mortal Wkly Rep*. 1995; 44:484–486. [PubMed: 7791736]
- CDC. Human rabies prevention--United States, 2008: recommendations of the Advisory Committee on Immunization Practices. *MMWR Recomm Rep*. 2008a; 57:1–28.
- CDC. Public health response to a rabid kitten--four states, 2007. *MMWR Morb Mortal Wkly Rep*. 2008b; 56:1337–1340. [PubMed: 18172419]
- CDC. Recovery of a patient from clinical rabies--California, 2011. *MMWR Morb Mortal Wkly Rep*. 2012; 61:61–65. [PubMed: 22298301]
- Christian KA, Blanton JD, Auslander M, Rupprecht CE. Epidemiology of rabies post-exposure prophylaxis--United States of America, 2006–2008. *Vaccine*. 2009; 27:7156–7161. [PubMed: 19925946]
- Cohn LA. Feline Respiratory Disease Complex. *Vet Clin N Am-Small*. 2011; 41:1273.
- Driscoll CA, Macdonald DW, O’Brien SJ. From wild animals to domestic pets, an evolutionary view of domestication. *PNAS*. 2009; 106:9971–9978. [PubMed: 19528637]
- Eidson M, Bingman AK. Terrestrial rabies and human postexposure prophylaxis, New York, USA. *Emerg Infect Dis*. 2010; 16:527–529. [PubMed: 20202438]
- Foley P, Foley JE, Levy JK, Paik T. Analysis of the impact of trap-neuter-return programs on populations of feral cats. *Javma-J Am Vet Med A*. 2005; 227:1775–1781.
- Fredebaugh SL, Mateus-Pinilla NE, McAllister M, Warner RE, Weng HY. Prevalence of Antibody to *Toxoplasma Gondii* in Terrestrial Wildlife in a Natural Area. *Journal of wildlife diseases*. 2011; 47:381–392. [PubMed: 21441191]
- Gunther I, Finkler H, Terkel J. Demographic differences between urban feeding groups of neutered and sexually intact free-roaming cats following a trap-neuter-return procedure. *Javma-J Am Vet Med A*. 2011; 238:1134–1140.
- Hawkins CC, Grant WE, Longnecker MT. Effect of subsidized house cats on California birds and rodents. *T W Sec Wil*. 1999; 35:29–33.
- Held JR, Tierkel ES, Steele JH. Rabies in man and animals in the United States, 1946–65. *Public Health Rep*. 1967; 82:1009–1018. [PubMed: 4964673]
- Hensley JA. Potential rabies exposures in a Virginia county. *Public Health Reports*. 1998; 113:258–262. [PubMed: 9633873]
- Jessup DA. The welfare of feral cats and wildlife. *J Am Vet Med Assoc*. 2004; 225:1377–1383. [PubMed: 15552312]

- Jones AL, Downs CT. Managing Feral Cats on a University's Campuses: How Many Are There and Is Sterilization Having an Effect? *J Appl Anim Welf Sci.* 2011; 14:304–320. [PubMed: 21932945]
- Levy JK, Gale DW, Gale LA. 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.* 2003; 222:42–46. [PubMed: 12523478]
- Lipinski MJ, Froenicke L, Baysac KC, Billings NC, Leutenegger CM, Levy AM, Longeri M, Niini T, Ozpinar H, Slater MR, Pedersen NC, Lyons LA. The ascent of cat breeds: genetic evaluations of breeds and worldwide random-bred populations. *Genomics.* 2008; 91:12–21. [PubMed: 18060738]
- Little S. A review of feline leukemia virus and feline immunodeficiency virus seroprevalence in cats in Canada. *Veterinary immunology and immunopathology.* 2011; 143:243–245. [PubMed: 21757241]
- Lohr CA, Cox LJ, Lepczyk CA. Cost and Benefits of Trap-Neuter-Release and Euthanasia for removal of urban cats in Oahu, Hawaii. *Conservation Biology.* 2012; 27:64–73. [PubMed: 23009077]
- Longcore T, Rich C, Sullivan LM. Critical Assessment of Claims Regarding Management of Feral Cats by Trap-Neuter-Return. *Conservation Biology.* 2009; 23:887–894. [PubMed: 19245489]
- McElroy KM, Blagburn BL, Breitschwerdt EB, Mead PS, McQuiston JH. Flea-associated zoonotic diseases of cats in the USA: bartonellosis, flea-borne rickettsioses, and plague. *Trends Parasitol.* 2010; 26:197–204. [PubMed: 20185369]
- Moore DA, Sischo WM, Hunter A, Miles T. Animal bite epidemiology and surveillance for rabies postexposure prophylaxis. *J Am Vet Med Assoc.* 2000; 217:190–194. [PubMed: 10909457]
- National Association of State Public Health Veterinarians, I. Compendium of animal rabies prevention and control, 2011. *MMWR Recomm Rep.* 2011; 60:1–17.
- Natoli E, Maragliano L, Cariola G, Faini A, Bonanni R, Cafazzo S, Fantini C. Management of feral domestic cats in the urban environment of Rome (Italy). *Preventive Veterinary Medicine.* 2006; 77:180–185. [PubMed: 17034887]
- Nutter FB, Dubey JP, Levine JF, Breitschwerdt EB, Ford RB, Stoskopf MK. 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. *Javma-J Am Vet Med A.* 2004a; 225:1394–1398.
- Nutter FB, Stoskopf MK, Levine JF. Time and financial costs of programs for live trapping feral cats. *Javma-J Am Vet Med A.* 2004b; 225:1403–1405.
- Olson CA, Mitchell KD, Werner PA. Bait ingestion by free-ranging raccoons and nontarget species in an oral rabies vaccine field trial in Florida. *Journal of wildlife diseases.* 2000; 36:734–743. [PubMed: 11085436]
- Richards JR, Elston TH, Ford RB, Gaskell RM, Hartmann K, Hurley KF, Lappin MR, Levy JK, Rodan I, Scherk M, Schultz RD, Sparkes AH. The 2006 American Association of Feline Practitioners Feline Vaccine Advisory Panel report. *J Am Vet Med Assoc.* 2006; 229:1405–1441. [PubMed: 17078805]
- Schmidt PM, Swannack TM, Lopez RR, Slater MR. Evaluation of euthanasia and trap-neuter-return (TNR) programs in managing free-roaming cat populations. *Wildlife Res.* 2009; 36:117–125.
- Shwiff SA, Sterner RT, Jay MT, Parikh S, Bellomy A, Meltzer MI, Rupprecht CE, Slate D. Direct and indirect costs of rabies exposure: A retrospective study in Southern California (1998–2002). *Journal of wildlife diseases.* 2007; 43:251–257. [PubMed: 17495309]
- WHO. First Report. WHO; Geneva: 2005. WHO Expert Consultation on Rabies. WHO technical report series No 931

Impacts

- Trap-Neuter-Vaccinate-Return (TNVR) programs are growing in popularity as alternatives to euthanizing feral cats
- Their ability to adequately address disease threats and population growth within managed cat colonies is not clear
- Appropriate animal control laws including removal of stray or unwanted cats should be enforced rather than relying on indirect population management strategies (e.g. trap, neuter, vaccinate, release programs) in order to control feral cat populations and reduce the risk of zoonotic diseases such as rabies.



Figure 1.
Potential interaction between a cat and raccoon. (Credit: Alan Hopkins).