Alliance for Contraception in Cats & Dogs

Bioeconomic analysis of free-roaming cat population management using a long-acting contraceptive

Introduction

An interdisciplinary expert team convened by the Alliance for Contraception in Cats & Dogs (ACC&D) used computer simulation modeling[1] to evaluate and compare different strategies for managing free-roaming cat (FRC) populations. The goal was to generate insights that could support decision-making about how to approach population management in a more impactful way. This work generated three peer reviewed publications, all of which can be viewed at no cost (Miller et al., 2014; Boone et al., 2019; Benka et al., 2022).

One question that motivated this project was whether a temporary contraceptive for cats (specifically GonaCon, described below) could offer advantages over traditional surgical spay/neuter for FRC population management. Results from ACC&D simulations (Miller et al., 2014) and a subsequent field study (Fischer et al. 2018a) suggested that GonaCon is not likely to be a useful FRC management tool with its current efficacy profile. To better quantify necessary improvements, the ACC&D-convened team performed additional simulations, and results are presented here.

Background

GonaCon is a single-injection immunocontraceptive vaccine, developed by the U.S. Department of Agriculture, that has been used to control fertility in several mammalian species (Miller et al., 2004; United States Department of Agriculture, 2022). An experimental version of GonaCon was tested in female and male cats in a controlled laboratory setting (Levy et al. 2004; Levy et al. 2011). In the study of females, the median period of infertility for vaccinated cats was about 3.3 years, but it varied widely across individuals. For example, 93% of vaccinated cats were infertile for at least one year, and 27% were still infertile at the conclusion of the 5-year study (Levy et al. 2011; Figure 1). When examined in a simulated FRC population through modeling, it was determined that this efficacy and duration profile would need to improve in order to have substantial value for population management (Miller et al., 2004).

[1] Simulation modeling is technique for studying the behavior of a real work system or process by mimicking it within a computer application.

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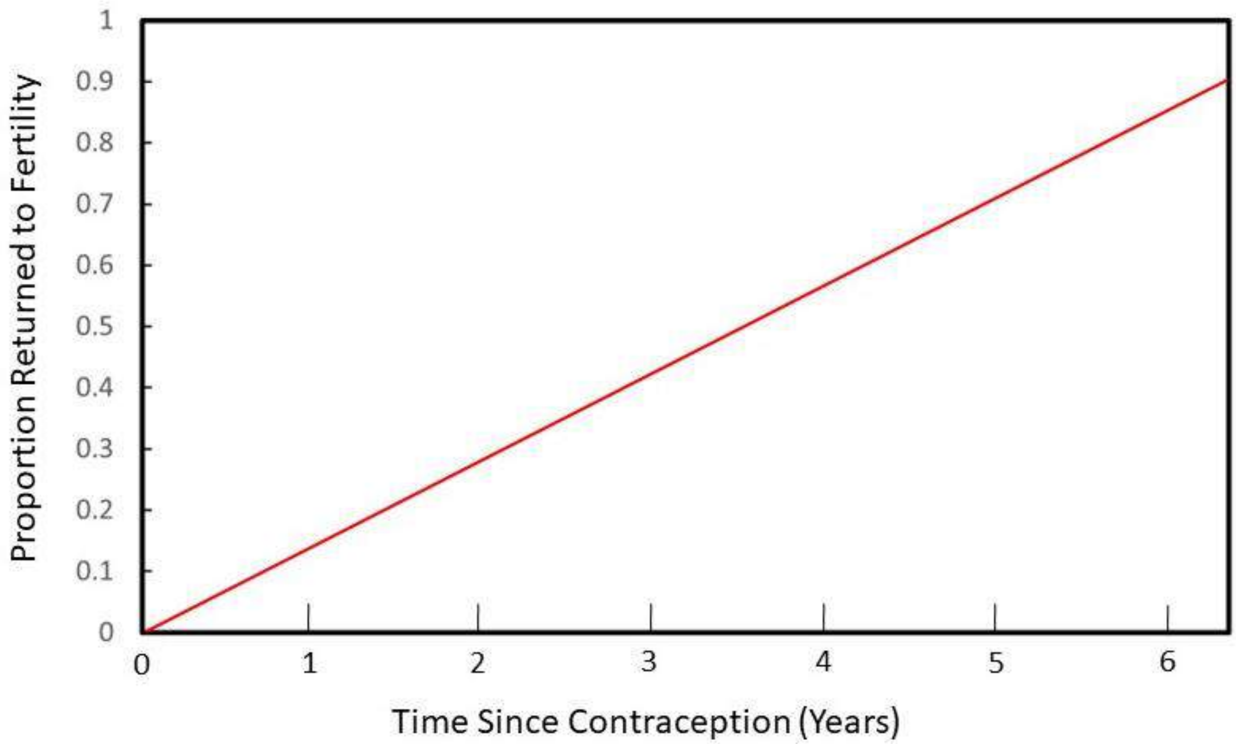


