

Note: This chapter examines published studies of the population level effects of spay and neuter of free-roaming domestic animals. It is heavy on study analysis and may be of limited interest to those working on practical matters in the field, but is included in order to provide context and a scientific background for the more pragmatic chapters that follow.

### Key points:

- Scientific evidence in peer reviewed journals strongly suggests that spay / neuter of feral animals has no effect on overpopulation at realistic levels
- TNR efforts are only successful when animals are removed from a population at high levels
- TNR coupled with food provisioning (colonies) increases deaths

Spaying and neutering of dogs and cats as a means of population control is one of the most frequently presented tenets of veterinary medicine. More specifically, Trap-Neuter-Release (TNR) programs are frequently claimed to be a scientifically sound method to reduce feral and street populations in a humane fashion with the added benefit of protecting wildlife via these reduced domestic animal populations (33).

Despite the conventional wisdom, however, a closer look at the studies presented as "evidence" reveals that TNR programs using conventional surgical methods of contraception lack valid scientific

basis and are not effective at population control on a realistic scale. Not only does promotion of TNR programs fail to reduce feral populations of domestic animals, the continued use of such programs poses a very real risk to wildlife if no real world population reductions occur and risks wildlife agencies electing mass euthanasia of free-roaming domestic animals. Additionally, TNR programs also promote a false sense of quality of life for feral domestic animals in harsh environments (34). Most importantly, TNR advocacy using current surgical methods ultimately generates revenue for large humane organizations but diverts attention and finite resources away from nonsurgical means of contraception that will be required to solve the global dog and cat overpopulation crisis.

## Where is the evidence?

Representatives from humane organizations and the animal shelter community frequently promote TNR programs as "evidence based", scientifically backed methods of population control. These stakeholders, as with most in the veterinary community, would ultimately like to see a reduction in shelter intake and euthanasia, and frequently cite a handful of key papers as the scientific basis for TNR programs. The position statement from the Association of Shelter Veterinarians (ASV) promoting TNR lists as its primary citation a 2014 article on the effect of "high impact" TNR on shelter intake of community (i.e. feral and semi feral) cats (35, 36). The metric used to evaluate the efficacy of TNR was a reduction of shelter intake, and this measure of success is the same used in many studies promoted by TNR advocates. However, a reduction in shelter intake is not the same as a reduction in actual feral populations, or as another less cited paper stated, "the current practice of TNR is rarely optimized for population control, and that its potential effectiveness for accomplishing population control...has not been clearly determined" (37).

A deeper look at studies that promote TNR as a means of reducing shelter intake reveals that there are other factors beyond simple sterilization that are involved as well. The 2014 study that sought to

determine "the effect of high-impact TNR" and "capture and neuter at least 50% of the estimated community cats" also involved "community outreach and assistance", "informational postcards....mailed to every residential and business address in the target area", and "study staff members and volunteers {going} door to door to speak with residents". Most importantly, "animal control staff referred concerns about free-roaming cats in the target area to program staff for further discussion...and encouraged residents to accept the option of neutering instead of having the cats impounded at the shelter" (36). Clearly, this study involved much more than simple TNR and its results should not be interpreted as evidence that TNR reduces feral populations. While shelter advocacy groups understandably want to minimize shelter intake, presenting such studies is misleading as most veterinarians and shelters will not look into the finer details of these studies beyond the title or abstract. Additionally, while the aforementioned study might be an ideal TNR scenario, the massive labor and financial effort involved in returning 1230 cats following neutering is well beyond the resources available in many communities in the US and especially worldwide.

After all, the second lead citation from the ASV position statement uses 20 year old estimates of up to 70 million feral cats in the US alone (38), far beyond the number of spays that could be performed using every vet in the US working together full time. Going south of the US border, a 2018 article from the journal Veterinary Medicine International estimates that there are greater than 16 million stray dogs in Mexico alone (39). Clearly, rerouting phone calls to shelters and going door to door is not a realistic option without a major cultural shift worldwide, and any implication that TNR in and of itself is an effective means of population control does a major disservice.

