Population Dynamics Modeling and Field Studies to Improve Development of Technologies for Non-surgical Sterilization of Cats and Dogs

ACC&D
Alliance for Contraception in CATS & DOGS

Scientific Think Tank
June 8-10, 2011
Upperville, VA

Overview

June 8-10, 2011, a scientific think tank on the application of modeling and field studies to understanding population dynamics of cats and dogs was held at Ayreshire Farm in Upperville Virginia. The think tank was convened by the Alliance for Contraception in Cats & Dogs (ACC&D), with support from the Leonard X. Bosack and Bette M. Kruger Foundation and PetSmart Charities®.

The mission of ACC&D is to expedite the successful introduction of methods to non-surgically sterilize dogs and cats and to support the distribution and promotion of these products to humanely control cat and dog populations worldwide. ACC&D's motivation is to reduce animal death and suffering by expanding the tools available to humane population control programs. Non-surgical approaches may prove to be less expensive and less labor-intensive options for sterilization, allowing far more animals to be treated quickly and safely.

ACC&D sees its role as a networker and catalyst, bringing together diverse stakeholders in humane population control, including animal welfare organizations, industry, science, and academia. ACC&D convened two previous think tanks in 2009, tasked with exploring the potential of immunocontraception and gene silencing to develop a non-surgical sterilant or contraceptive for cats and dogs. The aim of the prior think tanks was to bring together scientists and others at the forefront of the specified research areas to identify the most promising avenues of research for achieving ACC&D's mission. Outcomes were lists of recommended studies and research goals to serve as a guide to scientists in each field.

The goal of the population dynamics think tank, as described by ACC&D president Joyce Briggs, was to move from technical science to deployment science, to answer questions about where and how to target contraceptive/sterilization interventions to have the greatest impact. ACC&D recognized a need for better understanding of the dynamics of free-roaming cat and dog populations, to help guide the investment of resources in current surgical sterilization programs, and development and introduction of new contraceptive interventions. To that end, experts in modeling, wildlife biology, and cat and dog population and reproductive biology were invited to participate. The hoped-for outcome of the think tank was an assessment of the potential to apply modeling and other tools of wildlife biology to dogs and cats.

The following report captures the activities and discussion that took place during the think tank, and presents the conclusions and proposed plan of action developed by the participants.

Think tank participants

Attendees

(See "Resources and Symposia" at www.acc-d.org for bios of participants.)

Foundation and Nonprofit Representatives:

Note: An asterisk (*) indicates members of the planning committee for this think tank.

Joyce Briggs*, MS	President, Alliance for Contraception in Cats & Dogs, Portland, OR
Alicia Falsetto	Executive Director, Leonard X. Bosack & Bette M. Kruger Charitable Foundation, San Francisco, CA
Bryan Kortis, JD	Program Manager, PetSmart Charities, New York, NY

Scientific Panel:

Alan M. Beck, ScD	Department of Comparative Pathobiology, School of Veterinary Medicine, Purdue University, West Lafayette, IN
Claudia Baldwin, DVM, MS, DACVIM	Director, Maddie's® Shelter Medicine Program, Associate Professor, Veterinary Clinical Sciences Faculty, Center for Food Security and Public Health, College of Veterinary Medicine, Iowa State University, Ames, IA
John Boone*, PhD	Board of Directors, SPCA of Northern Nevada Senior Biologist, Great Basin Bird Observatory, Reno, NV
Dennis Lawler*, DVM	Research Scientist, Gerontologist, O'Fallon, IL
Julie Levy, DVM, PhD, DACVIM	Director, Maddie's® Shelter Medicine Program, College of Veterinary Medicine, Gainesville, FL
Phil Miller, PhD	Senior Program Officer, Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN
Joshua Mitteldorf, PhD	Department of Ecology and Evolutionary Biology, University of Arizona, Philadelphia, PA
Gary Patronek, VMD, PhD	Vice President for Animal Welfare and New Program Development, Animal Rescue League of Boston, Boston, MA
James A. Serpell, PhD	School of Veterinary Medicine, University of Pennsylvania, Philadelphia, PA
Margaret Slater, DVM, PhD	Senior Director of Veterinary Epidemiology, Shelter Research and Development, ProLearning, Urbana, IL
David Wildt, PhD	Senior Scientist and Head, Center for Species Survival, Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, VA
Steve Zawistowski*, PhD, CAAB	Science Advisor, ASPCA, New York, NY

Topics of Discussion

Joyce Briggs opened the think tank with a brief overview and history of the problem of pet overpopulation and an outline of the think tank agenda. An estimated 3.5 to 4.5 million dogs and cats are euthanized annually in the United States. Though this represents a dramatic 80% decrease relative to the number euthanized in the 1970s, it still means that about half of the shelter intake population is killed.

Pet overpopulation began to be recognized as a problem around 1970. The first spay/neuter clinics were introduced around this time, as was the first requirement by some shelters that all adopted pets be surgically sterilized, an idea that was controversial at the time but has gained acceptance over the past 40 years. Spay/neuter surgery has become routine, with some practitioners completing 30+ operations a day, and today as many as 87% of owned cats and 75% of owned dogs are surgically sterilized.[1] The decrease in euthanasia rates is often attributed to increased surgical sterilization of pets, though the panel pointed out during the course of the think tank that some of the decrease is likely also due to changes in societal attitudes, including a decreased tolerance for free-roaming animals, and a decrease in the number of people who feel having a litter is part of a "normal" pet lifespan.

Recently, the decrease in the number of pets killed in shelters has leveled off, and there is a feeling that a different approach is needed to further reduce the incidence of euthanasia. Spay and neuter surgery has proven to be relatively safe and effective and has become quite efficient with the development of high-quality, high-volume (HQHV) protocols. However, any surgery entails postoperative pain and health risks, and the cost and recovery time associated with spay/neuter surgery prevents it from becoming the high-throughput method needed to treat large populations of cats and dogs, especially in economically depressed areas. In addition, some pet owners resist surgical sterilization, believing it will negatively change their pets' behavior. Spay/neuter clinics and trap/neuter/return (TNR) programs can treat large numbers of animals, but often not enough to manage feral cat or free-roaming dog population sizes effectively.

Dr. Alan Beck and Alicia Falsetto

Though not a significant problem in the United States, free-roaming or community dogs present a health hazard in many parts of the developing world, where the dog serves as a vector for rabies and other zoonoses. Worldwide, there are about 55-thousand human rabies deaths per year, with dog bites being the primary source of transmission. In most of the affected areas, surgical sterilization cannot be delivered at sufficient levels to control the dog population size since it is too expensive and requires infrastructure that frequently is not available for financial and technical reasons

Therefore, a need for non-surgical alternatives is recognized. Contraceptive/sterilization approaches that are relatively inexpensive, are effective after a single treatment, and do not require extensive training or expertise to administer, would be most useful in managing feral or free-roaming populations. One commercialized sterilant, Esterilsol™, results in permanent sterilization of male dogs after one injection in each testicle, and is an option for pet owners who wish to spare their pet the pain associated with surgical castration, or to have their pet maintain an intact appearance or possibly behaviors. The potential of this product for controlling community or free-roaming dog populations is an open question, as Joyce Briggs pointed out, because the percentage of male dogs that must be treated to observe a specific effect on population size is unknown. Studies of wildlife populations dynamics suggest that treating females would be more effective than males in achieving population control, since one remaining intact male can impregnate numerous females, but scientifically based data to help predict the impact of programs that sterilize a mix of both males and females is lacking. Additionally, Esterilsol presents some of the same limitations associated with surgery, including

[1] American Pet Products Association 2009-2010 National Pet Owners Survey

requirements for sufficient expertise among those administering the treatment, and for a period of post-procedure monitoring.

This background sets the stage for the think tank mission; namely, to determine whether population modeling of cats and dogs would help answer such questions, and better target resources. Bryan Kortis pointed out that currently, organizations such as PetSmart Charities inform their funding decisions with available data, such as intake to shelters per zip code (especially of juvenile cats and dogs), to attempt to target resources to areas where they may have the greatest impact. However, a more scientific approach would be helpful, especially if it could guide how many or what proportion of animals need to be treated to have an impact on population size.

Wildlife biologists have developed tools to quantify population sizes and to predict changes in population dynamics as a consequence of environmental effects. The panel was tasked with assessing the feasibility and potential of modeling and field studies as tools to evaluate alternative strategies for reproductive management of cat and dog populations. Think tank planning committee member Steve Zawistowski asked to increase the sophistication and quality of the questions being asked in the field of cat and dog population control, to lead to better science and higher quality data.