Figure 1. Return to fertility for cats following contraception with GonaCon, based on findings from Levy (2011). The red line shows the proportion of all vaccinated cats that have become fertile over time. The graph shows that as time goes on, an increasing proportion of cats in the population regain fertility. At the start no cat is fertile, but total population infertility is very brief.

Levy et al.'s (2011) study results inspired the question of how GonaCon might perform in female FRCs, as compared to the cats in a controlled laboratory setting. ACC&D sponsored a study of GonaCon in a setting that was designed to resemble a community of FRCs, while ensuring the animals' safety and well-being throughout (Fischer et al. 2018a, Fischer et al. 2018b). Its results were much less encouraging than those of the first laboratory study, as the majority of cats recovered fertility within a year. The reasons for the dramatic differences in the results of the two studies of GonaCon in female cats are not definitively understood.

Given GonaCon's results in a simulated FRC setting, ACC&D is no longer working to advance the contraceptive (though another organization, SpayFIRST!, continues to do so). That said, there are feline contraceptive possibilities beyond GonaCon. Therefore, we used simulations to investigate the efficacy and cost effectiveness of improved contraceptive profiles for FRC population management, using Levy et al.'s (2011) results as a starting point.

Approach

Assuming 100% initial efficacy, there are at least two ways to improve the success of a temporary contraceptive: 1) lengthen the period of infertility, and 2) reduce the rate at which fertility is regained once it begins. These processes could, in theory, occur either singly or in combination, and to varying degrees. For this study, we defined four types of improvement that involve one or more processes. They are named based on their graphical depictions, as follows:

"Intercept Modification" (Figure 2): The guaranteed period of infertility following contraception is increased. After this period has elapsed, fertility among vaccinated cats is regained at the same rate as in the first GonaCon study.