Rarely, TNR advocates outside of the direct animal welfare industry network will occasionally admit this, in effect. For example, the author of a study promoting TNR stated that "Trap-neuter-return eliminates a huge amount of suffering" but when directly questioned by a scientific writer from the Smithsonian admitted that "small programs don't reduce populations and result in more preventative death" (40).

Further analysis of frequently cited papers from TNR advocates remains problematic. A 2003 "observational epidemiologic" study published in JAVMA commonly used to promote TNR as a means of population control concluded that a "comprehensive long-term program of neutering followed by adoption or return to the resident colony can result in reduction of free-roaming cat populations in urban areas" (41). However, the details of this study involved a total of 155 cats on a university campus, hardly representative of the realities of feral cats living in rural Utah or stray dogs living on the streets of Mexico City, Istanbul, or anywhere in the developing world.. Additionally, the results of this study indicated that 47% of the cats were adopted, 17% were found dead or were euthanized for various medical reasons, and 15% were lost to follow-up. Promoting this study as "evidence based" scientific proof that TNR works is again misleading since almost half of the study cats were adopted out and a further 32% did not survive the study or were lost to follow up. At best, this study suggests that surgical means of contraception coupled with high rates of adoption is an effective strategy, but again achieving these surgical and adoption numbers is far beyond what is achievable in places such as Latin America.

Virtually every study demonstrating that very high spay percentages are needed to actually achieve population reduction comes from independent university research without stated conflicts of interest, whereas most studies validating the use of TNR or TVNR in free-roaming dogs or cats are authored or funded directly or indirectly (via funding select university shelter medicine programs) by one of a handful of high income advocacy groups with total combined annual incomes approaching \$1B. The lifeblood of this income is donations from people who want results, i.e. methods that work. This can raise questions as to the possibility of financial incentive to show that spay programs at the heart of these agendas actually work, with questionable conclusions drawn from data. An example of questionable TNR data interpretation was published in 2020, with the journal abstract as follows.

“Recently, a growing collection of evidence that associates trap-neuter-return (TNR) programs with substantial and sustained

reductions in community cat populations across a variety of environments has emerged. Peer-reviewed studies emanating from the northeastern, midwestern, and southeastern United States, as well as Australia, document such reductions. The present study expands upon this body of evidence by examining the impact of a long-term TNR program on a population of community cats residing on a pedestrian trail adjacent to an oceanic bay located on the West Coast of the U.S. A population of 175 community cats, as determined by an initial census, living on a 2-mile section of the San Francisco Bay Trail declined by 99.4% over a 16-year period. After the conclusion of the initial count, the presence of cats was monitored as part of the TNR program's daily feeding regimen. Of the 258 total cats enrolled in the program between 2004 and 2020, only one remained at the end of the program period. These results are consistent with those documented at the various sites of other long-term TNR programs” (42).

Sounds perfect, right? But a closer look at the actual details from the article, suggests otherwise.

“As of June 2020, 1 of the 258 cats enrolled in the program (<1%) remained on-site (Figure 1); 107 (41%) had been adopted; 10 (4%) were admitted into foster care; 10 (4%) were relocated to barns or other sites as part of working cat programs; 60 (23%) disappeared; 35 (14%) were euthanized due to serious illness or injury; 31 (12%) were confirmed to have died from causes other than euthanasia (e.g., struck by a vehicle and body recovered); and 4 (2%) were known to have migrated out of the program area” (42).

Look again at the numbers. 49% removed from the study area, 26% known dead, 23%”missing” (i.e. likely dead), 2% left on their own. Physical removal and death explain decrease, not TNR. Death itself being inevitable for everybody, this factor might be disregarded, although the manner of death was likely not what most people would accept for their own cats. But, again, removing half (49%) of all cats is by far the most reasonable explanation for the decreased population, and from a study standpoint is a huge confounder. A quick look at the conflict of interest section confirms that this paper was funded by an animal welfare group with an annual income of over a quarter of a

billion dollars (11), with one of the paper's two authors is an employee of the same organization, with the other author "independent".

