Here, Kitty, Kitty: Modeling Feral Cat Populations and Their Control

Project Module Associated with
***2nd Edition, Introduction to Computational Science: Modeling and Simulation* by**
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Prerequisite for Projects 1-8: *Module 11.2, "Agents of Interaction: Steering a Dangerous Course"*
Prerequisite for Project 9: *Module 4.3, "Constrained Growth"*

Introduction

Piping plovers (*Charadrius melodus)* are small shorebirds that find themselves a threatened and endangered species. During the spring and early summer, the birds nest along beaches in the northern United States and in Canada. From late summer/early fall, they migrate south to overwinter along the southern Atlantic, Gulf Coast, and Caribbean. In November, 2007, an ornithologist in Galveston, Texas defended some of these birds as they were being menaced along the dunes by what he considered a feral cat. He took aim with his 22-caliber rifle and killed the cat, which had made its home under the San Louis Pass toll bridge, which connects two islands—Galveston and Follett (Barcott 2007).

The ornithologist was charged in the killing, and he could have been fined $10,000 and sentenced to two years in jail if convicted. In a courtroom charged with emotion, the prosecution showed gruesome photographs and accused the scientist of killing the animal in "cold blood"—the cat dying a slow, painful death, "gurgling on its own blood." The defense countered that the cat was a non-native predator attempting to feed on the endangered birds. The jury deadlocked, and the case was dismissed. The case hinged on whether or not the cat was 'feral,' and apparently the jurors couldn't agree (Barcott 2007).

The household cat (*Felis catus*) is derived from a wild cat (*Felis silvestris*), which was domesticated by human beings thousands of years ago somewhere in the Middle East, Far East, and/or Northern Africa. Initially, the cats were tolerated to kill rats and other rodents that frequented human agrarian settlements, particularly where grain was stored (Newman 1997; Ogan and Jurek 1997). Interestingly, humorists and some scientists believe that cats may have domesticated human beings to suit their needs. Human populations have since broadcast the domestic cat as they have spread themselves throughout the globe. Cats may be found on almost all the continents and many islands (Long 2003).

In the United States, about one-third of families have pet cats. At the end of 2011, the American Veterinary Medicine Association estimated that there were 74.1 million pet cats. In the 2015-16 survey by the American Pet Products Association, pet cats numbered 85.8 million (Humane Society 2016). Most of these pets are free-ranging (indoor) (Winter 2004). The American Human Society estimates that there are 30-40

million **community cats**. Definitions vary somewhat, but for this module community cats include stray, abandoned, and feral cats. Both stray and abandoned cats have had some degree of socialization with human beings. **Feral cats** are born from stray/abandoned or feral mothers and receive no socialization.

The domestic cat is considered by many conservation scientists as an exotic, invasive predatory species, introduced into habitats by human activity. There is evidence that invasive predators like the cat have been major contributors to the decline and extinction of native species (Clavero and García-Berthou 2005). Cats appear in nature in much higher densities than native predators, which in general are far less than prey species. If a natural predator overeats its supply of prey, its numbers decline, until sufficient prey are born to support increased numbers of predators. However, the large population of cats often exceeds the carrying capacity of an area. Even when cats are fed by human beings, their nature is to hunt and kill. This numerous predator can quickly eradicate large numbers of prey. Matters are made worse if the top-level predator, native to an area, is eliminated (e.g., wolves in certain areas of the U.S.), because, then, the cat population is not controlled by any predator.

Roaming cats threaten many kinds of animals, particularly birds, and this situation sets two groups of animal lovers against each other—bird lovers and cat lovers. Consequently, arguments often emanate from emotion and not on science. In his article in the *New York Times Magazine*, Bruce Barcott expressed effectively the two camps' points of view. "Depending on whom you talk to, cats are either rhinestone-collared mass murderers or victims of a smear campaign waged by lowdown cat haters." As it turns out, many of the most ardent birders also have cats, and many of the cat advocates also love birds. What does the scientific evidence say?

There are a number of anthropogenic factors that have caused a decline in bird populations and diversity, including habitat destruction, buildings, windows, other human-derived structures, pesticides, etc. Included in any list of such factors is predation by free-roaming, domestic cats. Estimates of their impact vary, but there is certainly consensus that the effects of cats are significant. In the United States, cat populations have increased three-fold since 1968 (Lepczyk, et al. 2008). With human encroachment on natural areas and the tremendous numbers of roaming cats, a host of animals, including birds, are at great risk. In a 2013 paper in *Nature Communications*, Loss et al. estimated that free-ranging domestic cats kill between 1.3 and 4.0 billion birds each year.