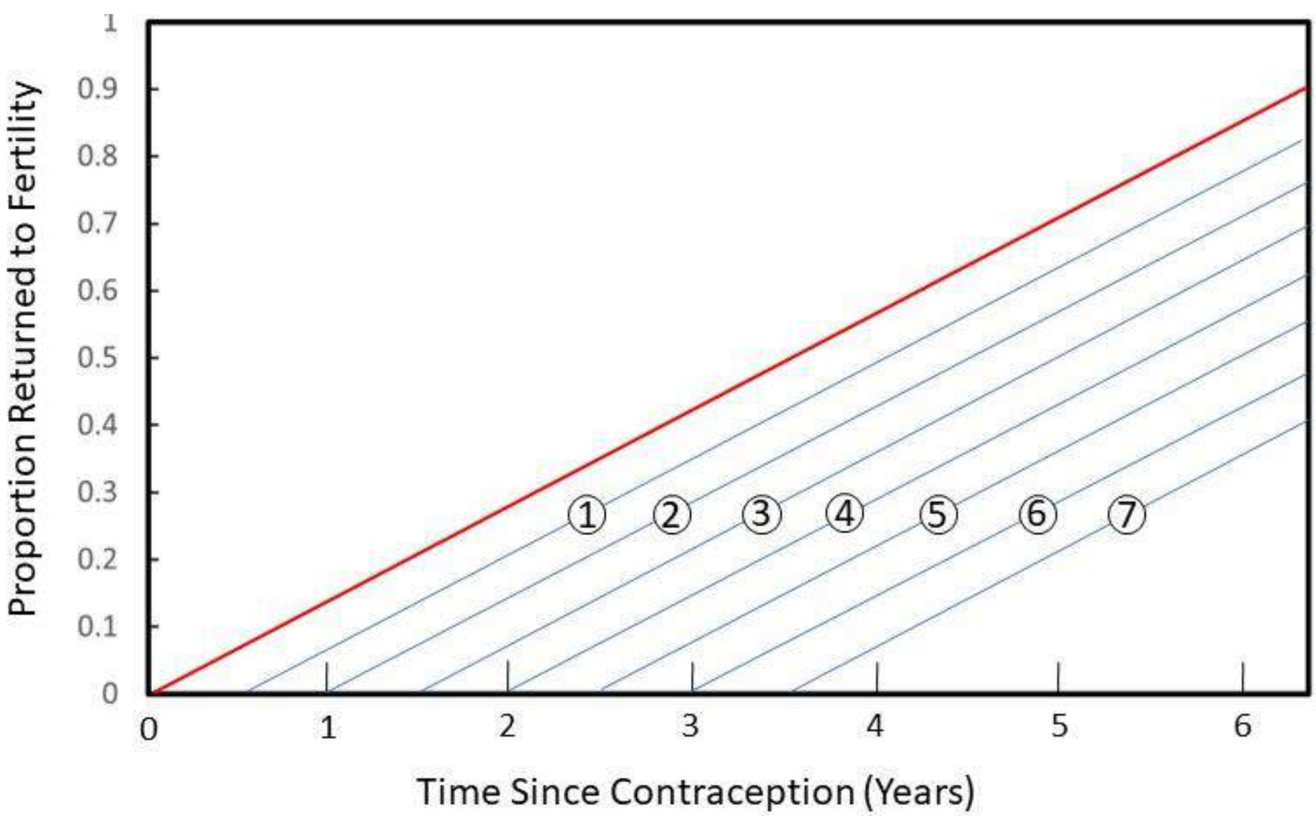


Figure 2. Seven different versions of "intercept modification" (blue lines), as described in the text. The red line from Figure 1 describing GonaCon is retained for reference. The rising numbers (1–7) of the blue lines show increasing guaranteed periods of guaranteed infertility among all vaccinated cats following contraception. For example, line #1 shows a contraceptive guaranteed to work in all cats for 0.5 years; line #2 shows a contraceptive guaranteed to work in all cats for 3.5 years.

"Slope Modification" (Figure 3): The rate at which fertility is regained in the population is reduced, but there is no guarantee of initial infertility.