Overview of Population Modeling and Field Studies in Wildlife Biology

Types of models

John Boone and Phil Miller presented overviews of the types of population models that are used by wildlife biologists, and of the ways field studies are used to inform and refine models.

John Boone introduced deterministic modeling, a set of classic equations used to explain how predator and prey populations change over time. When population numbers are plotted vs. time, deterministic models produce characteristic oscillations as the predator population increases and decreases as a function of availability of prey, with the predator number increasing if prey is abundant, leading to increased predation and a decrease in prey number, followed by a decrease in predator number as prey becomes more sparse. Similarly, these models can examine changes in population size in response to changes in abundance of food or shelter. These models describe idealized simple situations, but often do not work well to describe real-life populations.

In contrast to simple deterministic models, statistical models incorporate stochasticity (uncertainty). For this reason, they are often used to analyze "real world" data sets. One potential problem with this approach is that statistical results can be difficult for non-specialists to interpret correctly.

An application of matrix modeling to feral cat populations is described in a study2 published by Margaret Slater, a member of the scientific panel. In this work, the impact of a nonpermanent contraceptive was compared to surgical sterilization of cats, and the effects of treating different proportions of the population were tested using a population-based matrix model. Matrix models can be deterministic or incorporate stochasticity as the feral cat study did. John Boone introduced this work as a starting point for discussing modeling related to the mission of the think tank.

The panel expressed interest in the potential to model human behavior. Phil Miller explained that anything may be modeled, if the data can be obtained, but obtaining the data is often a limiting factor. Dennis Lawler asked if the number of parameters affects the type of model you choose. John Boone answered that most biologists use statistical modeling because biological systems are complex. Phil Miller agreed, adding that it can depend on

[2] Budke CM and Slater MR (2009) Utilization of Matrix Population Models to Assess a 3-Year Single Treatment Nonsurgical Contraceptive Program Versus Surgical Sterilization in Feral Cat Populations. *J Appl Anim Welfare Sci.* **12**:277-292.

the purpose of the model. Distilling a system to a few global parameters such as growth rate and variance in growth rate can allow for a simpler model, but often it is valuable to deconstruct a parameter, to tease out the underlying contributions to growth rate, for example, which requires a more complicated model but will allow the impact of the underlying contributions to be analyzed.

Phil Miller introduced simulation modeling, used as a tool by conservation biologists to predict the probability of extinction in small wildlife populations threatened by human activities. He defined a model as a representation of reality that can be queried with specific questions, such as a map. A highly detailed map can provide very precise predictions, such as the exact time it will take to travel a specific route between point A and point B. A less detailed map can still be very effective and robust for relative predictions, such as which direction to travel from A to reach B. In modeling wildlife populations, including cats and dogs for the purposes of the think tank, he proposed that the purpose of models is to produce the latter type of robust relative predictions, rather than precise predictions of exact numbers of animals to sterilize to achieve specific population numbers.

Simulation models typically incorporate multiple causal and stochastic factors in an attempt to capture the critical dynamics and behaviors of the system of interest. In population models, these factors may include spatial dynamics, dispersal rates, immigration and emigration rates, life history, age structure, carrying capacity, density dependence, catastrophes, and other parameters that affect population dynamics. One model used by Phil Miller's group is Vortex, which tracks each individual of a population, calculating a probability of death, reproduction, etc. for each individual and then projecting the future population size. Simulations are run repeatedly to account for stochastic effects, and plots of the results of all the runs can reveal clustering about the most probable outcome.

In answer to a question from Margaret Slater, Phil Miller explained that if parameterized correctly, a matrix model could provide the same answer as a simulation model, though the first is population-based and the second individual-based.

Strengths and weaknesses of models

In response to questions from Steve Zawistowski and James Serpell, Phil Miller confirmed that the models can be used to ask "what if" type questions, and to determine which variable has the greatest effect on population size under different scenarios using a methodology known as sensitivity analysis. For example, the effect of removing males vs. females, or of removing different age groups, from the reproductive population can be tested. Spider plots are often used to depict predicted population size as a function of different variables, making it easy to visually identify variables that have the greatest impact on outcome.

Alan Beck asked how one determines carrying capacity. John Boone said it can be measured, or can be based on an intelligent guess, though Phil Miller warned that there are studies about the pitfalls of estimating carrying capacity.

Drs. Claudia Baldwin and Phil Miller

John Boone explained that models are useful for understanding populations, more so than for prediction. For example, models are built based on prior observations. The model is run based on certain new parameters, and if the results are consistent with new observations, then the model is considered accurate. If the results do not agree with observation, then something is missing from the model and/or from the current understanding of the system. The model is then modified to more accurately reflect nature. Phil Miller agreed, pointing out that in adaptive management, if the relationship between environmental change and population response is not as expected, this results in reanalysis of the understanding of the system.

David Wildt stated that a benefit of models is that they can drive research, helping to identify data that is necessary, to design and prioritize appropriate studies, and to decide where to focus energy and money.

Joshua Mitteldorf expressed his skepticism towards numerical models, since they become very complex and intractable very quickly. If the model includes a limited number of independent parameters, then he argued you do not need a complex model but linear modeling of each variable will be sufficient. If the parameters do interact, then a spider plot will not provide a picture of the range of possibilities because it varies only one parameter at a time. The number of combinations of parameters that you need to check becomes large very quickly.

Margaret Slater questioned how to proceed if a complex model cannot be accurate, and Phil Miller suggested that you have to identify places where the system depends on few variables, and accept a certain degree of uncertainty.

Brainstorming and Discussion.

After the introduction of the types of computer models and the ways wildlife biologists use them, Dennis Lawler and Steve Zawistowski led a discussion among the full panel regarding how these tools might be applied to cat and dog population control.

Major topics of discussion are outlined below.

How to define the target population for the construction of the model.

An important first step was defining the target population for the model. Joyce Briggs and Bryan Kortis proposed that if the goal is to decrease euthanasia, then the target population should be defined by shelter intake and/or euthanasia. In the United States, organizations already use shelter intake as a metric to measure success of TNR programs or other interventions. In favor of the use of this definition is the existence of a large volume of shelter data that can be mined. Built into this definition would be an assumption that shelter intake numbers are a marker of free-roaming population size.

Margaret Slater and Julie Levy emphasized that there is not a direct relationship between shelter intake and free-roaming cat populations. Gary Patronek reported that in Boston, the proportion of shelter intakes that are owned vs. free-roaming varies widely by census tract, impacting the ability to try to relate intake numbers to free-roaming population size. Many variables impact shelter intake, including neighborhood tolerance of free-roaming animals and shelter admittance policies. Shelter intake could decrease while the number of free-roaming animals remained high and thus not reflect a decrease in animal suffering. Also, it was noted that shelter data varies in quality depending on the shelter and the training of those collecting the data, and the availability of these data should not direct the construction of a model. An argument was made that the target population should be defined as the number of free-roaming cats in the environment, and that a systematic method of counting these animals should be developed.

After discussion about the need for the target population to include owned animals that leave or escape the home, since these animals interact with the free-roaming population, Steve Zawistowski proposed the target population be defined as the unmanaged cat or dog population, and this was generally accepted as a good working definition to carry forward. Also, it was agreed that cats represent a metapopulation, or a spatially structured population of interacting subpopulations that may have different parameters depending on their density, environment, etc.

How to identify and collect the data needed to construct the model

Phil Miller advised starting any model by conceptually mapping the system, drawing a chart to identify important parameters and interactions between parameters. David Wildt argued in support of basic field research to collect the data needed based on guidance from such a model. Julie Levy and Margaret Slater expressed that a standardized method for counting cats is badly needed to obtain the data to fill in a model for cats.

Gary Patronek expressed concern that cat populations might differ so greatly among cities and environments that identifying a standardized way to count cats would be difficult. John Boone suggested that wildlife biologists have devised methods to estimate populations based on counts, density, and other factors that should be able to be applied to solve this problem. Gary Patronek cautioned that any method used to estimate population numbers must have an inherent error smaller than the expected effect size from an intervention, so that measurement error does not obscure the effects of viable interventions.

James Serpell argued that no intervention trial should be initiated unless the starting population is known, and the output can be measured. Bryan Kortis agreed, but pointed out that many PetSmart Charities-funded projects are currently ongoing in the animal welfare field, and it would be beneficial to add a layer of scientific analysis to these projects, to guide data collection. James Serpell and John Boone agreed that with standardized methodology and scientific guidance, it could be possible to combine data from these on-going projects.

