UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

Agent-based models to identify and evaluate dog population management strategies

L.M. Kisiel[1,2]*, A. Jones-Bitton[1], and A.L. Greer[1]

[1]Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, ON Canada

[2]Control Etico de la Fauna Urbana y Tenencia Responsable de Mascotas A.C. Puebla, Mexico

INTRODUCTION

Developing countries are faced with finding novel and humane ways to permanently reduce and control their dog populations. This is especially important for the sustainability of canine disease control programs.

Agent-based models developed to describe dog population dynamics and zoonotic disease transmission represent a unique platform for using computer-based simulation to identify control strategies with the greatest potential for success, aid in the design of more effective control measures, and provide a means to evaluate the success of different interventions.

OBJECTIVES

- Introduce the basic agent-based modeling framework for the creation of a simulation model to describe the population dynamics of dogs within a given environment.
- Provide a modeling example of simple dog population control strategies and demonstrate the utility of using a simulation model to evaluate these strategies while also incorporating economic considerations.
- Highlight the data requirements for the development of the model.

METHODS

1. Model parameters describing dog reproductive biology were extracted from the published literature (Table 1).
2. An agent-based model was developed using Anylogic ™ software. The model includes both male and female canine agents. Each agent type is defined by a number of discrete and mutually exclusive reproductive states (Figures 1 & 2). The model does not include the immigration or emigration of dogs into or out of the population.
3. State transitions for each agent were defined based on the parameter values described in Table 1. In addition, we incorporated information about intervention costs into our analysis (Table 1).
4. As a case study, we modeled three different spay intervention strategies within our simulated dog population. The interventions were begun 365 days into the model simulation. We assumed that for each intervention, eligible females had a 30% chance of receiving the surgical intervention each time a clinic was held. Interventions are described in Table 2.
5. The simulation was run for a 5-year time horizon to evaluate the potential impact of the different intervention strategies (Table 2).
6. Model outcomes measured included, the total number of dogs, the total number of spayed female dogs and the total spay cost after 5 years.