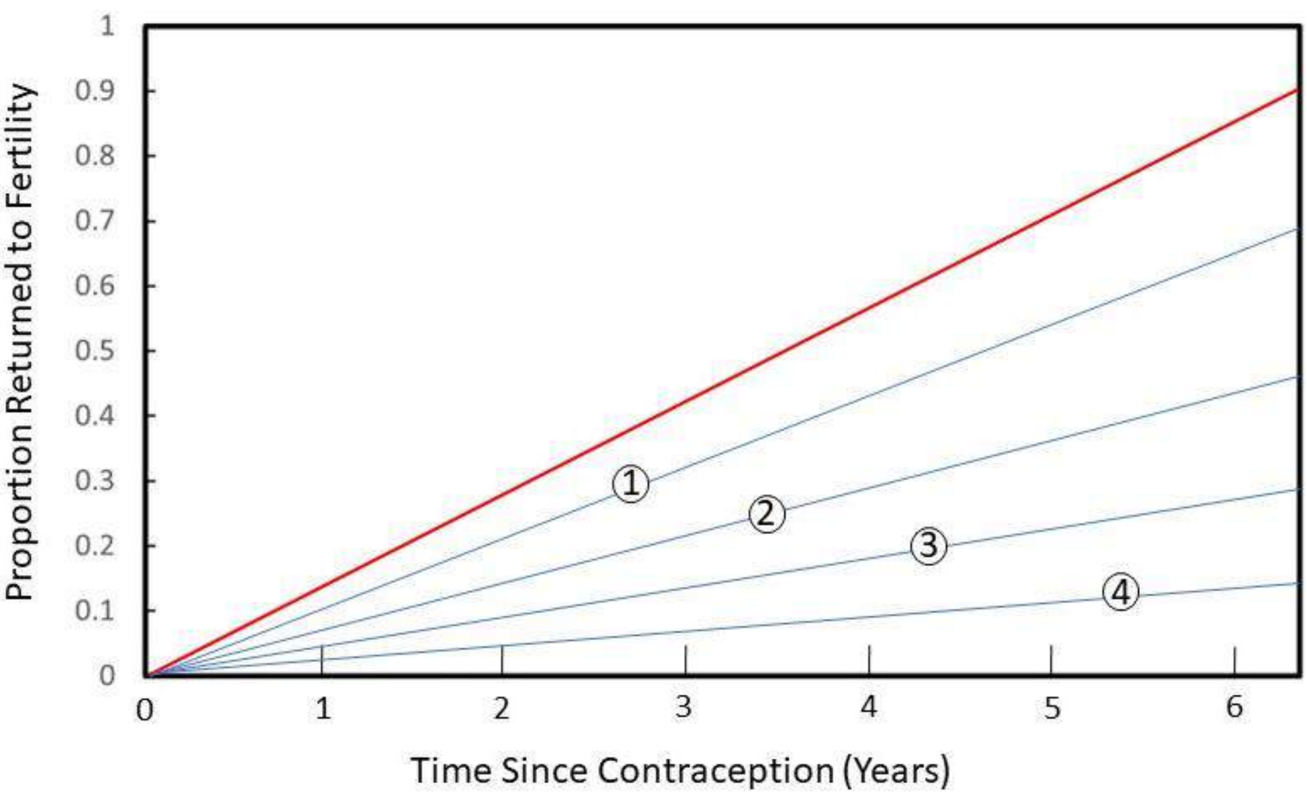


Figure 3. Four different versions of "slope modification" (blue lines), as described in the text. The red line from Figure 1 describing GonaCon is retained for reference. The rising numbers (1 – 4) of the blue lines show an increasingly effective