Importantly, many articles promoting spay neuter for population reduction in free-roaming animals have this same adoption confounder skewing their results, with some studies via adopting out many as seven times the animals that the original study population even comprised to begin with.. Even if one were to disregard this as a major source of bias interpreting any results, this "science" operates within a vacuum. Rescue and animal advocacy groups that have established a network of adoption and foster programs are providing an outlet for excess animals that do not exist in the real world outside of the suburban USA, Canada, and a handful of other places on earth. Culturally, this network does not exist in Latin America, the Middle East, Africa, and Asia. There are few homes available for any street animals, and studies on these populations that do not involve adoption always find the same answers, namely that high spay percentages are needed far beyond the number of vets or resources available. For every stray dog in the USA, there are 100 others somewhere else who will never have a home, so any data manipulation subverts and delays finding real answers to the problems faced by animals outside of the rescue bubble in the USA, or even on the reservations today.

Although TNR advocacy groups cite the results of the aforementioned studies as proof that surgical sterilization of feral domestic animals reduces populations, other much larger real world studies have explicitly stated that TNR programs are not effective at the population level. A 10 year study that involved TNR of almost 8000 feral domestic cats in Rome, Italy found that "spay/neuter campaigns brought about a general decrease in cat number but the percentage of cat immigration (due to abandonment and spontaneous arrival) {was} around 21%" (43). The study authors concluded that "all of these efforts without an effective education of people to control the reproduction of house cats (as a prevention of abandonment) are a waste of money, time, and energy". and "TNR programs alone are not sufficient for managing urban feral-cat demography". Despite these clear statements from the authors, TNR advocacy groups instead use

this study to validate TNR, claiming that this study's "long-term program significantly reduces community cat colony size" (44).

Another large study published in JAVMA but not frequently mentioned by TNR advocacy groups involved TNR of 14,452 feral cats over an 11 year period in San Diego County, California and another 11,822 feral cats in Alachua County, Florida over a six year period. The results of this study "did not indicate a consistent reduction in per capita growth, the population multiplier, or the proportion of female cats that were pregnant" (45). Surgical contraception of over 26,000 animals is beyond the capability of many shelters even over a multi-year span, and certainly exceeds what can be performed by well-intended TNR groups that perform spays and neuters both year-round and as humanitarian missions throughout the US and the rest of the world. Thus, promotion of surgical means of contraception as a stand-alone method to reduce stray and feral populations is not a valid scientific approach.

Most studies of surgical TNR have focused on feral cats, but there is little evidence that TNR works to reduce stray dog populations. A study of the effectiveness of sterilization of free-roaming dogs in a Brazilian city compared two groups of captured and released dogs, in which the group of one region was surgically neutered and the group of the other region left intact. The study found "no differences in abundance, survival, and recruitment between the regions" and concluded that "sterilization did not affect the population dynamics" (46).

Finally, there are studies that demonstrate that feral domestic animal populations actually increase in the face of TNR. An example of this was in a peer reviewed journal article simply titled "Trap/neuter/release methods ineffective in controlling domestic cat "colonies" on public lands" (47). In this study, cat populations in one of the two study areas remained unchanged over time but actually increased in the second study area due to food provisioning by TNR advocates.

## Why might someone misinterpret or manipulate data?

The presentation of scientifically flawed data without basic study controls can often be explained when one looks at the conflict of interest statement. From the preceding article, "In recognition of MDPI policy and our ethical obligations as researchers, the authors acknowledge that one of us... is employed by [an advocacy group], advocating for the protection of domestic cats via public policy initiatives. In addition, the authors acknowledge that the funding sponsors provided general guidance for the design of the study and were periodically apprised of project status during data collection, analysis, and interpretation and the writing of the manuscript" (41). This is a significant conflict of interest, especially when a study funder is an advocacy group. This reason that peer reviewed scientific journals have a conflict of interest section is to effectively advise readers that there may be financial motivation involved. It certainly does not guarantee that data manipulation is involved, i.e. making data fit an agenda, but readers may wish to take the purported results with a proverbial grain of salt. The above cited papers are just a few examples of many throughout the literature with potential conflicts of interest. Not surprisingly, most of the journal articles promoting TNR have advocacy groups funding the research and authoring papers, even at the university level (14, 48). By way of comparison, virtually all of the studies that demonstrate no beneficial effect to TNR are from university researchers not directly tied to these advocacy groups, and list no conflict of interest. That is to say, beneficial effects of TNR are usually "proven" by research from those associated with one of the multimillion dollar advocacy groups, while government funded research or that from university departments without an advocacy group connection consistently shows no free-roaming population reduction in numbers unless very high spay rates can be achieved in a very short timespan (over 70% of all females within 6-12 months).