The Humane Society's has a conservative estimate of 30-40 million free-roaming (community) cats, while the ASPCA estimates up to 70 million community cats, and other sources indicate there may be 80 million feral cats, alone. Obviously, getting a precise estimate is very difficult, but the actual numbers are less important than the reality that millions of community cats are hunting daily, and many of their prey are birds. What are possible solutions to reduce the risk of these effective hunters on bird populations? Many birding organizations try to encourage cat owners to keep their pets inside. Stray cats have some human socialization, so it might be relatively easy to capture them and take them to a shelter. Even if we control roaming cat populations better, we are still left with huge numbers of feral cats. Cats with no human association are much warier of human interaction and are therefore harder to catch. In many areas, feral cats live in colonies, usually near some food source. There are colonies, termed **managed**, that are regularly fed by local cat-lovers.

Many cat advocates, some of whom help manage feral colonies, are in favor of a control measure called **Trap-Neuter-and-Return** (**TNR**). They claim that this method is a humane method of controlling feral cat populations. TNR and other methods of population control will be discussed below and modeled in the projects.

Description of Agent-Based Approach

Modeling the population growth and control for a colony of feral cats requires us to know some detailed information about the physical and the behavioral characteristics of felines. Moreover, as with all models, for feasibility, we must make some simplifying assumptions.

Female cats become sexually mature between the ages of 10 and 12 months old, while males require between 12 and 14 months. More specifically, from age 300 days up to 365 days, we assume the probability of a juvenile female becoming sexually mature is 1/65; at day 365, if not yet mature, we assume she becomes mature. A male becomes mature during the 55-day period between age 365 up to age 420. During the 220-day mating season, which begins March 1, we assume a 13-day estrus cycle. Specifically, a female is in estrus (i.e., heat) and can become pregnant during an 8-day period. If she does not become pregnant or pseudo-pregnant during that time, there is a 5-day pause before she goes into estrus again (Ireland and Neilan 2016, Neilan and Ireland 2016).

Pregnancy lasts approximately 65 days, after which the mother gives birth to a litter of 3 or 4 kittens with an average litter size of 3.2. Thus, she has a 0.2 probability of having a litter of 4 kittens and a 0.8 probability of 3 kittens. A kitten, whose age is about 0-42 days, remains with the mother; and we assume a juvenile's age is from 43 to 180 days old. The duration of a pseudo-pregnancy (i.e., false pregnancy) is about 45 days. After having a pseudo-pregnancy or weaning her kittens, the adult female re-enters an estrus cycle if the time is still in the mating season (Ireland and Neilan 2016, Neilan and Ireland 2016).

The feral cat population's growth potential, can result in many problems: overpopulation; nuisance from such behaviors as urine spraying, noise, and aggression; spread of disease; and ecosystem impact from predation. Several humane, non-lethal methods of population control are available. The **Trap-Neuter-and-Return** (**TNR**) method spays (i.e., removes ovaries) or neuters (i.e., removes testicles) most of a colony's cats that are at least 6 weeks old and vaccinates the animals before returning them to the wild. In the **Trap-Vasectomy-Hysterectomy-Return** (**TVHR**) method, sterilization involves a vasectomy (i.e., cutting the tubes from the testicles to the seminal vesicles) or a hysterectomy (i.e., removing the uterus), allowing continued hormone production, along with vaccination and return. With both methods, the cats are infertile and do not exhibit reproductive behaviors. However, a female with a hysterectomy who mates with a fertile male or a fertile female who mates with a male who has had a vasectomy may have a pseudo-pregnancy. With TNR, the cats become less aggressive and do not spray or roam (Ireland and Neilan 2016, Neilan and Ireland 2016).

The method of birth control has an impact on the survivability of a cat. Survival depends on the age and reproductive situation of the cat as well as the size of the population. The baseline survival rate, S_0, is 0.99233 d^{-1}. However, the survival probability at the carrying capacity of the colony, S_K, is less: 0.9991 d^{-1} for kittens and

juveniles, 0.99804 d^{-1} for non-neutered adult males, 0.99904 d^{-1} for unspayed adult females, and 0.99905 d^{-1} for spayed or neutered adults. For the projects, assume the initial population of a single colony is 25 females and 25 males and the carrying capacity of the colony is 50 cats. Ireland and Neilan modeled the individual daily survival probability, $\Pr_S$, to be close to S_0 when the population, P, is small and to approach S_K, as the population size approaches the carrying capacity, K, as follows (Ireland and Neilan 2016, Neilan and Ireland 2016):

$$\Pr_S = S_0 - \frac{(S_0 - S_K)P}{K}$$

Other Physical Characteristics

Ireland and Neilan considered a more details than we do for these educational projects, but for completeness we elaborate here. Non-neutered males exhibit dominance, which tends to increase with age until about the age of three years. A more dominant male has a higher probability of mating, and less dominant males are more likely to migrate to another colony in attempts to mate and to have better access to food.