contraceptive based on progressively lower rates for reversion to fertility.

"Combined Modification" (Figure 4): Seven levels of intercept modification are combined with one level of slope modification.

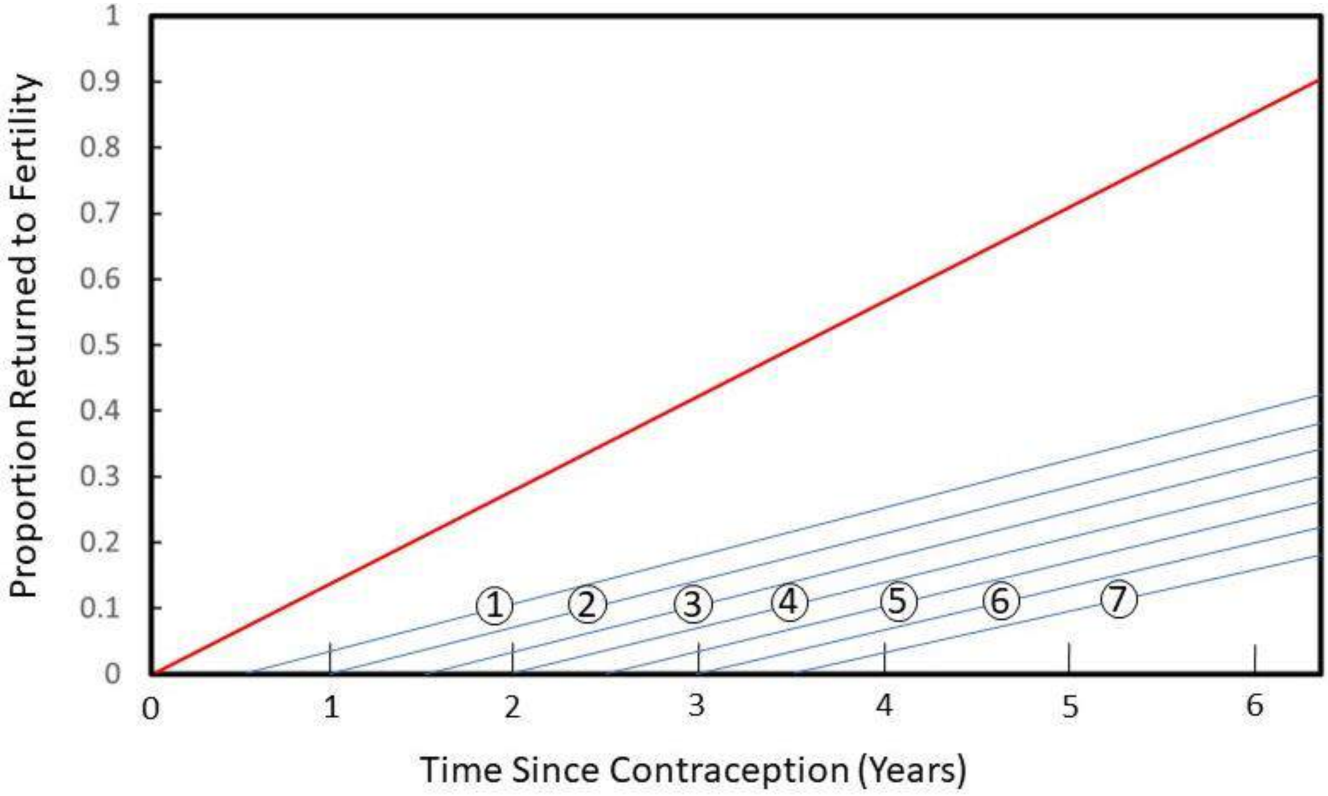
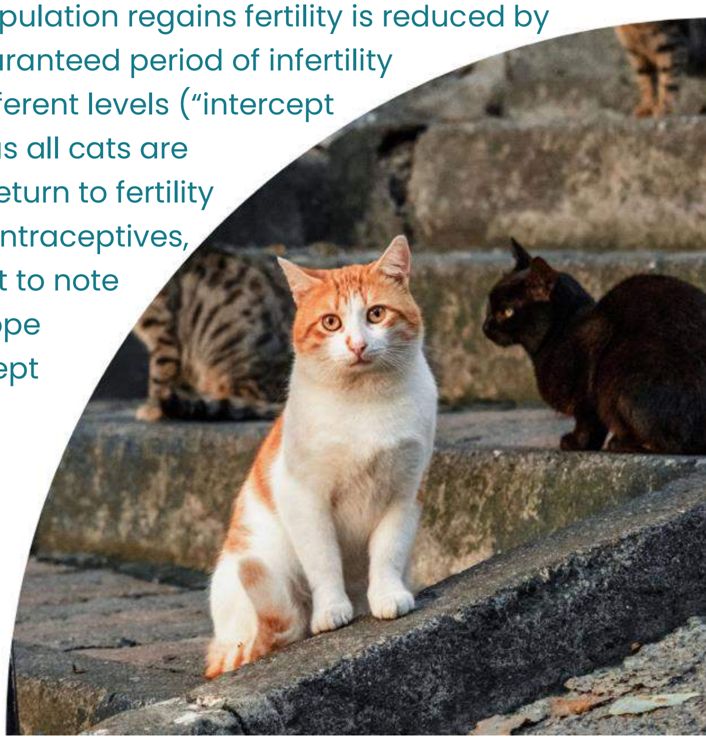


