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Improving and Evaluating Trap-Neuter-Return (TNR) Management for Outdoor Cats on the Human Landscape

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ABSTRACT: The trap-neuter-return (TNR) method for outdoor cat management is widely utilized, but wildlife advocates have argued in recent years that TNR does not reduce cat population size and does not mitigate the threat of cat predation. In this article, we suggest that the current practice of TNR is rarely optimized for population control, and that its potential effectiveness for accomplishing population control has therefore not been clearly determined. We further suggest that it would be possible to implement larger-scale TNR "flagship" programs that are optimized for population management, and by doing so to more definitively assess the capabilities and limitations of TNR as a population management tool. This knowledge would provide a better basis for identifying situationally-appropriate management strategies through a consensus-building process.

KEY WORDS: adaptive management, cat management, *Felis catus*, feral cat, outdoor cat, trap-neuter-return

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INTRODUCTION

Outdoor cats have a significant presence on the landscape in many parts of the world, usually functioning as human commensals (Ferreira et al. 2011). Outdoor cats may also be present in natural areas where human-derived resources are scarce or absent. These cats rely on predation to secure food, and consequently lethal removal is a commonly employed management approach in protected wildlife areas, particularly on islands where birds are not adapted to the presence of mammalian predators (Nogales et al. 2004, Short and Tanner 2005). In recent years, biologists have focused increasing attention on characterizing the threat that outdoor cats may pose to native wildlife (especially birds) in an array of non-natural and semi-natural settings such as cities, suburbs, parks, and urban wildlife sanctuaries (hereafter termed the "human landscape"). A number of studies have concluded that predation and nest disturbance can reach substantial levels (Warner 1985, Bonington et al. 2013, Loss et al. 2013), and many conservationists have become convinced that more aggressive cat management is needed on the human landscape. Despite the information that has been accrued, however, further work remains to be done to determine whether cat impacts on wildlife are systemic or localized, and to determine the importance of these impacts in relation to other drivers of mortality, nest failure, and population decline. The unintended secondary consequences of removal-based management also deserve further examination and consideration (see LeCorre 2008, Bergstrom et al. 2009, Balogh et al. 2011, and Cooper et al. 2012 for relevant examples).

Outdoor cats living on the human landscape have traditionally been either unmanaged, or managed by animal control agencies using lethal removal in a sporadic and reactionary manner – primarily in response to nuisance complaints. In reaction to this latter practice, a strong advocacy movement for outdoor cats has developed in parts of North America and Europe and has grown rapidly in size and in organizational sophistication. Specific goals and practices of different outdoor cat advocacy groups appear to vary considerably, but all are motivated by an animal-welfare ethic, and they generally share a belief that proactive sterilization programs and adequate cat care will help to prevent excessive reproduction, control population size, and reduce nuisance behaviors (Levy et al. 2014). Their management method of choice is termed "trap-neuter-return" (TNR), which involves the following steps:

1) Capture of unaltered outdoor cats in live traps.
2) Sterilization of cats at a clinic, often accompanied by other procedures such as vaccination and ear marking to allow for visual identification of sterilized cats.
3) Return of cats to the point of capture.
4) In many cases, ongoing feeding of cats at established "feeding stations".

Several variants of this approach exist, distinguished from one another primarily by the types of supplemental care provided in addition to sterilization, and the degree to which kittens and socialized cats are removed from the managed population for adoption (Levy et al. 2003, 2014). Where TNR programs incorporate active feeding into their operation, they often lead to a noticeably clumped distribution of cats, which congregate around feeding stations at high densities (Natoli et al. 2006, Schmidt et al. 2007, Ferreira et al. 2011, Gunther et al. 2011).

In many municipalities, traditional management based on nuisance cat removal has been supplemented or supplanted by TNR. However, neither traditional removal methods nor TNR have yet been widely successful in persistently reducing the number of outdoor cats across large swaths of the human landscape, although localized successes have been documented (Levy et al. 2003, Natoli et al. 2006, Jones and Downs 2011). This lack of results stands in apparent contrast to intensive removal programs on islands, which often do succeed in eliminating or greatly reducing cats (Campbell et al. 2011, but see LeCorre 2008, Bergstrom et al. 2009). Noting this disparity, some biologists and wildlife advocates have suggested that TNR does not accomplish meaningful population control under any plausible implementation scenario (Longcore et al. 2009).