Parameters that would be appropriate for modeling cat and dog populations

Many parameters were discussed that would be important in the modeling of unmanaged cat and dog populations, included birth rate, death rate, death rate by gender, age, and reproductive capacity, immigration, and emigration.

Alan Beck pointed out that the habitat is also an important variable; in some cases, such as managing rat populations, a greater impact is achieved by changing the environment and removing food sources than through poisoning animals. James Serpell agreed, noting that 80% of owned animals are intact in Sweden without an accompanying overpopulation problem, which points to the importance of human attitudes and behavior to the issue, something beyond the control of contraceptive interventions.

Working groups focused specifically on modeling applied to cats or dogs

The participants were divided into two groups, tasked with developing a conceptual framework to model either cat or dog populations, identifying available data to fill the model, and identifying missing data that would point to goals for future research. The groups reported their results to the panel as a whole for fuller discussion. There was a great deal of overlap in the parameters identified by each group.

Dogs

The dog working group defined their target population as unmanaged community dogs, and identified many parameters affecting the dynamics of this population. The group decided that the three most important parameters for this population were mortality rate, reproductive rate, and dispersal, and identified multiple factors that contribute to each of these (Appendix A). Resource availability, human valuation, and disease were common influences on each parameter. The parameters were organized into a flow chart (Appendix A), indicating the interactions between them and having population growth as the final outcome. All three main variables were considered to be density dependent.


Drs. Julie Levy and James Serpell

The information to populate the model parameters was thought to exist in the literature, but not to be located in a single study or available from a single location on the globe. With the flow chart as a guide, it was decided the literature could be searched to find the relevant data. The group discussed whether female or male animals should be the targets of interventions in dogs, and it was decided that this is not known.

Cats

The cat working group identified their target population as free-roaming cats not subject to reproductive control, and to include free ranging neutered cats since these interact with the intact population.

This group identified four main areas affecting population reduction: population dynamics, ecology, culture/economics, and disease (Appendix B). Population dynamics included immigration and emigration, fertility, and mortality. Ecology included food, shelter, climate, and safety with a focus on the role of human sources of food, and a question as to whether reproduction is resource- or density-dependent. Human interaction was considered to be a very important variable, with human impact dependent on local animal control practices, socioeconomic status, and different attitudes towards the value of animal lives, and towards birth control. Disease was a broad term affecting many of the others, since disease can cause mortality, disease incidence can be dependent on ecology, and human feelings towards cats may be influenced by the perception that cats are vectors of disease.

The cat working group did not diagram their parameters, but went through a list of input data required by Vortex to identify values that are known and those that would require future research. Most of the 25 variables were considered to be relevant to cats, and most of the values could be found or approximated from existing data (Appendix B). The main gaps in the current data are age-related survival, habitat carrying capacity, and whether cat reproduction is density-dependent. The group was encouraged that a solid foundation exists to begin modeling in cats, with specific goals to acquire the remaining data.

Since both groups identified human intervention as an important parameter, discussion turned to how to

measure the impact of human valuation on a population. Phil Miller explained the process of participatory rural appraisal (PRA) in wildlife situations, where researchers interview individuals, careful not to instill bias, and parameterize the answers. Also relevant to the importance of human valuation as a parameter for both populations, Alan Beck introduced a new resource, the Human Animal Bond Research Institute (HABRI) at Purdue University, which could be a repository for such data.

Closing Discussion

The half-day session on Friday focused on developing an action plan, identifying the most important next steps. The group discussed whether to focus an initial modeling effort on dogs or cats. The working groups had identified many similar parameters for both dogs and cats. Though more resources may be available to study dogs because of the public health aspect of dogs carrying rabies, free-roaming cat populations are a greater issue in the United States. The remaining discussion focused primarily on moving forward with a cat model, with the understanding that once complete, this model could be modified to apply to dogs.

There was general agreement with John Boone's recommendation that to make better use of field data, standardized methods are needed to count animals and collect data, and with Steve Zawistowski's recommendation that terminology (e.g. community, owned, stray, free-roaming, feral, etc.) be standardized so everyone involved in these studies speaks same language with regard to target population and other parameters.

Gary Patronek felt it was important to clearly define population, since many feral cats in Boston live in small subpopulations, some of which can be so small that it approaches counting individual cats. Phil Miller agreed that for an animal as fecund as a cat, small populations likely should not be ignored because they can serve as a source of animals to migrate into or repopulate other areas. John Boone pointed out that the most important thing is not the definition chosen, but to pick a definition and stick to it for continuity.

Margaret Slater discussed the fact that for feral cats, carrying capacity and the mode and intensity of density dependence are unknown, and this information would be valuable to obtain. Her published model assumed a closed population, and no impact of reproduction or age on survival. To improve the model, she would introduce these parameters, break down reproduction and survival by age and sex, and add other factors discussed at the think tank including immigration and emigration rates, and maximum reproduction age for females. Some of these data could be collected from field trials.

James Serpell recommended field-testing the cat matrix model in existing TNR programs. Margaret Slater noted that a method to obtain population counts is still needed, and that the population would have to be followed for a long time. Steve Zawistowski agreed that many communities are not interested in a trial that is followed for several years – they want someone to come in and remove or deal with the troublesome population now. Claudia Baldwin suggested that for this reason rural areas may be more conducive to conducting trials.

Phil Miller encouraged the group to consider exactly what questions they want to ask, which will guide the development of the model. Joyce Briggs stated that ACC&D would like to query the model regarding whether it makes sense to develop a 3-year contraceptive in cats, or whether treating only male dogs is an effective strategy, or whether a contraceptive that is only 75% effective could be useful. As a starting point, Margaret Slater's matrix model might be modified by adding additional parameters such as age-specific life expectancy, life expectancy related to reproductive status, and rate of sterilization of males.

July Levy suggested plugging the existing cat data into Vortex, just to see what kind of answer it might give for the question of a 3-year contraceptive. Phil Miller recommended adding some variables, such as duration of contraceptive state, to allow modeling of scenarios where the contraceptive loses effectiveness more or less gradually.

Joshua Mitteldorf cautioned against unexpected consequences, and against assuming contraception can solve the problem. He referenced the attempt in Australia to exterminate rabbits with a virus, and how after a few years, the rabbits developed immunity to the virus. Homeostasis may apply to population size, and in spite of all attempts to change it, animals may adapt, by increasing reproductive rate for example, to maintain the optimal population size. He recommended controlling the size of the habitat as being more effective than trying to change reproduction.

Bryan Kortis agreed with Joshua Mitteldorf that contraceptive approaches work best in conjunction with education and environmental changes within the community, otherwise, the problem returns within a few years. Margaret Slater suggested a future think tank focused on the human side of implementing a program for a new nonsurgical contraceptive tool, including how to administer and monitor a program in addition to community psychology, and the roles of veterinarians, pet owners, and local governments. Joyce Briggs noted the expertise of PATH (www.PATH.org) and other organizations in social marketing to implement human health campaigns.

Joshua Mitteldorf also warned against expecting predictions from a model. Models can interpolate between two conditions, but are but are not sufficiently reliable to extrapolate outside the range of parameters for which we have existing data. John Boone agreed that prediction of the future is not the goal of a model, but that the model can allow you to explore multiple scenarios that would not be able to be tested experimentally due to time or other constraints.

Drs. Zawistowski, Patronek, and Serpell

Action plan

In conclusion, the panel agreed that it was worthwhile to develop a model for cat populations, and that modeling would be useful in establishing an array of research priorities ranging from identification of more precise data needed to improve the model to identification of sterilization approaches most likely to influence population size. The panel proposed the following action items:

1. Creation of a subgroup that will generate a 1-3 page report outlining scope of future work for cats, including the basic form a model would take, goals, and estimated time to completion/size of effort

2. Identification of other individuals and programs that may have data to aid in construction of a model, starting

with authors of studies in the background information compiled by Dennis Lawler for the think tank

3. Creation of a subgroup to identify ways to count cats and obtain other important missing data such as carrying capacity and density dependence, drawing on expertise used in wildlife scenarios

4. Field studies to obtain missing data related to effects of surgical sterilization on cats

5. Identification of ongoing TNR programs that might have or could generate data that would be valuable related to cats

6. Observation of cat density in various areas to approach question of carrying capacity

7. Examination of the literature to identify values for parameters to model unmanaged community dog populations, in anticipation of development of a dog model based on the initial cat model

8. Potential future meeting in 6 months to follow up on the progress since the think tank

In closing, there was enthusiasm regarding the feasibility of modeling cat and dog populations, and of collecting the data that would be needed to populate a model, either from existing literature or from newly designed field trials. Participants expressed interest in future meetings, via virtual meeting software or in conjunction with other meetings, such as NIMBIOS, that several participants already planned to attend. Joyce Briggs expressed the willingness of ACC&D to maintain a list of references generated by Dennis Lawler as a common resource, and to continue to act as facilitator in the modeling effort, happy with the momentum the think tank had generated to carry the work forward.