Figure 4. Seven different versions of "combined modification" (blue lines), as described in the text. The red line from Figure 1 describing GonaCon is retained for reference. This shows a scenario in which the rate that the cat population regains fertility is reduced by a fixed amount ("slope modification") *and* the guaranteed period of infertility following contraception is increased at seeven different levels ("intercept modification"). Scenario #7 is the most effective, as all cats are infertile for at least 3.5 years. After 3.5 years, cats return to fertility at the same rate as with the other hypothetical contraceptives, but more slowly than with GonaCon. It is important to note that in this scenario we look only at one level of slope modification combined with seven levels of intercept modification; other modifications exist and would yield different results.



"Tradeoff Modification" (Figure 5): The guaranteed period of infertility following contraception is increased at seven levels, but each stepwise increase is accompanied by an increase in the rate at which fertility is regained.

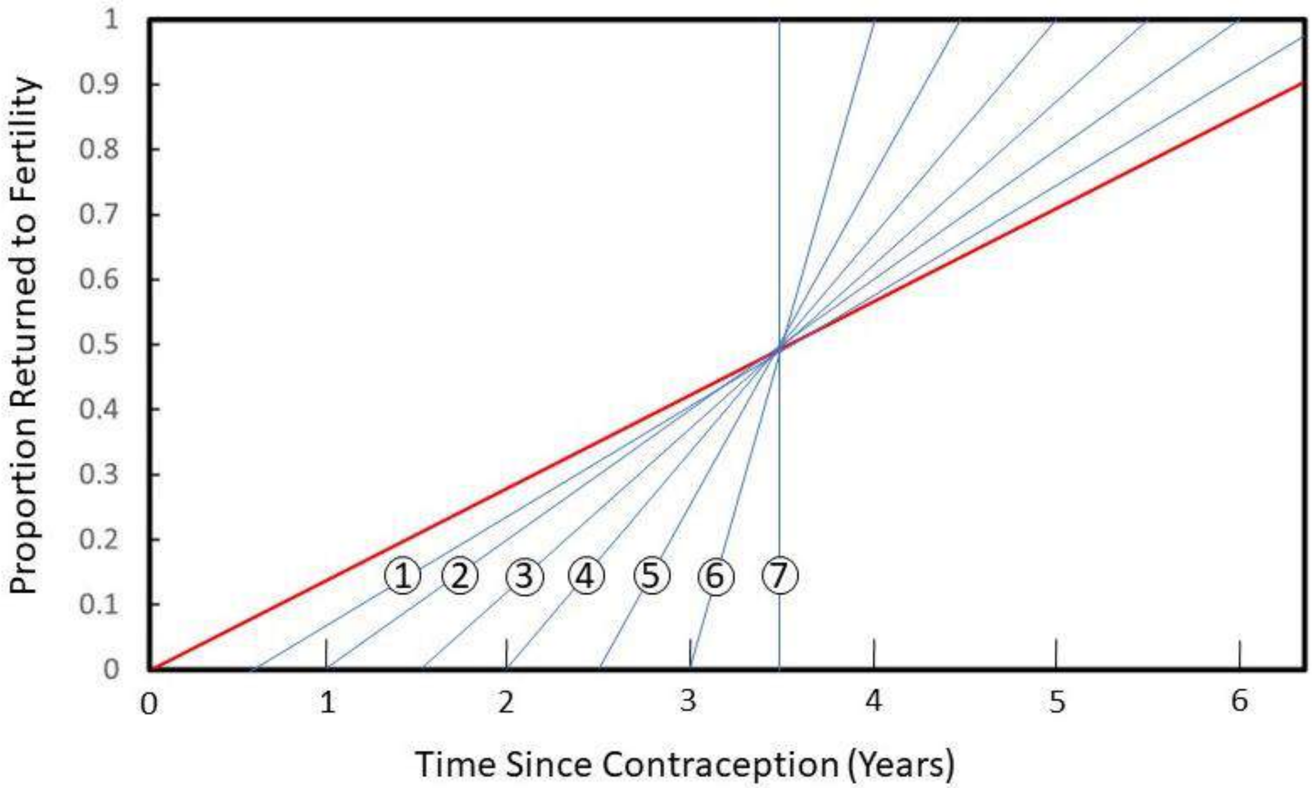


Figure 5. Seven different versions of "tradeoff modification" (blue lines). The red line from Figure 1 describing GonaCon is retained for reference. In this Figure, the guaranteed period of infertility following contraception is increased at seven levels (1–7), but each stepwise increase is accompanied by an increase in the rate at which fertility is regained. As a result, the average age when individual cats return to fertility remains constant. In the most extreme version of tradeoff modification (level 7), all cats remain infertile for about 3.5 years, and then all cats immediately return to fertility.

Each of these 25 hypothetical contraceptive scenarios (i.e., each unique type x level combination) was tested in a management simulation over a 10-year period. Each scenario began with 50 cats in the population, and management intensity was standardized across all scenarios by randomly trapping and contracepting 75% of fertile cats at each six-month time step, as described in Miller et al. (2014). This created a fair basis for comparing the hypothetical contraceptive profiles to

GonaCon, as well as to traditional surgical spay/neuter. Comparisons were based on these metrics:

1) Final number of cats in the population after 10 years.
2) Total number of contraception or surgical procedures performed over 10 years.
3) Total estimated cost of these treatments.[2]
4) A "Treatment Efficiency" metric calculated from the number of procedures divided by the amount of population reduction over 10 years. This metric shows the number of treatments required to reduce final population size by one individual, and lower values indicate better treatment efficiencies.
5) A "Cost Efficiency" metric calculated from the total management cost divided by the amount of population reduction over 10 years. This metric shows the number of dollars required to reduce final population size by one individual, and lower values indicate better cost efficiencies.

Findings

The results of our simulations are shown in Table 1 on the following page. All hypothetical contraceptives were designed as improvements to the GonaCon profile, and as a result all required fewer treatments while achieving better population reduction. The size of these positive effects increased with increasing levels of contraceptive modification, as expected. We also explored whether any of the hypothetical contraceptives offered potential cost-benefit advantages over permanent surgical sterilization. In answering this question, it is important to remember that some cats who receive temporary contraceptives will require retreatment to maintain sterility. Therefore, the total number of treatments needed to achieve a given level of reproductive suppression over time will always be higher than with permanent surgical sterilization, and treatment efficiency will be less favorable. With regard to cost, however, some hypothetical contraceptives offer improvements over surgery.[3] As shown in Figure 6, all modified contraceptives with better cost efficiencies than surgical sterilization involve higher levels of intercept modification. In other words, they all provide at least two years of guaranteed infertility after vaccination for all cats. Contraceptives modified only by slope modification (with no guaranteed period of infertility or lower degrees of intercept modification) were less cost effective than surgery over a 10-year period.