All of these developments have produced a situation in which cat advocates and wildlife advocates appear to be espousing fundamentally incompatible policy positions. Given the degree of polarization that is now manifested in the evolving "cat debate", the exploration and promotion of pragmatic, data-driven management approaches that seek to balance competing priorities have sometimes been neglected or overshadowed. This paper attempts to direct one element of the cat debate onto more objective ground by suggesting mechanisms to improve the current practice of TNR, which would in turn allow its potential utility for population management to be more fairly evaluated. Despite a vigorous ongoing discussion about the merits and deficiencies of TNR, it is our premise that this "fair evaluation" has not yet occurred, for the following reasons:

1) TNR programs are usually undertaken by organizations whose primary mission and primary expertise lies in animal welfare. In order to express their full potential for population management, TNR programs also need to mobilize and draw upon expertise in population biology and population management.
2) Any management technique can fail to achieve population-level goals if it is not conducted with sufficient intensity, persistence, and spatial coverage. Indeed, lethal control programs can easily fail to accomplish population objectives for these very reasons. Drawing conclusions about the potential of TNR for population management by referencing what are clearly non-optimal or inadequately-funded implementations of this method is a proverbial "straw dog" scenario.
3) Controlling cats in natural areas, where they typically exist at relatively low densities with little if any resource supplementation, is a substantially different undertaking than controlling cats on the human landscape, where they are directly or indirectly provisioned with human-derived resources, and where cat numbers are constantly bolstered by the ongoing abandonment of former pets. The potential of TNR for population management on the human landscape can only be fairly evaluated with this reality in mind.

TNR's potential as a population management tool can best be determined by designing, implementing, and monitoring TNR programs that are optimized for population management. Few such programs currently exist, but we attempt to demonstrate in this paper that they could be created now by drawing upon well-established principles of population biology and adaptive management. We do not suggest or expect that TNR will prove to be an "easy" method for controlling outdoor cats on the human landscape, or that population management via TNR will necessarily be a feasible undertaking for all TNR practitioners. However, developing a better understanding of TNR's real potential, limitations, and resource requirements would allow for a more informed, productive, and objective discussion about cat management options on the human landscape.

INADEQUACIES OF TNR AS TYPICALLY PRACTICED

TNR as typically practiced is not optimized for population management. This may present itself in one or more of the following ways:

1) Population abundance goals are not formally identified.
2) Target management populations are not clearly delineated.
3) Realistic population processes such as density-dependence are not accounted for in program design.
4) Baseline population abundance surveys are not conducted.
5) Ongoing population monitoring is not conducted or is inadequate.
6) When population monitoring is conducted, resulting data are not analyzed in a timely fashion, and data-driven adjustment of program operations (i.e., adaptive management) does not occur.

Although some TNR programs have avoided these pitfalls (Scott et al. 2002, Levy et al. 2003, Nutter et al. 2004, Natoli et al. 2006, Jones and Downs 2011), most do not. We discuss these issues in turn in the sections below.

CHARACTERISTICS OF OPTIMIZED TNR MANAGEMENT

Goals and Target Populations

Explicit and measurable goals should be formulated as part of any management program. In order to set goals, a target population must be clearly delineated and preliminarily characterized. Failure to define management goals and target populations leads to confusion as to what constitutes "success", and a certain amount of the controversy surrounding TNR can probably be attributed to this phenomenon. Many TNR practitioners probably equate success with reductions in suffering (whether measured or perceived), shelter intake, or nuisance complaints, whereas biologists have tended to assume that TNR programs are undertaken with the implicit goal of managing population size. The potential for confusion has been amplified when some organizations have prematurely promoted TNR as an effective population management tool without empirically demonstrating this to be the case.

In addition to being explicit, goals should be realistic and achievable. Determining reasonable goals requires the consideration of multiple factors, including the size of the target population, its degree of isolation from other populations, and the resources that can be mobilized for the management effort. Furthermore, all of these factors must be interpreted within the context of expected population function. Subsequent sections discuss some of the approaches that can be used to formulate and refine management goals.