Following:
Appendix A: Parameters identified by dog working group for population modeling, including model chart
Appendix B: Parameters identified by cat working group for population modeling, including discussion of Vortex parameter values
Appendix C: Review of recent literature related to population dynamics and population modeling

Participants gather after the meeting

This Report was prepared by Tamara Golden, PhD, of Golden Bioscience Communications

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Appendix A: Parameters identified by dog working group for population modeling, including model chart

Define population: unmanaged dogs

A metapopulation that includes:

- Owned but unmanaged dogs
- Community dogs
- Stray/feral dogs

Output: population growth

Important parameters to include in model:

- Reproductive rate
- Population density
- Sex ratios
- Mortality rates, juvenile and adult
- Emigration/immigration
- Polygyny
- Sexual maturity
- Sexual senescence
- Mate guarding/territoriality
- Habitat/resource availability, impacts on reproduction and mortality

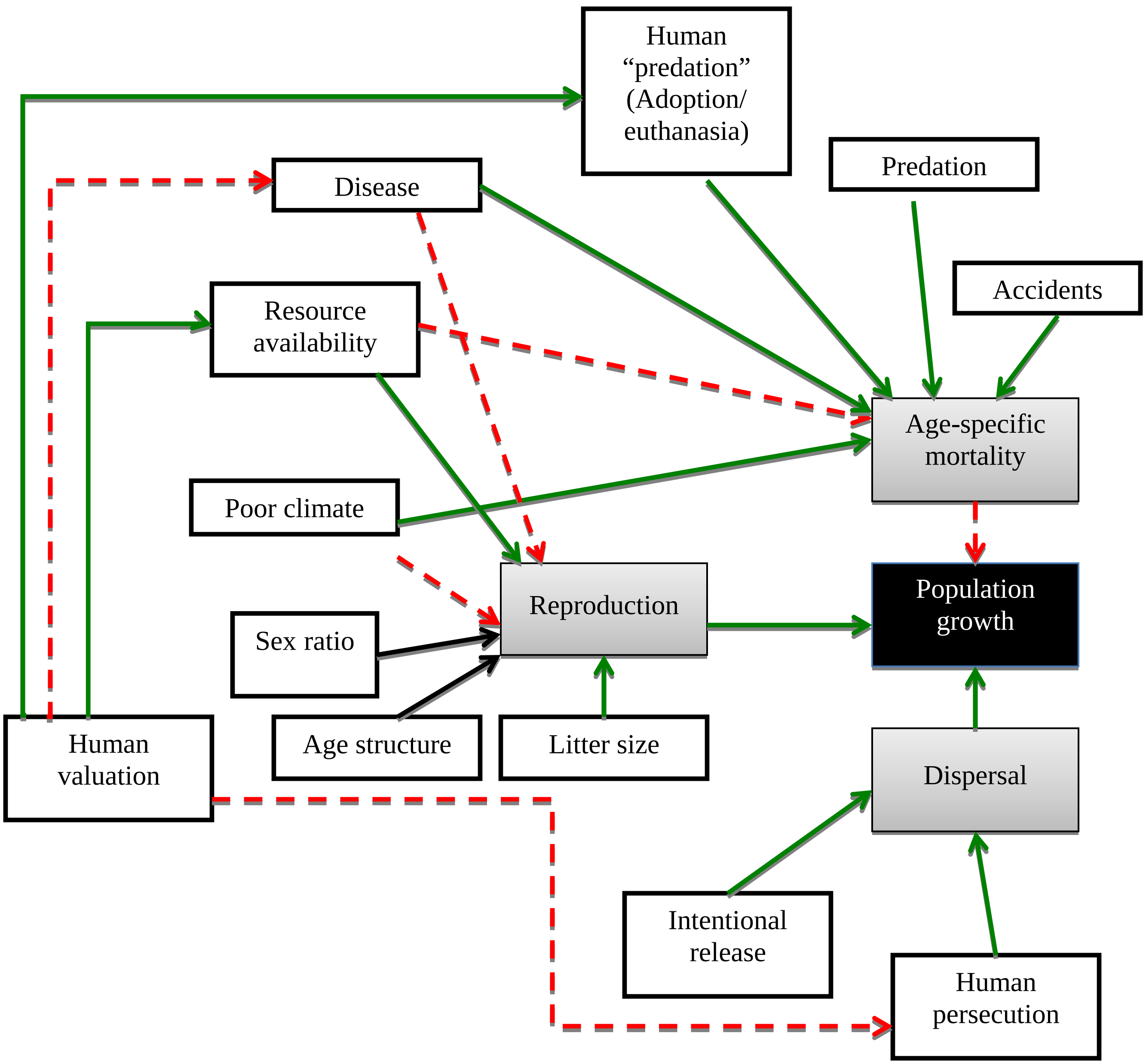
Highest Level Parameters (and contributors)

1. Mortality
    - Resources
        - Water
        - Garbage
        - Supplemental feeding
        - Slaughterhouse waste
        - Prey
        - ShelterPredation
        - Natural predators
        - Government control/"culls"
    - Disease
        - Distemper, Parvo, Rabies, parasites, etc
    - Climate/weather
    - Catastrophe
    - Accidents
    - Valuation of dogs as helpful/useful
    - Affective value, aesthetics/breed
    - Community social economic status

2. Reproduction
    - Health and nutritional status
    - Seasonal/climate
    - Sex ratios (slight male bias)
    - Age structure (data are available)
    - Litter size (several papers, most data from India)

3. Dispersal
    - Intentional or accidental release
    - Human persecution

Initial model chart drawn up by the dog working group
Population: Unmanaged community dogs
Red dashed arrows: negative effect on target parameter
Green arrows: positive effect on target parameter
Black arrows: variable or unknown effect on target parameter



Appendix B: Parameters identified by cat working group for population modeling

Define population: cats not subject to reproductive control
A metapopulation that includes:
Feral/free-roaming cats
Stray cats
Owned cats that go outside

Output: population reduction

Important categories affecting population:

Population Dynamics

- Immigration (from another population)
- Emigration
- Birth rate/fertility – age effects
- Death/mortality
- Frequency of movement – migration, function of food availability
- Toms holding territory

Ecology

- Food – what is the true influence of human supplementation? Do all populations depend on humans for food?
- Shelter – hiding places, related to reproduction
- Climate – affects survival
- Carrying capacity – can you calculate resources required per cat?
- Density dependence – resource based (is there compensatory reproduction?)
- Safety – predation (owls, hawks, coyotes), accidents, natural disasters

Culture/economics

- Animal control
- Social economic status
- Value of life
- Source of funds
- Attitudes to birth control
- Resistance to authority

Disease

- Affects youth mortality
- Depends on population density
- Cats as source of disease, affects human value

Availability of data for parameters in *Vortex:* Input data required for *Vortex*, relevant to cat population modeling
From PHVA Workshop Process Reference Packet, Appendix I, pp. 16-19, Published by IUCN/SSC Conservation Breeding Specialist Group

1. **Species and geographic range**: Cat
2. **Breeding system**: Variable, not monogamous
3. **At what age do females begin breeding?** 6-7 months on average
4. **At what age do males begin breeding?** 9-10 months
5. **Maximum breeding age?** 72 months female, life-long male
6. **What is the sex ratio of offspring at birth?** 50:50
7. **What is the maximum litter size?** 2-5 (3.5 supported, 2.9 feral)
8. **In the average year, and at optimal densities (see below), what proportion of adult females produces a litter?** 40% (Discussion about whether this information can be obtained from trapped animals: are pregnant animals easier to trap? Gary Patronek reports observing as many as 80% pregnant in March)
9. **How much does the proportion of females that breed vary across years?** Think no variance
10. **Is reproduction density-dependent?** Unknown
11. **Of litters that are born in a given year, what percentage are litters of** can be found
    1 offspring
    2 offspring
    3 offspring
    4 offspring
    5 offspring
12. **What is the percent survival of females at each year of age?** Unknown, but 35% mortality within first year sheltered, 70-80% mortality unsheltered
13. **What is the percent survival of males at each year of age?** As in 12, unknown, but data may be out there
14. **For each of the survival rates listed above, enter the variation across years as standard deviation.** Unknown
15. **Do you want to incorporate inbreeding depression?** No

16. **Do you want environmental variation in reproduction to be correlated with environmental variation in survival?** Yes
17. **How many types of catastrophes should be included in the models?** Outbreak of disease, dog attack
18. **Probabilities of each catastrophe in 17** Not estimated
19. **Are all adult males in the "pool" of potential breeders?** Yes
20. **If you answered "No" to Question 19, then answer the following**
21. **What is the current population size?** Could estimate
22. **What is the habitat carrying capacity?** Unknown, correlates with human population and human supplemental feeding
23. **Will habitat be lost or gained over time?** Habitat may increase with increase of urban sprawl
24. **Will animals be removed from the population?** Yes – adoption, numbers not estimated, should be broken down by sex and age
25. **Will animals be added to the population?** Yes – immigration from indoor population may correlate with regional socioeconomic status or human population density

Appendix C: Review of recent literature related to population dynamics and population modeling

Prepared by research veterinarian Dennis F. Lawler, on behalf of the ACC&D Think Tank planning committee.