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[2] Costing formulas were based on information in Benka et al. (2022). For this analysis, the cost per dose of any theoretical improved contraceptive is assumed to be the same as previously estimated for GonaCon.
[3] This conclusion assumes that the cost estimates we used for surgical sterilization and contraception are reasonably accurate. If actual or relative costs were different, the Cost Efficiency metric might change as well.

Table 1. Results from simulation models after 10 years of implementing the management scenario. Surgical sterilization and GonaCon are shown for comparison to the 25 modified contraceptives.

Management Scenario	Final Population Size	Total # Treated	Total Cost	Treatment Efficiency	Cost Efficiency
Surgical Sterilization	26	103	$9,353	4.27	387.77
Gonacon	37	241	$10,844	18.15	816.59
Combined Modification 1	29	216	$9,669	10.32	461.77
Combined Modification 2	27	209	$9,366	9.12	408.63
Combined Modification 3	26	207	$9,265	8.67	388.14
Combined Modification 4	26	206	$9,216	8.57	383.54
Combined Modification 5	26	180	$8,086	7.53	338.17
Combined Modification 6	26	158	$7,140	6.57	296.87
Combined Modification 7	26	147	$6,624	6.07	273.48
Intercept Modification 1	32	225	$10,105	12.23	549.48
Intercept Modification 2	28	213	$9,556	9.67	433.98
Intercept Modification 3	26	207	$9,256	8.71	389.57
Intercept Modification 4	26	206	$9,200	8.51	379.85
Intercept Modification 5	25	179	$8,036	7.30	327.87
Intercept Modification 6	26	160	$7,202	6.76	304.16
Intercept Modification 7	26	147	$6,632	6.05	273.02
Slope Modification 1	35	235	$10,592	15.76	710.41
Slope Modification 2	33	227	$10,220	13.02	586.00
Slope Modification 3	29	216	$9,693	10.39	466.22
Slope Modification 4	27	211	$9,433	9.25	413.36
Tradeoff Modification 1	33	227	$10,174	13.11	587.41
Tradeoff Modification 2	28	207	$9,658	9.62	448.80
Tradeoff Modification 3	26	207	$9,271	8.67	388.42
Tradeoff Modification 4	26	208	$9,285	8.71	388.83
Tradeoff Modification 5	26	207	$9,287	8.72	391.37
Tradeoff Modification 6	26	205	$9,184	8.51	381.39
Tradeoff Modification 7	26	159	$7,184	6.69	302.11