AGENT-BASED MODEL

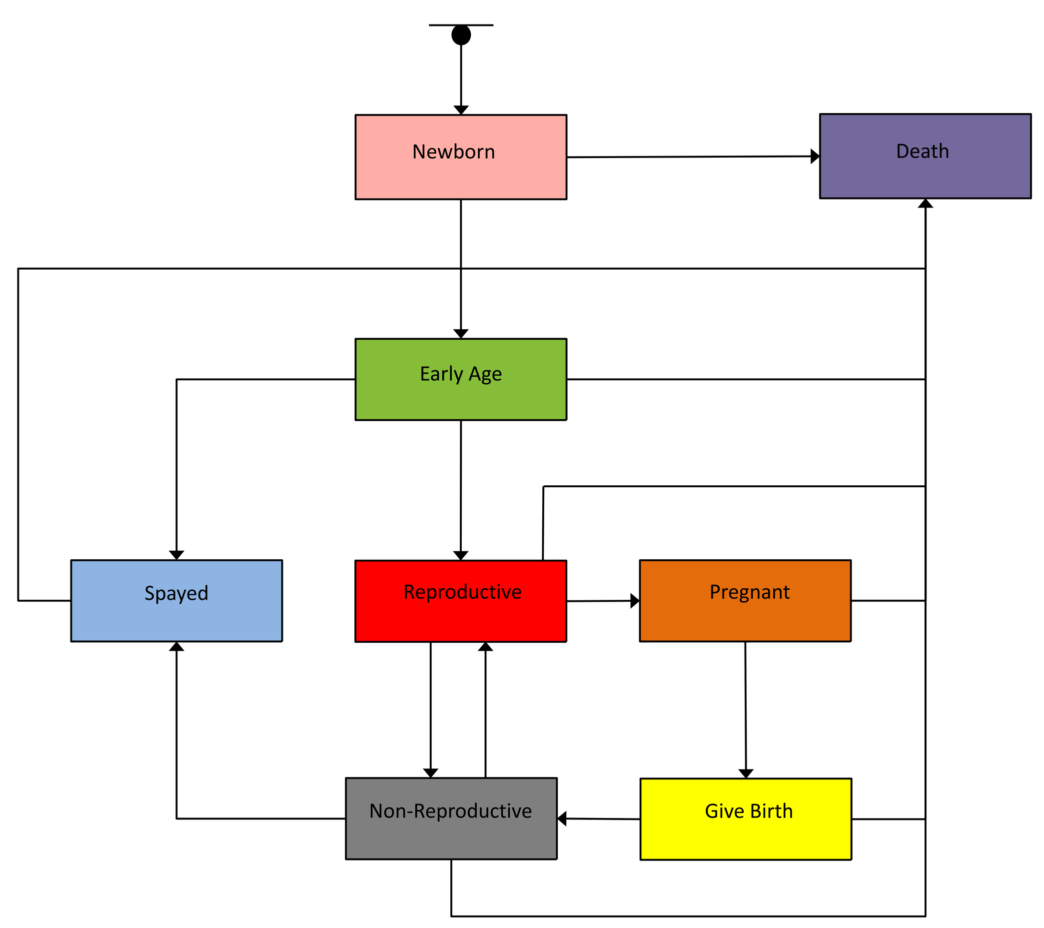

Figure 1. *Female Dog Agent*

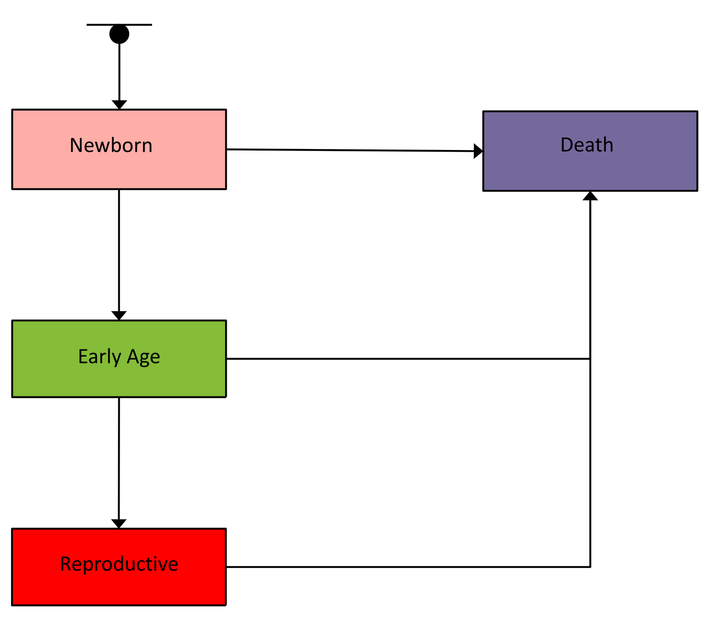

Figure 2. *Male Dog Agent*

Table 1. *Model Parameters*

NAME	VALUE	SOURCE
Weaning Period	8 weeks	1
Female Dog Puberty	8 months	1
Male Dog Puberty	10 months	1
Oestrous Duration	9 days	1
Time to New Proestrous	7 months	1
Gestation Period	63 days	2
Litter Size	6 puppies	3
Sex Ratio for New Litters Male : Female	2:1	3
Mortality Rate	0.33 per year	4
Cost Female Spay	$40 US	5
Initial Dog Population Size	100 (50 male and 50 female)	Assumption
Initial Female Dog Population Structure	10%-Newborn, 10%-Early Age, 10%-Reproductive, 10%-Pregnant, 60% Non-reproductive	Assumption
Initial Male Dog Population Structure	10%-Newborn, 10%-Early Age, 80%- Reproductive	Assumption
Probability of Female Dogs in Oestrous Getting Pregnant	50%	Assumption

Table 2. *Model Interventions*

INTERVENTION	TIMING	COVERAGE
1. Early Spay (females aged 2 to 8 months)	Intervention every 12 months	30% probability of receiving spay intervention
2. Adult Spay (females >8 months)	Intervention every 6 months	
3. Both Early and Adult Spay Combined	Intervention every 3 months	