PURPOSE AND STRUCTURE OF DOCUMENT
The studies listed below are organized by cat and then dog, with a few combined studies added. Within grouping, they are listed chronologically, and by lead author's surname within the same year. This list is not exhaustive.

Cats
Haspel C, Calhoun RE. Home Ranges of free-ranging cats (Felis catus) in Brooklyn, New York. Can J Zool 67:178-181, 1989.

Urban cats were studied in two neighborhoods, distinguished primarily by presence or absence of poverty factors, including multiple housing, vacant buildings, and exposed garbage in the latter. Home ranges in male (2.6 ha) and female cats (1.7 ha) were smaller than in more rural areas. Male home ranges varied more in size than those of females, and males were more active at home range peripheries. Seasonal estrus, neighborhood, garbage, abandoned buildings, and supplementary feeding did not influence home range size. Rather, cat size was the influential factor, as a gender effect, averaging 4.1 kg among males and 2.9 kg among females ($p<0.01$). Urban, New York, USA

*Urban home ranges of male and female cats were accounted for primarily as a size-related gender effect.

Levy JK, et al. Evaluation of the effect of a long-term trap-neuter-return and adoption program on a free-roaming cat population. JAVMA 222:42-46, 2003.

Long-term (11+ yr) evaluation of the effect of TNR on population dynamics of un-owned, free-roaming cats (n=155). 75% of the cats were truly feral, and 25% showed some human-orientation. 56% of the originals were kittens. After year 4, no kittens were on site. Immigrants were provided TNR prior to reproduction opportunity. By study conclusion, human-orientation allowed 47% adoption, while 15% were on site. 11% were euthanized, 15% had disappeared. College Campus, Florida, USA

*Consistently-applied TNR, along with population monitoring, effectively reduced and maintained this population of cats over a long period of time.

Levy JK, et al. Number of unowned free-roaming cats in a college community in the Southern United States and characteristics of community residents who feed them. JAVMA 223:292-205, 2003.

In a telephone survey, 587 households (0.7% of county households) answered questions regarding feeding unowned, free-roaming cats. 12% of households fed an average of 3.6 cats; 43% of households feeding unowned cats did not own cats. 90% of owned household cats were sterilized, compared with only 11% of feeding households that attempted to have roaming cats sterilized. Frequencies of observations were analyzed using chi-square. Florida, Alchera County, USA, mixed geography

*Feeding unowned cats is a human behavior that crossed socio-economic status and pet-ownership, as previous studies have shown.

Andersen MC, et al. Use of matrix population models to estimate the efficacy of euthanasia versus trap-neuter-return for management of free-roaming cats. JAVMA 225:1871-1876, 2004.

A matrix population model was constructed using parameter estimates of: Mean litter size 3.6; litters/year 1.1 low – 2.1 high; first conception mean age 212 days; offspring 50:50 sex ratio; 1.98 - 3.78 female offspring/yr; juvenile survival estimates 50 - 75%; adult survival 2 -3 yr. Annual population growth rate in this model: 1.34 – 2.49, geometric mean 1.84. TNR intervention at 75% of females = population growth rate 1.08 annual. Population females euthanasia ≥ 50% = population growth rate < 1.00 annual.

*Population growth was more sensitive to survival than fecundity, for equivalent percent interventions TNR or euthanasia.

Nutter FB, et al. Reproductive capacity of free-roaming domestic cats and kitten survival rate. JAVMA 225:1399-1402, 2004.

Data were collected from managed (human intervention) feral colonies, as part of a trap-neuter-release (TNR) study of 625 individuals. Litters/yr/queen ranged from 1.4 low - 3.0 high, with fetus mean count (at surgery) exceeding mean full term count for kittens. 75% of full term kittens died or disappeared by age 6 months. North Carolina, USA, semi-feral cats.

*Given mortality rates, colony regenerative capacity is surprisingly high without intervention.

Foley P, et al. Analysis of the impact of trap-neuter-return programs on populations of feral cats. JAVMA 227:1775-1781, 2005.

Excel and “R” software were used for data analysis and modeling. A Ricker model was used to describe population dynamics. Subjects were 26,274 (semi-feral) cats in CA and FL, over 11 and 6 years, respectively. 9% of over 1M households fed mean 2.6 semi-feral cats. 14,129 surgeries were done during the study. Overall and annual neutering rates to achieve 1.0 population growth rate were calculated for various mean life spans, growth rates, and survivorship. Semi-feral cats fed by householders in California and Florida USA

*The authors interpreted their data as mixed results with respect to TNR effectiveness.

Short J, Tanner B. Control of feral cats for nature conservation. IV. Population dynamics and morphological attributes of feral cats at Shark Bay, Western Australia. Wildlife Res 32:489-501, 2005.
Investigators studied population dynamics of feral cats over a 14-year period. Two adjoining semi-arid sites had differing levels of site management. Project goal for non-cat species conservation: Identify levels of harvest to eliminate or control feral cats at low density, via euthanasia. Cat diet was 88% rabbits, 4% other small mammals, 3% carrion, 2% birds, and invertebrates. Two (trap-shoot-poison) terminal studies were done: Total capture and index-manipulation-index. Density, size, age, and sex of cats, and their distributions, were evaluated. Summer peak density (carrying capacity) was the index = 0.244 (slope/intercept of population regression plot). Season and energy availability influenced cat condition, ease of trapping. Cat densities averaged 0.6 – 1.0 km-2, with considerable variation. Feral populations, Australia

*Constant harvest at 0.37 cats km-2 was estimated to maintain the population near local extinction, but approximately 6-fold increase of capture effort occurred with declining density, indicating ongoing problems in larger ranges.

Mendes-de-Almeida F, et al. The Impact of Hysterectomy in an Urban Colony of Domestic Cats (Felis catus Linnaeus, 1758). Int J Appl Res Vet Med 4(2):134-141, 2006.

A mark-recapture method (n=96 cats) was used to estimate the population for a 36-month study. Upon capture, gender was determined and age estimated via dental appearance; vaccination, microchip implanting, and parasite control was practiced at this time. Females (n=37) underwent hysterectomy, while ovaries remained intact. Kittens declined from initial 17% percent to 2.5 percent, and male:female ratio of adults was 1:3. Immigrations decreased from 54% to 15% of the population. 22 attritions occurred, influencing the population size. Rio de Janeiro Zoological Garden grounds, Brazil

*Biennial intervention by hysterectomy stabilized the population structure at no growth.

Natoli E, et al. Management of feral domestic cats in the urban environment of Rome (Italy). Prev Vet Med-2214, on-line, 2006.

Data are presented on colony cats in Rome from 1991-2000. Italian law protects free-roaming cats, requires TNR, and institutionalizes human care of the colonies; the cat colonies are registered. Over 10 years, neutering reduced median cats/colony from 12 to 10; large colonies were fewer. Given sterilization and mortality/disappearance, overall decline in cat numbers was about 22%. Non-sterilized cats have greater mortality risk, and immigration/emigration impact total numbers. Rome, Italy, urban

*TRN programs can reduce numbers of free-roaming colony cats, but unsterilized roaming (abandoned) cats and immigration must be controlled as well. Public education is critical to these efforts.

Wallace JL, Levy JK. Population characteristics of feral cats admitted to seven trap-neuter-return programs in the United States. J Fel Med Surg 8:279-284, 2006.