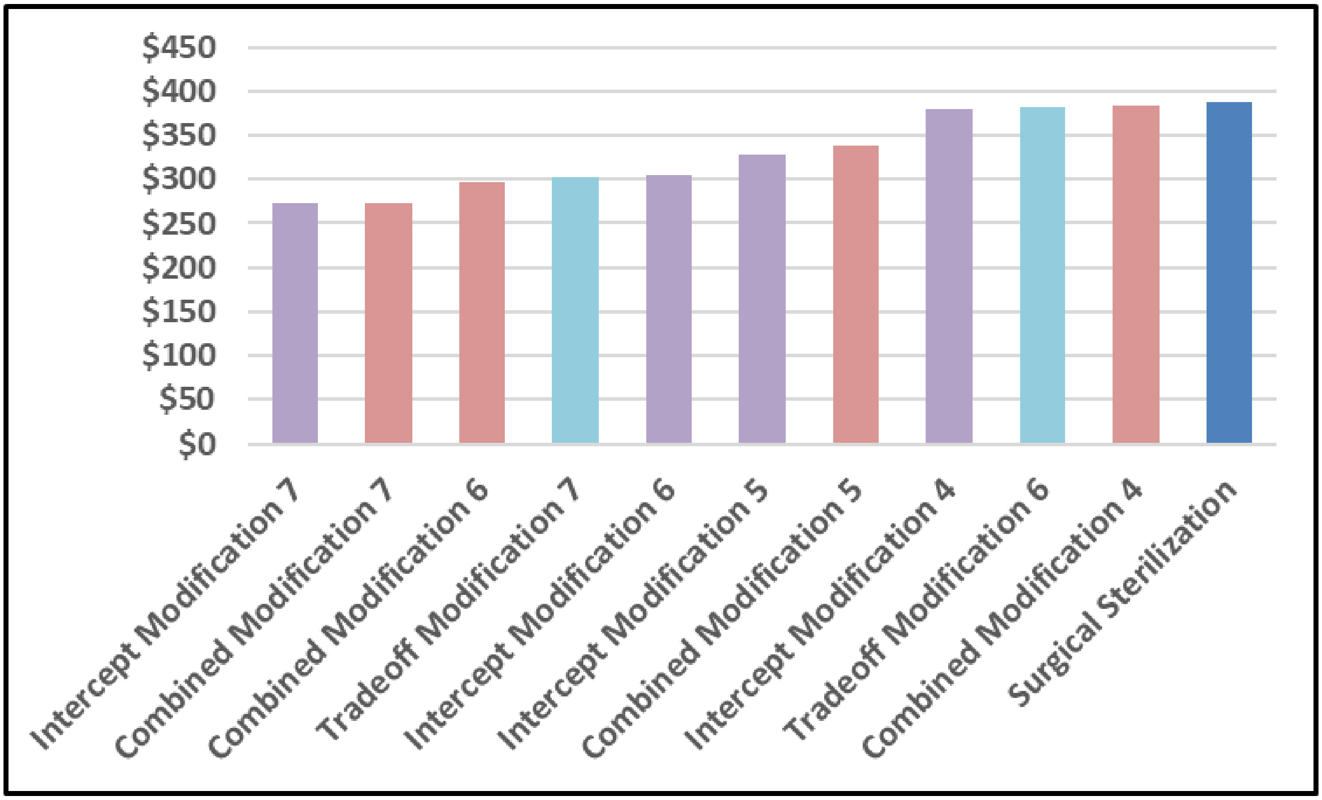

Figure 6. Cost efficiencies (y-axis) of surgical sterilization (far right) and the subset of modified contraceptives that improve on this baseline. Smaller values indicate better cost efficiencies. Bars are color-coded according to the type of contraceptive modification.

Conclusions

Based on this analysis, a temporary contraceptive needs to provide two years or more of guaranteed infertility to be a cost-effective alternative to surgical sterilization for FRC population reduction. Whether or not this is achievable remains to be determined. There are multiple efforts underway to develop a long-acting non-surgical contraceptive or permanent sterilant for cats. We note that other factors – such as the availability of skilled spay/neuter surgeons or surgical facilities, or end goals other than population size reduction (e.g., reducing nuisance behaviors) – could tip the balance in favor of a less-effective temporary contraceptive in some cases, but we did not explore this broader set of scenarios.

Appendix: Details on model development

The models developed for this analysis are based on FRC population management research, described in a series of recent papers (Miller et al., 2014; Boone et al., 2019; Benka et al., 2022). The basis of the analysis is a simulation model of cat population dynamics constructed using the population viability analysis software package Vortex (Lacy and Pollak, 2022). This software is used extensively in the endangered species conservation community to guide development of effective management strategies to reduce risk of future population decline and extinction. We adapted Vortex to assess the likelihood of reducing or eliminating FRC populations by applying a host of management alternatives, including removal of cats from the population, permanent sterilization and return of cats (Trap-Neuter-Return), and temporary contraception of cats with treatment given in the field.

Vortex uses data on the demography of animal populations as input, including birth rates, mortality rates, and extent of dispersal across the spatial landscape of interest. Our models ran at 6-month "timesteps" to project future abundance of a local FRC population in a typical urban area. This choice of timestep length included a seasonal aspect to kitten production, where a more favorable summer season contrasts with a harsher winter where kitten survival is lower. We assumed that the core urban area of interest would be the target of cat population management, with FRCs in the surrounding neighborhoods left unmanaged. A total of 50 FRCs initially occupied the core area in the model, while 200 cats occupied the surrounding neighborhood. Importantly, intact cats from this neighborhood were free to occasionally disperse into the core managed area through an arbitrary porous boundary defining the two population units.

We used the following specific input parameters as the basis for our simulation models:

- Females can begin breeding (i.e., move from juvenile to adult) after six months of age.
- About 90% of adult females produce a litter in the summer phase of the annual cycle, while only about 50% reproduce in the winter phase.
- Breeding females produce an average of 3 to 4 kittens per breeding cycle, with only about 25% of those kittens surviving to six months of age.
- Annual survival of adult cats is approximately 90% per year, with the risk of dying over that year spread evenly across the summer and winter timesteps.
- In addition to reproduction, cats can be added to the core urban population through either dispersal of a small percentage of intact cats from the surrounding neighborhood, or through abandonment of a small number of surviving intact kittens from local households.

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