When a female cat is in heat, mating triggers ovulation with additional copulations increasing the probability of ovulation. With the TVHR technique of population control, an altered female continues to have an estrus cycle, and an altered male persists in exhibiting dominance and mating; thus, noise associated with mating continues to be a problem.

Description of System Dynamics Approach

(Schmidt et al. 2009) considered a system dynamics approach to the problem of modeling a feral cat population with two methods of control, euthanasia and **trap–neuter–release** (**TNR**). The researchers modeled the logistic growth under various scenarios involving percentages of each kind of control with several levels of immigration into the colony. Calculations included the total population and percent change in population after twenty-five years.

Research discovered different birth rates for feral and semi-feral cats. A **semi-feral cat** is one that was originally domesticated but which is now wild. On the average, a semi-feral mother cat gives birth to 1.6 litters per year with a mean of 2.75 kittens per litter surviving at least 12 weeks, while a feral mother averages 1 litter per year with 1.75 kittens surviving to age 12 weeks. For simplicity, the modelers assumed equal representation of feral and semi-feral cats in a colony, and we refer to the population as one of feral cats.

For both kinds of cats, females have a higher probability of survival (0.88) than males (0.57) from one year to the next. For the simulations, researchers used a starting population of 540 cats with an equal number of females and males and assumed a carrying capacity of 724 cats (Schmidt et al. 2009).

Projects

1. **a.** As described in the section "Description of Agent-Based Approach," develop an agent-based model for the growth of a colony of feral cats, assuming no population control. Also, assume a closed population, so that no abandoned cats join the colony and no cats migrate from the colony. Plot the population over a 6-year period. Discuss the results.

b. Refine the model so that the simulation runs a desired number of times from 1 to 1000 but does no plot the population. Using at least 100 simulations, display the mean population at the end of six years. Additionally, use the cumulative daily number of adult, non-neutered males as a metric for the spraying nuisance and cumulative daily population size as a metric for the population abundance nuisance.

c. Refine the model so that the simulation runs a desired number of times from 1 to 1000, and run at least 100 simulations. Plot the mean population for each day over a 6-year period, and display the minimum and maximum populations for this graph. Display the mean population at the end of six years. Discuss the results.

2. **a.** Revised Project 1 so that, starting in the third year, Trap-Neuter-and-Return occurs each year on April 30, immediately before seasonal births. Run the simulation for capture rates of 50%, 75%, 90%, 95%, and 100%. Discuss the results.

b. Compare the results for colonies with and without TNR population control at various capture rates.

3. **a.** Revised Project 1 so that, starting in the third year, Trap-Vasectomy-Hysterectomy-Return occurs each year on April 30, immediately before seasonal births. Run the simulation for capture rates of 50%, 75%, 90%, 95%, and 100%. Discuss the results.

b. Compare the results for colonies with and without TVHR population control at various capture rates.

4. Do Projects 2 and 3 comparing the populations and spraying nuisance for no, TNR, and TVHR control measures.

5. **a.** Revise Project 1 to allow for abandoned cats being about 10% of the colony's carrying capacity per year.

b. Compare the results for colonies with and without abandonment.

6. Revise Project 2 to allow for abandoned cats being about 10% of the colony's carrying capacity per year.

7. Revise Project 3 to allow for abandoned cats being about 10% of the colony's carrying capacity per year.

8. Revise Project 4 to allow for abandoned cats being about 10% of the colony's carrying capacity per year.

9. **a.** As described in the section "Description of System Dynamics Approach," develop a system dynamics model for the growth of a population of feral (and semi-feral) cats, assuming no population control. Also, assume a closed population, so that no abandoned cats join the colony and no cats migrate from the colony. Plot the population over a 25-year period. Discuss the results.

b. For no immigration, run the model for the following levels of TNR: 0%, 25%, 50%, and 75% of the untreated cats. Record the population and percent change in population after one year and after 25 years. Determine a minimum percentage of treatment that results in a population reduction after 25 years. Discuss the results.