Data were evaluated from seven TNR programs in various geographical areas. Between 1993 and 2004, a total 103,643 cats underwent TNR. Intact females were 53.4%, intact males were 44.3%, with 2.3% previously sterilized. 16% pregnancy was noted seasonally, with average litter size 4.1 (larger than a well-known average litter size at parturition). 5.2% were retrovirus-positive; must were euthanized. 0.4% TNR-related mortality was recorded. Multi-source, free-roaming, USA

*Large numbers of cats can be sterilized with good safety records, and infectious disease control can be practiced effectively at the same time, although additional investment is required.

Schmidt PM, et al. Survival, fecundity, and movements of free-roaming cats. J Wildlife Management 71(3):915-919, 2007.

Investigators tracked 54 radio-collared cats that were owned, semi-feral (being fed), or feral. Feral cats had 1.0 litters/year, semi-feral 1.6 (owned cats sterilized). 7 feral litters mean of 3.50 kittens, survival 1.75. 8 semi-feral litters mean 3.60 kittens, survival 2.75 (survival ≥12 wk). Feral cat survival was only slightly lower than semi-feral survival. Annual ranges decreased with increasing “ownership”. Feral cats 50% kernel estimate 1.4 ha, 95% kernel estimate 10.4 ha; Semi-feral cats 50% kernel estimate 0.4 ha, 95% kernel estimate 3.3 ha; Owned cats 50% 0.06 ha, 95% 0.4 ha. No determination whether predation, nuisance behaviors, or disease transmission are altered by TNR or other sterilizations. Texas, USA, suburban

*Human interventions, such as feeding, can concentrate free-roaming cats to increase local environmental effect, or limit their impact by keeping them in a smaller area. These factors need to be considered in population management strategies.

Budke CM, Slater MR. Utilization of Matrix Population Models to Assess a 3-Year Single Treatment Nonsurgical Contraception Program Versus Surgical Sterilization in Feral Cat Populations. J Appl AnimWelfare Sci 12:277-292, 2009.

A hypothetical matrix model was constructed to explore feral cat population growth under conditions of (a) no interventions; (b) TNR intervention; (c) single 3-yr nonsurgical contraception. Juvenile and adult cats were considered. Fecundity was defined as female kittens/year/queen. Data were processed with Excel and Poptools software. Assumptions for the model included: A single, closed breeding population with males and females available; half-year survival rates for breeding individuals; no breeding seasonality; no carrying capacity; modeling of sterilized females only; nonsurgical contraception 100% effective. Vital rates (lifecycle metrics) included juvenile and adult female fecundity and survival. Other assumptions: No re-trapping of contracepted cats; contracepted cats fertile at +3 years; each model began with 100 adult females; carrying capacity was not represented; environmental effects such as climate were not represented; males and male-dominance-related breeding patterns were not represented; immigration was not assumed. 10%, 20%, and 30% annual TNR and contraception were modeled. Zero population growth required ≥ 51% annual juvenile/adult TNR, with continuing maintenance of 71% & 81% all-female and adult-female sterilized rate after stabilization. Without juvenile sterilization, 91% annual sterilization was necessary. 100%-effective contraception required 60% application, with re-trapping and re-sterilization as well.

*These practices might be logistically infeasible in very large populations. Long-term effect of contraception would depend on survival and re-treatment. Colony-specific metrics can be quite variable, and at times, ecosystem sensitivity must be considered in option-selection.

Schmidt PM, et al. Evaluation of euthanasia and trap–neuter–return (TNR) programs in managing free-roaming cat populations. Wildlife Res 36:117-125, 2009.

Investigators evaluated a 25-yr model of euthanasia and TNR methods of controlling free-roaming cat populations. Parameters were estimated from 43 radio-tracked cats, from an unmanaged free-roaming cat population and within the same population described in reference (1) above. TNR and euthanasia were modeled at 25%, 50%, and 75% of the population, as was a 50:50 TNR:euthanasia model at these rates plus 100% implementation. Maximum immigration rates were included in the model, at 0%, 25%, 50%, and 100%. STELLA7 was used for programming. Primary readouts were final population size, cats handled, method effort. TNR and euthanasia resulted in population decreases that were similar across options and implementation rates at 0% immigration, but decreases were greater for the 25% euthanasia with 50% immigration. Texas, USA, suburban

*Carrying capacity was a more sensitive outcome indicator than was immigration, but both influenced final population size. The euthanasia effort was greater than was the TNR effort. Implementation rates must be high, and immigration prevented, to achieve population reduction.

Loyd KAT, DeVore JL. An Evaluation of Feral Cat Management Options Using a Decision Analysis Network. Ecol Soc 15(4):10, 2010.

A model-based approach was developed to predict population response to management options, and to extend calculations to impact on wildlife. A Bayesian Belief Network was developed to evaluate and rank population management decisions by efficacy, regional cultural factors, and cost. Choice of management variations depended on initial cat population size. The model predicted that TNR programs are initially optimal for local populations n<50 cats. Removal programs were predicted to best protect adjacent wildlife when cat populations are larger. Costs for removals are about ½ those of TNR-variant programs; public opinion plays an important role in regional solutions.

*The decision analysis network predicts that removal will reduce feral cat populations quickly, which may be important in some environments.

Patronek GJ. Mapping and measuring disparities in welfare for cats across neighborhoods in a large US city. AJVR 71:161-168, 2010.

Addresses (cat-related, n=15,285) in a large American city were geocoded and evaluated with cat mortality data from two sheltering groups and from animal control data. Addresses were overlaid into 16 polygonal neighborhood maps, defined socioeconomically. Software used was ESRI Arcmap 9.3. Greater cat mortality was significantly associated with human-related socioeconomic deprivation markers (public assistance, unemployment, crowded housing, children in poverty, female head of household, overall poverty, under-education, males in professional occupations). Premature human death (<75 yrs) explained 77% of cat mortality variation. Combined shelter cat mortality data indicated 2.6 cat deaths/1000 humans, consistent with good city-wide animal sheltering, but neighborhood-related cat death gradients differed between 14- and 40-fold. Massachusetts, urban, owned cats, USA

*Shelter-associated cat deaths correlated with premature human death and socioeconomic indicators of deprivation, and thus may be an index for the latter. Given cat death gradients, the need for low-cost spay-neuter programs may be more localized than previously was recognized.

Finkler H, et al. The Impact of Anthropogenic Factors on the Behavior, Reproduction, Management and Welfare of Urban, Free-Roaming Cat Populations. Anthrozoos 24(1):31-49, 2011.

In neighborhoods with differing socioeconomic status (SES), the authors examined caretaker relationships to eight free-roaming cat populations. High SES neighborhoods covered 12 km2, compared to 15km2 in low SES neighborhoods. Of 622 feeding groups, 392 were in higher SES areas and 230 were in low SES areas.

Four hypotheses were considered: (a) Caretaker behaviors and housing type (density of humans) influences cat behaviors; (b) Reproduction control is influenced by city management and caretaker behaviors; (c) Pregnancy rates are influenced by city management and caretaker behaviors; (d) Cortisol levels are affected by caretaker attitudes and socioeconomics.
City veterinary data were acquired for the years 2000-2005 for (a) Number of cat groups; (b) Number of cats sterilized; (c) Number of veterinary visits to cat group; (d) Pregnancy rate; (e) Rabies vaccination rate.
SES variables for selection of 8 of 63 neighborhoods included (a) Educational matriculation; (b) Employment rate; (c) Immigration rate; (d) Computer ownership; (e) Income. Final neighborhood selection (n=8) also included predominant type of housing.

Cat group inclusion criteria included (a) Nutritional adequacy; (b) Cooperating caretaker; (c) At least 10 cats; (d) Cooperation of neighbors; (e) Access for observation.
Density was 33 groups/km2 in high SES areas vs 15/km2 in low SES areas. In high SES areas, more cats were sterilized, more were vaccinated, and there were more veterinary visits with more captures/veterinary visit. Caretaking resulted in improved behaviors, as did sterilizing, while housing and SES did not influence behaviors. High SES areas had lower frequency of pregnancies, while housing and caretaking had no influence. Sterilized cats had lower serum cortisol, but caretaking had no influence.

*Anthropogenic factors need to be considered in municipalities that are considering cat population control measures.

Gunther I, et al. Demographic differences between urban feeding groups and sexually intact free-roaming cats following a trap-neuter-return procedure. J Am Vet Med Assoc 238(9):1134-1140, 2011. (Same study as following paper.)