Goals should be expressed in the form of standard population metrics (usually some measure of relative density), and a timeline should be provided. As an example, a hypothetical TNR program might state as its goal in terms of population abundance as follows: "reducing the outdoor cat population in the 89502 zip code by 20% over the first 3 years of operation as measured by standardized cat counts, and reducing the population by an additional 10% over the subsequent 3 years, eventually stabilizing and maintaining the population at 70% of its original size". This goal can then be more specifically operationalized in terms of targeted number of sterilization procedures at specific locations. In all likelihood, goals and timelines will have to be fine-tuned as the program progresses and additional information is accrued (see "Adaptive Management" below), but setting specific goals at an early stage creates a clear basis for program evaluation and provides motivation to optimize program operations on an ongoing basis.

Consideration of Population Dynamics

Setting goals and timelines requires some understanding of population dynamics. Animal populations are regulated by multiple factors, some of them interacting, and as a consequence, our understanding of population function is always approximate. However, by combining insights from field studies and population models, we can make reasonable projections about how a cat population is likely to respond to a particular management program. A full accounting of this process is beyond the scope of this article (see Miller et al. 2014 for more detail), but below we describe some critical elements of population function that should be considered in designing management programs and setting management goals.

1) ***Intrinsic growth rate*:** Unmanaged cat populations have the capacity to grow over time if sufficient resources are available, and the maximum rate at which this growth will occur under ideal circumstances is the intrinsic growth rate. The goal of sterilization-based population management is to reduce the intrinsic growth rate below zero until the desired degree of population reduction is reached. In its initial phases, a TNR program may reduce intrinsic growth rate, but until that rate becomes negative, the desired population-level response cannot occur.
2) ***Carrying capacity*:** Carrying capacity is the maximum abundance or density of cats that a given area can support over the long term given the resources that are present. When a cat population reaches its carrying capacity, it will no longer grow even if its intrinsic growth rate is positive. Carrying capacity is not necessarily static, but can change with resource availability.
3) ***Spatial population structure*:** Cats on the human landscape are usually distributed unevenly, mirroring patterns of resource availability. Some individual cats may disperse away from their area of origin (or be moved by people), creating "connectivity" between discernible locale populations. Target populations for management should be delineated in a way that reflects natural cat groupings and minimizes connectivity with outside populations to the extent possible. Artificially dividing a natural grouping of cats for management purposes results in high rates of immigration into the management area. If the recruitment of outside individuals into the target population occurs at a sufficiently high rate, it can make population management by means of sterilization functionally impossible (Schmidt et al. 2009, Gunther et al. 2011, Miller et al. 2014).
4) ***Density-dependence*:** Certain vital rates tend to change with population density. For instance, juvenile survival will typically be higher in populations below their carrying capacity than in populations at their carrying capacity. Likewise, survival rates of immigrants, per capita reproductive output, and adult lifespan may tend to increase as population density declines. The relevance of density-dependence to management is that it may become progressively more difficult to further reduce population density as population density declines (see Nutter et al. 2004, Short and Tanner 2005). It should be understood that the difficulties posed by density-dependence are in all likelihood an inevitable reality of effective population control, regardless of the management method used. TNR practitioners sometimes invoke concern about a "vacuum-effect" (i.e., a density-dependent increase in immigration rate) to argue against lethal control methods, but in reality, a TNR program that succeeds in reducing population below carrying capacity is just as likely to invoke a vacuum effect as a lethal control program.
5) ***Lag times*:** Sterilization has no immediate effect on population size. Population-level effects manifest

only as sterilized animals fail to reproduce and then eventually die. Management programs must be designed to operate over sufficiently long time frames (several years, minimally; see Miller et al. 2014) to generate population changes.

6) ***Target sterilization rates*:** Most evidence suggests that population sterilization rates must exceed a threshold value of 50 - 75% to drive the intrinsic growth rate of an outdoor cat population below zero (Budke and Slater 2009, Schmidt et al. 2009, Miller et al. 2014). However, populations with high immigration and/or abandonment rates will require higher sterilization rates to achieve a comparable effect. Furthermore, the rate of population decline and the eventual equilibrium population size depends on the sterilization rate that is achieved. It is important to recognize that reaching a particular sterilization rate is not sufficient to accomplish population goals; that rate must be maintained over time. It should also be recognized that as the sterilization rate increases, it may become more difficult to capture the remaining unsterilized animals (Short and Tanner 2005). Therefore, provision for sufficient trapping effort must be explicitly considered. Because it is difficult to make precise predictions about the sterilization rates that are required to meet a specific management goal, analysis of monitoring data and adaptive management (see below) are likely to be critical elements in management success.