Advocacy groups with budgets far beyond any university veterinary epidemiology department work directly with university faculty, with program funding coming directly from these groups who have a financial stake in the outcomes of "studies" (14) and papers published with co-authorship shared by employees of advocacy groups and



university faculty (48). This could simply be the result of limited funding at the university level for research into animal population control methods, and that there is no scientific compromise of integrity whatsoever. But, it might suggest that any research whose results demonstrate no effect on overpopulation could compromise financial donations to advocacy groups. That is, donors wanting to help animals give to causes that they believe will actually help, so it may be in the best financial interest for an advocacy group to “prove” their methods actually work. Data manipulation is one way to do this, and another way to do this is by flooding journals with multiple papers with small numbers of animals in unique settings not representative of free-roaming animals in the real world. Given that very few readers go beyond Google, and even fewer go beyond the abstract in a PubMed search and read the actual details of the “study” methodology or the conflict of interest section, the easiest way to trick readers is to have multiple abstracts burying the biased data within the paper. Add questionable statistical analysis that produces a series of numbers and decimals points, and the reader will assume that the “study” was real. It is obviously a case by case basis, and funding does not automatically equate to scientific deception or bad intention.

## What level of spay / neuter actually reduces free-roaming populations?

Despite their domestic classification within the veterinary community, free-roaming cats and dogs can and should be considered as mammalian populations within the environment at large and are not immune to the principles of population dynamics such as carrying capacity. Whether or not they are truly feral, semi-feral, or owned but simply free-roaming, domestic cats and dogs that interact outside of a confined home represent members of a greater population that mate, compete for resources, and are subject to outside pressures of predation, starvation, human caused deaths, etc. Some humane advocacy groups have begun to recognize this and have started to include wildlife biologists on advisory boards to address the issue of how to handle feral and stray pet overpopulation. Wildlife agencies in

the United States have arguably been the most successful in managing wild mammalian populations, both in terms of increasing numbers where desired and decreasing numbers where not desired. Wildlife managers have recognized that populations exist within a range ultimately limited by resources, and that removal of fairly large percentages of the individuals does not affect the total population in the long run. Extrapolating wildlife biology principles to feral populations of domestic cats and dogs in effect suggests that decreasing the numbers of future births (by any means) will ultimately be offset by a rebound in the population back to its carrying capacity unless a certain threshold is surpassed. As such, studies on domestic animals have attempted to determine what level of TNR actually reduces feral population levels in the long term.

A demographic population model published in 2009 of a small ~822 ha area determined that a greater than 50% rate of TNR or euthanasia was needed to reduce free-roaming cat populations (49). This study also took into consideration that very few populations operate within a vacuum, however, and reduction of a portion of a population in one area ultimately results in immigration from outlying areas. The 2009 study determined that "euthanasia resulted in greater total population decreases than did TNR", and that "when populations experienced maximum immigration rates between 25% and 50%, euthanasia rates at or above 75% were required to reduce the population below initial abundance".

A population model published in JAVMA in 2013 compared TNR with both euthanasia and Trap-Vasectomy-Hysterectomy-Release (TVHR) and determined that a >82% TNR (or euthanasia) rate annually was needed to achieve elimination within ~11 years of a theoretical population of only 80 total starting individual cats. The study concluded that if population control is the desired end point, TVHR was actually significantly more effective than TNR, with an annual TVHR rate of >57% needed to achieve elimination of the total population within ~11 years (50).