Four feeding groups of free-roaming cats (n=184), widely separated to prevent interactions, were evaluated from October 1999 to October 2000. Regular feedings and observations were conducted, although there were some differences among the four groups in observation length, cat handling, and caretaker preferences for particular cats. Cats within group varied in affinity to humans. Caretakers provided food daily, usually in excess of need, at times familiar to the cats in each group. For the study, cat group A was TNR at 73%; group B was TNR at 75%; groups C and D were not TNR. TNR cats were mixed male and female. Efforts were made to identify and track cats as individuals, with behaviors and presence/absence recorded as such. Observation periods were group-specific in length, done before and during feeding. For the first 5-7 weeks, observations were 2-3 days/week. For the following 8 months, observations were weekly. For the last 5-7 weeks, observations were 2-3 days/week.

Groups A and B experienced post-TNR population increases through unsterilized immigrations and few emigrations. Groups C and D experienced population decreases over one year. Groups A and B demonstrated greater kitten survival. Israel, Tel-Aviv, urban

*The authors interpreted their observations to be reflections of lesser reproductive and competitive pressures. The authors concluded that continuous TNR would be required to maintain a high proportion of sterilized individuals in a free-roaming population.

Finkler H, et al. Behavioral differences between urban feeding groups of neutered and sexually intact free-roaming cats following a trap-neuter-return procedure. J Am Vet Med Assoc 238(9):1141-1149, 2011. (Same study as preceding paper.)

Four feeding groups of free-roaming cats (n=184), widely separated to prevent interactions, were evaluated from October 1999 to October 2000. Regular feedings and observations were conducted, although there were some differences among the four groups in observation length, cat handling, and caretaker preferences for particular cats. Cats within group varied in affinity to humans. Caretakers provided food daily, usually in excess of need, at times familiar to the cats in each group. For the study, cat group A was TNR at 73%; group B was TNR at 75%; groups C and D were not TNR. TNR cats were mixed male and female. Efforts were made to identify and track cats as individuals, with behaviors and presence/absence recorded as such. Observation periods were group-specific in length, done before and during feeding. For the first 5-7 weeks, observations were 2-3 days/week. For the following 8 months, observations were weekly. For the last 5-7 weeks, observations were 2-3 days/week.

Groups A and B, sterilized at approximately 75%, displayed fewer agonistic encounters. Male-male encounters were more agonistic between intact cats than between sterilized cats. Group A neuters appeared for feeding earlier in feeding periods than intact cats, and stayed longer. Israel, Tel-Aviv, urban.

*The authors conclude that neutered cats timed their arrival for feeding earlier than intact cats, possibly as an available response to decreased sexual and agonistic interactions, and possibly as learned behaviors related to better choices among offered foods. Further, TNR reduced fighting and vocalizations, which would be expected to result in fewer injuries and opportunities to transmit diseases.

Horn JA et al. Home range, habitat use, and activity patterns of free-roaming domestic cats. J Wildlife Management 9999(xx):1-10; 2011; DOI: 10.1002/jwmg.145.

Radiotelemetry and activity sensors were used to study home ranges, habitat use, and activity of owned and unowned free-roaming cats. Groups of 11 owned and 16 unowned cats were monitored over 2544-hectares during 2007-2008. Owned cats (all sterilized) had smaller home ranges ($p=0.02$) than unowned cats (2 sterilized). Annual ranges of unowned cats were larger than their seasonal ranges because of season-related habitat use that did not occur in owned cats. No gender-related interactions or seasonal differences were found. Time given to denning and sleeping was less ($p<0.01$) among unowned cats, while time given to high activity levels was greater ($p<0.01$) among unowned cats. Among a group of 27 unowned and 12 owned cats, following censoring of data from 5 unowned (disappeared) cats, cumulative survival was 50% among unowned cats (392 days) and 92% among owned cats (596 days). USA, Champaign-Urbana Il, urban to rural.

*The authors concluded that ranging and activity suggest that unowned cats may influence local wildlife more than owned cats, although greater effect of owned cats in smaller ranges also is possible. Feeding and owner care modify space use and activity.

NOTE: Sample sizes were quite small.

Dogs

Patronek GJ, Glickman LT. Development of a model for estimating the size and dynamics of the pet dog population. Anthrozoos 7(1):25-42, 1994.

Data were collected in Washington and Iowa. Assumptions for the model included birth-death equilibrium, negligible feral component, total population can be estimated from known sub-population proportions, and an equilibrium population can be estimated from supply side numbers. The model estimated total annual population mortality at 12.4% and total annual (owned pets) turnover at 14.7% (7.71 million). Household breeding contributed <20% of supply-side breeding females. The contribution to the total dog population by failure to retain homed dogs was 3-fold that of household breeding. Washington, Iowa, mostly owned, USA

*Designing dog population control measures necessitates close examination of shelter and owned populations at the community level. In this study, an important problem was failure to retained previously homed dogs.

Frank J. An Interactive Model of Human and Companion Animal Dynamics: The Ecology and Economics of Dog Overpopulation and the Human Costs of Addressing the Problem. Human Ecol 32(1):111-130, 2004.

A model was constructed to understand canine population dynamics and control policies. Model parameters included population data (owner, shelter, rescue, stray, feral, breeder, pet store); endogenous data (births, deaths, shelter adoption, stray adoption, abandonment, relinquishment); exogenous data (births, deaths, sterilization owned & stray, life span, space, stray and animal control data, influences on abandonment). Many factors were estimated because of incomplete information.

Spay-neuter: 47% reduction of non-spay/neuter households would decrease shelter deaths to zero. Against a goal of 50% less euthanasia in 30 years, spay/neuter achieved stabilization after 40 years.

Encouraging adoptions: 90% increase in adoption rate, through substitution of sources, would decrease shelter deaths to zero. With a goal of 50% less euthanasia in 30 years, increasing adoptions through source substitution had a rapid effect that was sustained, whole increasing adoptions through new ownerships showed evidence of decreasing effect with time and eventual re-stabilization at a lower level of reduced euthanasia.

Reducing abandonment: Abandonment must be reduced 70% to stop euthanasia in 1 year. Against a goal of 50% less euthanasia in 30 years, reduced abandonment had a temporary effect. However, two-dog purchase deterrence with reduced abandonment was successful.

Synergies among options: Adoption + spay/neuter synergistically reduced euthanasia; spay/neuter + reduced abandonment had a negative effect; reduced abandonment + increased adoption had a negative effect.

*Spay/neuter and increased adoption, alone or in combination, were most effective for reducing euthanasia over time.

Reece JF, Chawla SK. Control of rabies in Jaipur, India, by the sterilisation and vaccination of neighbourhood dogs. Vet Rec 159:379-383, 2006. TNR was combined with simultaneous rabies vaccination.

Over the years 1994-2002, a total 24,986 free-roaming local dogs underwent TNR and rabies vaccination. TNR was done sequentially in 6 pre-determined urban districts. For some dogs, euthanasia was deemed necessary by veterinary staff. Over this time, direct local observation indicated that 65% of females had been sterilized, along with a 28% decrease in the dog population. Between 1992 and 2002, annual human rabies declined from about 10 to zero in managed areas, but not in unmanaged areas. Jaipur, urban, India

*The TNR program was intended for rabies control, but had the effect also of reducing and stabilizing local dog populations.

di Nardo AD, et al. Modeling the effect of sterilization rate on owned dog population size in central Italy. Prev Vet Med 82:308-313, 2007.

A spread sheet model was used to evaluate data regarding owned dogs collected from managed (shelter) kennels and telephone survey of dog owners. Data were used to estimate 2.6% annual dog population increase, assuming 30% sterilization at age 3 years. To halt growth using this model, 55% sterilization was estimated. Sterilization at age <1 year was estimated to require only 26% sterilization rate to halt population growth. Estimated 1% decrease in death rate across age groups increased annual growth to 3.4%. Italy, Provincial, owned or supervised pets

*Continued at the current sterilization rate of female dogs, a continuing population increase should be expected.

Lenth BE et al. The effects of dogs on wildlife communities. Nat Areas J 28(3):218-227, 2008.

The authors compared wildlife activity in areas that were dog-permissive or dog-exclusionary.
5 metrics were observed on trails and up to 200 lateral meters away: pellet plots, track plates, cameras, on-trail scat, prairie dog locations. Dog-permissive areas had lower trail-proximate activity for mule deer, rabbits, squirrels, and prairie dogs. Among carnivores, bobcat sightings were reduced, but red fox sightings increased.