Baseline Surveys and Monitoring

Measurable goals are only useful if actual measurement occurs. Here, we distinguish between initial baseline surveys and subsequent monitoring surveys, though in most methodological respects they are (and should be) identical. A baseline survey should be conducted prior to a new management initiative to quantify the "pretreatment" condition against which subsequent population response can be evaluated. Optionally, baseline surveys can be designed to generate a population size estimate, which can be helpful in formulating work plans, budgets, and ensuring that program goals are reasonable and achievable. After management begins, monitoring surveys should be conducted in standardized locations and at fixed intervals (typically annually or semi-annually) to document population response. Relative indices of population size (i.e., direct counts using a standardized method) are usually adequate for this purpose, and monitoring surveys can therefore be less time-consuming and resource-intensive than baseline surveys that seek to estimate population size.

The design and operation of baseline surveys and monitoring surveys is beyond the scope of this document, but is thoroughly reviewed in ACCD (2013). Although some expertise is required for proper survey design, field work can potentially be conducted by volunteers or other non-biologists who receive sufficient training.

Adaptive Management

In addition to retroactively documenting management outcomes, monitoring data can also be used to proactively optimize ongoing management programs. For example, based on the proportion of ear-marked cats observed during monitoring surveys, we might conclude that despite having reached a goal for number of sterilization surgeries, the population has not reached the desired sterilization rate. Sterilization efforts can then be increased in a timely fashion until the desired sterilization rate is achieved. This is a simple example of adaptive management. Invoking adaptive management effectively requires not only the collection of monitoring data, but its systematic analysis and assessment at regular intervals.

Integrated Management

The population-level impact of sterilization can be enhanced by reducing the influx of new individuals into the target population by immigration or abandonment. Although we do not minimize the difficulty of accomplishing this task, helpful approaches might include subsidizing and facilitating the sterilization of unconfined pet cats, encouraging cat owners to keep their pets indoors, and pursuing legal or educational approaches to discourage cat abandonment. It can also be helpful for TNR programs to work with animal adoption agencies to move adoptable cats from the outdoor population into homes (Levy et al. 2003, 2014). Supplementing the primary management technique (TNR) with the other approaches described above is an example of integrated management. TNR programs with ambitious long-term goals could benefit substantially from the synergies of integrated management.

CONCLUSIONS

The recommendations given in this paper for improving the practice of TNR have been made before on multiple occasions (see Foley et al. 2005, Sparks et al. 2013, and Hiby et al. 2014 for examples), but they are not routinely incorporated into TNR practice. As a consequence, the population management potential of TNR has perhaps been obscured by a focus on suboptimal implementations. We believe that by adhering to the guidelines presented above, it is possible to develop "flagship" TNR programs – particularly at larger spatial scales – that significantly improve upon standard TNR practice, and to thereby come to a better understanding of TNR's real capabilities and limitations. If TNR proves to have potential for effective population management, as several authors have suggested (Scott et al. 2002, Andersen et al. 2004, Foley et al. 2005, Budke and Slater 2009, Schmidt et al. 2009), the practicality of deploying this method at larger scales would remain to be determined. A number of factors would need to be considered in such a feasibility analysis, including the following:

1) The comparative economic costs of different management options for a given management result.
2) The resources that could be mobilized under different management paradigms. Traditional lethal control programs usually rely upon municipal resources and personnel. TNR programs in the United States draw most heavily upon resources provided by volunteers, donors, and animal charity organizations, with additional municipal funding in some locations. In Europe,

municipally-funded TNR programs are more common.

3) The costs of securing sufficient expertise to design optimized TNR programs, conduct necessary monitoring activities, and analyze monitoring data.
4) The potential availability of non-surgical sterilants and contraceptives that are currently being researched and developed. If approved for field use, non-surgical options could significantly lower the cost of reproductive control on a per-animal basis.

Given what appears to be growing public support for non-lethal animal management, we believe it is advisable to explore the potential of methods like TNR to the extent reasonably possible. With a better understanding of our options, we can hope to identify situationally-appropriate management goals and approaches through a consensus-building process (see Loyd and DeVore 2010 for an example). If we fail to search for constructive management solutions that balance the interests of different stakeholder groups, the cat debate will continue to be driven by strong feelings, premature conclusions, and selective examples, leading to further polarization and management gridlock.

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