c. For no immigration, run the model for the following levels of euthanasia: 0%, 25%, 50%, and 75% of the untreated cats. Record the population and percent change in population after one year and after 25 years. Determine a minimum percentage of treatment that results in a population reduction after 25 years. Discuss the results.

d. For no immigration, run the model for the following levels of combined TNR and euthanasia: 0%, 12.5%, 25%, and 37.5% of the untreated cats for each control measure. Record the population and percent change in population after one year and after 25 years. Determine a minimum percentage of treatment that results in a population reduction after 25 years. Discuss the results.

e. Compare the results for Parts b-d, and make a recommendation for population control assuming no immigration.

f. Repeat Parts b-e, where immigration is 25% of the difference between the carrying capacity and the current population.

g. Repeat Parts b-e, where immigration is 50% of the difference between the carrying capacity and the current population.

References

American Pet Products Association. 2016. http://www.americanpetproducts.org/pubs_survey.asp. (Accessed Jan. 23, 2017)

ASPCA, American Society of the Prevention of Cruelty to Animals. https://www.aspca.org/animal-homelessness/shelter-intake-and-surrender/pet-statistics. (Accessed Jan. 23, 2017)

American Veterinary Medicine Association. 2017. https://www.avma.org/Pages/home.aspx. (Accessed Jan. 23, 2017)

Barcott, Bruce. 2007. "Kill the Cat that Kills the Bird?" *New York Times Magazine*, Dec. 2, 2007 http://www.nytimes.com/2007/12/02/magazine/02cats-v--birds-t.html. (Accessed Jan. 23, 2017)

Bayless, Rachel Louise. 2017. "Modeling Feral Cat Control," presentation at Joint Mathematics Meeting.

Bradshaw J.W.S., Casey R.A., Brown S.L. 2013. *The Behaviour of the Domestic Cat*. CABI, Wallingford, UK.

Clavero, Miguel, and Emili Garcia-Berthou. 2005. "Invasive species are a leading cause of animal extinctions." *TRENDS in Ecology and Evolution* 20, no. 3 (2005): 110-110.

Doherty, Tim S., Chris R. Dickman, Chris N. Johnson, Sarah M. Legge, Euan G. Ritchie, and John C.Z. Woinarski. 2016. "Impacts and management of feral cats *Felis catus* in Australia." *Mammal Review*.

---, Glen A.S., Nimmo D.G., Ritchie E.G., Dickman C.R. 2016. "Invasive predators and global biodiversity loss," *Proceedings of the National Academy of Sciences of the United States of America* 113: 11261–11265.

Humane Society. 2016. Pets by the Numbers. The Humane Society of the United States. http://www.humanesociety.org/issues/pet_overpopulation/facts/pet_ownership_statistics.html. (Accessed Jan. 23, 2017)

Ireland, Timothy and Rachael Miller Neilan. 2016. "A spatial agent-based model of feral cats and analysis of population and nuisance controls." *Ecological Modelling* 337 (2016) 123–136.

Lepczyk, C. A. 2008. "An overview of the natural history, human dimension, and management of outdoor cats" (abstract). 126th Stated Meeting of the American Ornithologists' Union, Portland, OR.

Long, J. 2003. *Introduced Mammals of the World*. CSIRO Publishing, Melbourne, Vic., Australia.

Loss, Scott R., Tom Will, and Peter P. Marra. 2013. "The impact of free-ranging domestic cats on wildlife of the United States." *Nature communications* 4 (2013): 1396.

McCarthy, R.J., S.J. Levine, and J.M. Reed. 2013. "Estimation of effectiveness of three methods of feral cat population control by use of a simulation model." *JAVMA* 243 (2013) 502-511.

Neilan, Rachael Miller and Timothy Ireland. 2016. “A Spatial Agent-based Model of Feral Cats and Analysis of Population and Nuisance Controls.” SIAM Conference on the Life Sciences.

Newman, C. 1997. “Cats: Nature’s Masterwork.” *National Geographic* 191:54-76.

Ogan, Chester V., and Ronald M. Jurek. 1997. "Biology and ecology of feral, free-roaming, and stray cats." In Mesocarnivores of northern California: biology, management, and survey techniques, workshop manual, pp. 87-92.

Schmidt, Paige M., Todd M. Swannack, Roel R. Lopez and Margaret R. Slater. 2009. “Evaluation of euthanasia and trap–neuter–return (TNR) programs in managing free-roaming cat populations.” *Wildlife Research*, 36, 117–125