Going back further, a 2004 JAVMA study using a matrix population model also compared TNR with euthanasia and determined that

"population was most susceptible to control through euthanasia" but that effective cat population control would be achieved by "annual neutering of >75% of the fertile population" (51). This publication is not frequently cited by TNR advocates, possibly due to the conclusion that euthanasia is more effective in population control, but a model published in 2019 that found similar results for TNR is frequently cited instead.

The 2019 study determined that "high intensity TNR", defined in the study as "75% of intact individuals sterilized" in a 6 month time span, "substantially [reduced] population size" and "[minimizes] preventable deaths" whereas with "low intensity TNR", defined as 25% of intact individuals sterilized, "these advantages are greatly reduced or eliminated" and "large numbers of kittens remain subjected to high mortality rates over time" (52).

The 2019 study is frequently cited by TNR advocates as validation that TNR programs actually work to reduce populations, and a closer examination of the study reveals that the study conclusion of the efficacy of "high intensity TNR" also took into account the theoretical number of births and deaths that would occur over a 10 year period of time. In other words, if population reduction is not the only goal but also a reduction in the number of individuals that live and die within a time frame, "high intensity TNR" may be effective. However, the jump from 25% TNR rates to 75% TNR rates in a 6 month period is far beyond what veterinarians and TNR groups using surgical means can achieve in rural, isolated communities in the United States, let alone impoverished Third World urban areas with large populations of animals quickly able to migrate into an area if competition pressures were reduced. I.e., even if 75% of individuals in focal areas could be sterilized within the time frame allotted, migration and increased fecundity of the remaining intact females given the same resources over time would cause a fairly quick rebound towards the normal carrying capacity, if principles of wildlife biology are any indication.

Given the above 2019 publication that concluded that "high intensity TNR" was effective at reducing feral population levels, shelter medicine programs and TNR advocates are using the term "high

intensity" to promote the use of spay/neuter programs both for stray populations as well semi-feral and owned but free-roaming populations of cats and dogs. However, the 75% benchmark within a 6 month time span (similar to the 75-82% estimations from other modeling studies) is rarely mentioned since this is largely an unachievable feat using conventional, surgical methods of cat and dog contraception even within small communities with seemingly vast human and financial veterinary resources. Additionally, the data from the aforementioned studies would suggest that previous efforts at spay/neuter rates below 50% within one heat cycle of free-roaming populations likely have had no effect on total population numbers, something that large humane organizations that promote spay/neuter as effective means of population control do not freely discuss.

The lack of any real world, long term reduction in feral domestic animal populations using current surgical methods of TNR would not surprise wildlife biologists at fish and wildlife agencies that interpret these types of data on a routine basis for non-domestic species. Spaying female cats and dogs that are in direct competition for resources would initially result in a decrease in new additions to the overall at-large population, and in the face of ongoing losses (deaths, migrations, adoptions), there might be an early decrease in the total population. This would in turn lead to increased resources (i.e. food) and decreasing starvation pressures. Any increased access to food would result in an increase in females coming into heat, an increase in females actually getting pregnant, larger litter sizes, and increased survival of offspring. The net end result would be a rapid return to the steady state carrying capacity, in effect undoing any beneficial effects of spaying on the overall population. Despite the traditional mentality of the inverted pyramid of births (i.e. that spaying one female prevents the birth of 6-8 new kittens or puppies, which in turn prevents 6-8 new offspring for each subsequent generation of females), the theoretical reduction in future offspring is offset by increased fecundity in the remaining intact females and populations remain the same unless a critical threshold is reached. The studies and models of TNR programs suggest that this number is around 75% as discussed previously, but this number must be achieved within one to two

generations (6-12 months). If this number is not achieved prior to the next generation of offspring reaching sexual maturity, the production of new offspring will offset any gains in reducing the overall population.

Finally, the other primary factor involved, that wildlife managers have understood for decades, is that males and females cannot be regarded the same from a reproductive standpoint. As previously discussed, leaving even a small percentage of males intact in a population results in the same number of females becoming pregnant. As such, neutering males has extremely limited effects, and time and resources spent neutering free-roaming males are not an effective means of reducing populations.