SIMULATION RESULTS

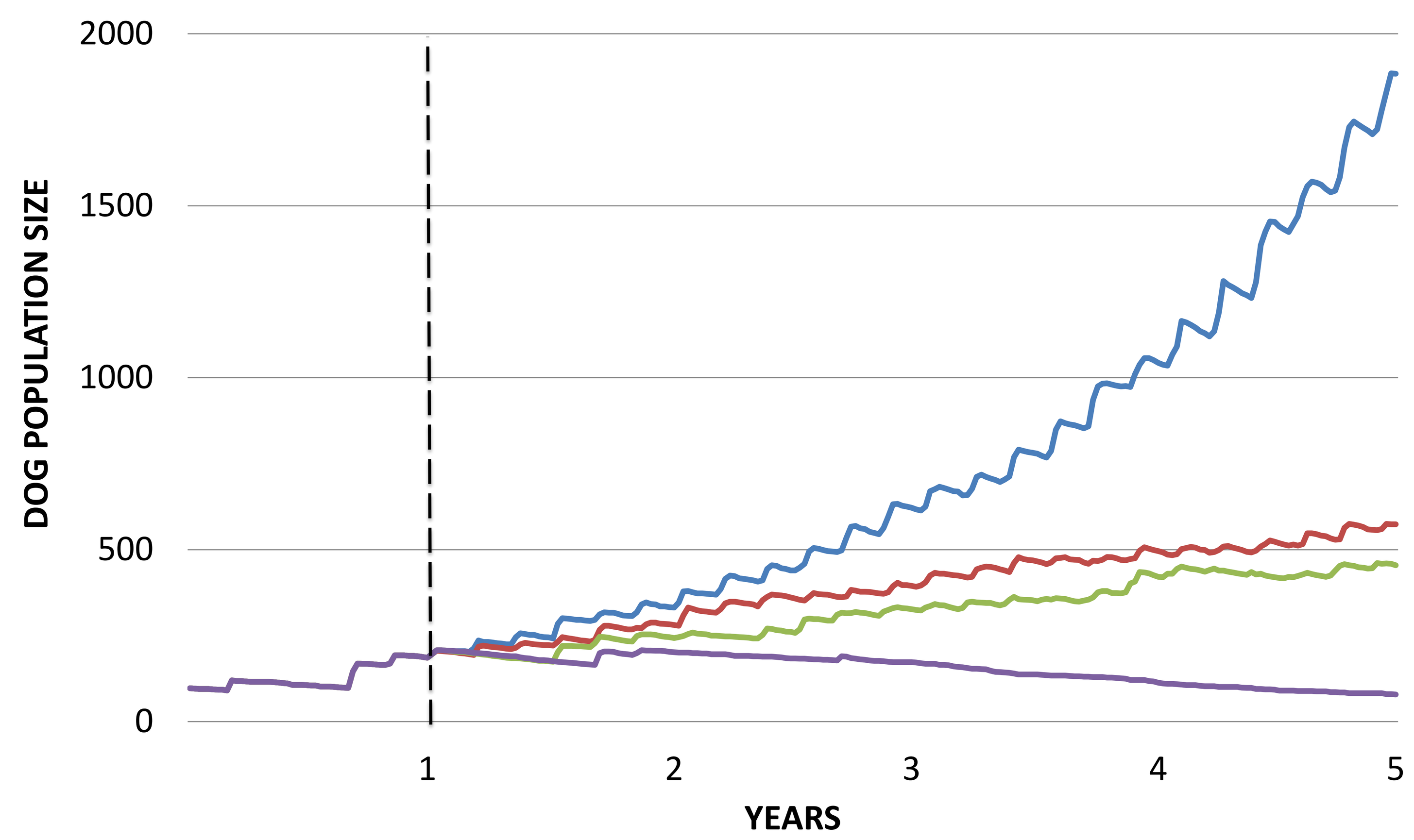

Figure 3. *Projected population size over a 5-year period: 1) No intervention (blue line), 2) Early spay intervention (red line), 3) Adult spay intervention (green line), and 4) Early and Adult Spay Combined intervention (purple line).* The dashed line represents the time at which each intervention strategy was begun in the population.

Table 3. *Spay Interventions at Different Recurrence Levels*

	MODEL OUTCOMES AFTER 5 YEARS		
	# DOGS	# SPAYED	COST
EARLY SPAY INTERVENTION			
Intervention deployed every 12 months	574	156	$6,240
Intervention deployed every 6 months	240	159	$6,360
Intervention deployed every 3 months	220	137	$5,480
ADULT SPAY INTERVENTION			
Intervention deployed every 12 months	455	196	$7,840
Intervention deployed every 6 months	138	113	$4,520
Intervention deployed every 3 months	126	112	$4,480
EARLY AND ADULT SPAY INTERVENTIONS COMBINED			
Intervention deployed every 12 months	79	101	$4,040
Intervention deployed every 6 months	53	82	$3,380
Intervention deployed every 3 months	54	54	$3,320

CONCLUSIONS

- Agent-based models allow us to create a simplified representation of dog population dynamics.
- Comparing the dog population size after 5 years in the presence of no intervention and after the implementation of the three spay interventions, allows us to identify the intervention that has the greatest impact.
- The evaluation of the three spay interventions deployed with different recurrence times allows us to identify the intervention and timing that yields the greatest population reduction at the lowest intervention cost.
- In conclusion, the use of agent-based models offers the potential to help advance the identification of successful dog population management initiatives.

FUTURE DIRECTIONS

- Free roaming dog population density will be estimated and owned dog population demographics will be collected in a small community in the State of Hidalgo (20,000 inhabitants) in collaboration with the Mexican Ministry of Health.
- Using the information collected, an agent-based model will be developed to describe the dog population dynamics in this community.
- Male and female reproductive control interventions at early and adult age will be evaluated to determine their impact on the dog population.
- Traditional and novel interventions for reproductive control such as surgical spay/neuter, and permanent and temporary chemical sterilization will be evaluated to determine the expected impact of different intervention strategies. These interventions will be evaluated at different coverage levels and times of implementation.
- The developed model will incorporate a health economic component to incorporate both costs and benefits into the analysis.
- Zoonotic disease transmission will be incorporated into the base model to evaluate the projected impact of the modeled interventions on rabies control in Mexico.
- The overall goal of this work is to provide evidence-based research to support decision making related to dog population control programs.

REFERENCES

1. Kustritz, MR. Clinical Canine and Feline Reproduction Evidence-Based Answers. Hoboken, NJ, USA: Wiley-Blackwell, 2010.
2. Kutzler M. (2010). Reproductive Biology 101, Paper presented at the 4th International Symposium on Non-Surgical Contraceptive Methods of Pet Population, Dallas, Texas.
3. Pal SK. (2005). Parental care in free-ranging dogs, *Canis familiaris*. Applied Animal Behaviour Science, 90, 31–47.
4. Kitala, PM, McDermott, JJ., Coleman, PG. & Dye, C. (2002). Comparison of vaccination strategies for the control of dog rabies in Machakos District, Kenya. Epidemiology and Infection, 129, 215–222.
5. Berry P. (2001). Mobile Spay-Neuter Clinic Operations, Best Friends Animal Sanctuary, 20.