*These observations have implications for managing natural areas that allow off-leash dog activities.
Colorado, USA, rural

Ratsitorahina M, et al. Dog ecology and demography in Antananarivo, 2007. Biomed Central Veterinary Research 5:21, 2009. Open Access.

A questionnaire survey was done among 1541 urban households. Owned dogs per city district (n=6) were estimated by multiplying estimated own dogs/person x number of persons in that district. Data were analyzed using EpiInfo6 software. Total dog population across districts estimated at 235,085, of which estimated 29,449 were un-owned. 91% of un-owned dogs were known by human residents.

Male:Female ratio 1.5 ($p<0.01$). 51% of owned females had a pregnancy during the preceding 12 months, with mean survival 3.7 pups. 79% of owned dogs spent much of their time off the owners' property. 81% of owned dogs were considered guard dogs; 52% were outwardly aggressive. 25% of owned dogs had regular veterinary care and 42% had no history of medical care. 36% had some history of rabies vaccination; 22% were revaccinated regularly; only 7% of dog owners had documentation of vaccination. Urban, owned and un-owned dogs, Madagascar

*Madagascar has a serious rabies problem, compounded by a large dog population that is dynamic, poorly supervised, and inadequately vaccinated. Risk for rabies transmission is high, and the human population not well-educated about rabies and reproduction management, both of which would reduce animal and human rabies.

Vanak AT, Gomperr ME. Dietary niche separation between sympatric free-ranging domestic dogs and Indian foxes in central India. J. Mammalogy 90(5):1058-1065, 2009.

Fox and dog diets were determined by fecal analysis in a sanctuary with a largely agrarian-type resident human population. Resident dogs are predominantly used for herding work, farming work, or they are village dogs. Radio-tracking studies show that fox habitat use is negatively associated with dogs, which will kill fox without consumption, suggesting competition. Dogs subsisted primarily on human-derived foods, ungulate carcasses, and crop residue. Fox subsisted primarily on invertebrates, rodents, and fruits, although the fox is a generalist carnivore. Rural, mostly owned, India

*Data suggested a diet-related separation of sympatric species, imposed primarily by dogs, the dogs thus having a negative wildlife impact via interference competition.

Zinsstag J, et al. Transmission dynamics and economics of rabies control in dogs and humans in an African city. PNAS 106(35):14996-15001, 2009.

Deterministic models of rabies transmission among dogs were extended to include dog-human transmission. Modeling estimated dog-dog transmissions/week = 0.087 km-2, and dog-human transmissions/week = 0.0002 km-2, with stability of transmission rates. Dog vaccination scenarios were simulated at 50% and 70% application. 70% vaccination would interrupt transmissions. 50% vaccination application or 2 annual shooting events of 5% and 10% of the urban dog population were not projected to be similarly successful. Related data include dog birth rate estimate at 0.013/week; dog mortality estimate 0.0066/week. Program cost analyses indicated that 70% mass vaccination with post-exposure prophyllaxis for human is cost-effective at about year 5-6. Urban, ownership undefined, Chad.

*70% dog vaccination with post-exposure prophyllaxis for humans was cost-effective at year 5-6; human post-exposure prophyllaxis alone (the current practice) was less cost-effective from year 7 than the combined program.

Carroll MJ, et al. The use of immunocontraception to improve rabies eradication in urban dog populations. Wildlife Res 37:1-12, 2010.

Three rabies control methods were modeled using a continuous time, compartmental model: Vaccination alone, Vaccination with fertility control, or Euthanasia. These methods were evaluated at various rates and durations. 3 categories of subjects were Healthy and rabies susceptible, Exposed and incubating rabies, or Symptomatic and contagious. Likelihood of birth, death, exposure, and receipt of control measures were equalized across categories.
Density dependent mortality rate was assumed to drive all density-dependence. Parameter values were acquired from literature. Possible outcomes were rabies persistence, rabies eradiction, and population extinction.

*Vaccination alone was least effective in continuous application, while vaccination + fertility control was consistently most effective.

Massei G, et al. Immunocontraception to control rabies in dog populations. Human-Wildlife Interactions 4(2):20-21, 2010.

Estimates suggest that dogs are associated with 90% of 55,000 human deaths annually. Over 14 million people receive post-bite rabies prophylaxis annually, with Asia and Africa being most involved. Lethal measures for dog control raise many welfare and safety questions, one reason for the advent of TNR programs. TNR can be effective locally but research suggests that reproduction rates among large populations may outpace TNR control efforts. Hence, the advent of immunocontraception, used with rabies vaccination, is the next step in developing more effective controls. Models suggest that immunocontraception with rabies vaccination could effectively reduce rabies in the red fox population, and also limit the spread of other zoonoses.

*Combined non-surgical control of conception and rabies vaccination is advocated as a practice to which validation research should be directed.

Dogs and Cats

Patronek GJ, Beck AM, Glickman LT. Dynamics of dog and cat populations in a community. JAVMA 210(5):637-642, 1997.

A cross-section, random-digit telephone survey was used to collect pet ownership data from 1272 households in a single community. 63% of dogs and 80% of cats were sterilized. Among unsterilized females, 3.4% of dogs and 7.9% of cats had a pregnancy within 12 months of the study. Cat litters were unplanned, but 2/3 of dog litters were planned. Annual turnover of owned dogs was 14.1%, vs 18.4% for cats. Surveyed pet owners under-reported relinquishment. Urban, Washington, Iowa, USA

*The dynamics of pet populations should not be assumed across communities, but need to be evaluated locally when control measures are being considered.

New JC Jr. Birth and death rate estimates of cats and dogs in US households and related factors. J Appl Anim Welfare Sci 7(4):229-241, 2004.

A commercial survey company sent questionnaires to 7400 American households in 1996, based on an unequal probability sampling plan, from which data national (USA) estimates were acquired. 1996 estimates suggested 9 million cat and dog deaths (8.3% of estimated household cats, 7.9% of estimated household dogs). Cat litters were estimated at 2x dog litters, averaging 5.73 kittens and 7.57 puppies. Kitten births were estimated at 11.2/100 household cats. Puppy births were estimated at 11.4/100 household dogs.

*This was, evidently, the first nationalized estimate study of its kind. The data, while from 1996, illustrate the magnitude of household turnover of US pet dogs and cats. NOTE: These numbers align well with my experience (DFL) in community practice and in available various research publications.

Campos CB, et al. Diet of free-ranging cats and dogs in a suburban and rural environment, southeastern Brazil. J Zool 273:14-20, 2007.

Investigators estimated density of cats in winter 181 km-2; cats in summer 112 km-2; dogs in winter and summer 77 km-2. Suburban cat density in winter was 4.6/ km-2/day; summer 0.10/ km-2/day. Invertebrates were most-consumed by cats, followed by mammals that included opossum 19.3%, guinea pig 15.4%, small rodents 21.4% winter, armadillo 14.3%winter, opossum 14.3% winter, rabbit and hare 16.7% winter. Murinae were consumed also. Brazil, suburban-rural

*These data could be useful for developing programs to minimize impacts of feral cat (and dog) predatory behavior against wildlife.

Trevejo R, et al. Epidemiology of surgical castration of dogs and cats in the United States. J Am Vet Med Assoc 238:898-904, 2011.

The authors evaluated medical records of 320,172 cats and 1,339,860 dogs examined at 651 Banfield-owned USA veterinary hospitals during 2007. Conditions for inclusion were age, breed, sex, spay-neuter (castration) status, and knowledge of wellness plan enrollment status. Data were divided into six geographic regions.

In this database, intact cats averaged age 1.5 yr, compared to 5.2 year for castrated cats ($p<0.001$). Male cats were slightly more numerous, at 83% castration versus 81% of females ($P<0.001$).

Cats enrolled in prepaid wellness plans were more likely to be castrated ($p<0.001$).

The lowest prevalence of cat castration was in the northeastern US, at 80% ($p<0.001$).

Castrated dogs averaged age 4.7 yr, compared to intact at 2.2 yr, with slightly greater female numbers than males ($p<0.001$).

Dogs enrolled in prepaid wellness plans were more likely to be castrated, and the lowest prevalence of dog castration was in the southeastern US, at 61% ($p<0.001$).

*The authors concluded that wellness communications need to be tailored to age, sex, and breed observations by geographic region, with respect to trends for intact or castrated status.

Comment: Regional societal attitudes likely are reflected in these data, but the demographics of location for Banfield-owned practices, and characteristics of employed clinicians, should be considered also.

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