Evaluating the effect of surgical sterilization on owned dog population size in a small, semi-urban community in Mexico using an individual-based simulation model

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INTRODUCTION

Inadequate control of dog populations can have grave consequences for public health and dog welfare (Stafford, 2007)

FOR PEOPLE
- Zoonotic Diseases
  - Dog aggression (bites) and intimidation
  - Nuisance, noise and fouling
  - Traffic accidents

FOR ANIMALS
- Malnutrition
  - Livestock predation
  - Wildlife predation

- Untreated disease
- Abusive treatment
- Inhumane methods of control

http://wagpetshop.blogspot.ca/2012/07/puppy-play-party.html
Uncontrolled Dog Population Growth

Dog Ownership

- Age
- Sex
- Reproductive Status
- Level of Confinement
- Food
- Garbage
- Water
- Shelter
- Abandoned buildings
- Abandonment
- Behaviors
- Marital Status
- Culture
- Attitudes

Adapted from: https://ecommons.usask.ca/handle/10388/7688
WHY SIMULATION MODELS?

Model

Problem

Risk Zone

Experiment

Simulation

Optimized Model

Solution

Risk Free Zone

INDIVIDUAL-BASED MODELS

Adapted from: http://www.anylogic.com/upload/medialibrary/748/7481bdd58f16c6e7529d61c9f147aab.jpg
OVERVIEW

Owned Dog Population

Mexico

Subsidized rabies vaccination program

Subsidized surgical sterilization program
LOCATION

• Villa de Tezontepec, Hidalgo, Mexico
MEAN AGE

2.9 years

55.2% under 3 years of age

SEX RATIO

1.4 : 1

Male Dog

Female Dog

http://www.hillspet.co.uk/images/weurg/ib_lifestages_dog.jpg

CONFINEMENT STATUS

• More than half of the owned dogs were allowed to ROAM FREE

55.1%

http://vistaridgekennels.homestead.com
SPAY AND NEUTER STATUS

SPAYED 36.9%

NEUTERED 14.1%

80.0% sterilized in government subsidized spay/neuter clinics

http://etc.usf.edu/clipart/70400/70422/70422_262_rg-240_s.htm
METHODS

A stochastic, individual-based model (Anylogic 7.2.0)

Model parameterization:
• Empirical data from Kisiel et al., 2016
• Peer reviewed literature

The primary outcome of interest: final population size (mean population size, standard deviation, median, and absolute range)

Model time horizon = 20 years
Each model scenario was run 1000 times
State chart
Life cycle for male dogs
State chart
Life cycle for male dogs

Birth

Puppy

Time to weaning

Young

Time to sexual maturity male

Adult

Reproductive

Neuter event

Neuter event

Death

Sterilized risk of non-age related mortality unconfined

Sterilized risk of non-age related mortality confined

Sterilized male risk of age related mortality

Male risk of age related mortality

Puppy annual risk of non-age related mortality confined

Young annual risk of non-age related mortality confined

Adult annual risk of non-age related mortality confined

Puppy annual risk of non-age related mortality unconfined

Young annual risk of non-age related mortality unconfined

Adult annual risk of non-age related mortality unconfined

Neutered
State chart
Life cycle for male dogs

- Birth
  - Puppy
    - Time to weaning
    - Young annual risk of non-age related mortality confined
    - Time to sexual maturity male
  - Adult
    - Adult annual risk of non-age related mortality confined
    - Neuter event
    - Sterilized male risk of age related mortality
    - Male risk of age related mortality
    - Neuter event
    - Sterilized risk of non-age related mortality unconfined
  - Death
- Immigration
  - Neuter event
  - Sterilized risk of non-age related mortality unconfined
  - Neonatal risk of non-age related mortality unconfined
- Emigration
State chart
Life cycle for male dogs

- Birth
  - Puppy
    - Time to weaning
      - Young
        - Time to sexual maturity male
          - Adult
            - Neuter event
              - Sterilized male risk of age related mortality
        - Adult annual risk of non-age related mortality
          - Adult annual risk of non-age related mortality
            - Adult annual risk of non-age related mortality unconfined
              - Adult annual risk of non-age related mortality confined
                - Male risk of age related mortality
                  - Death
                    - Neuter event
                      - Sterilized risk of non-age related mortality unconfined
                        - Sterilized risk of non-age related mortality confined
                          - Neuter event
                            - Sterilized risk of non-age related mortality
                              - Birth
State chart
Life cycle for male dogs

Immigration

Emigration

Birth

Puppy
- Time to weaning
  - Puppy annual risk of non-age related mortality confined

Young
- Time to sexual maturity male
  - Young annual risk of non-age related mortality confined

Adult
- Adult annual risk of non-age related mortality confined

Reproductive
- sterilized risk of non-age related mortality unconfined
- sterilized male risk of age related mortality

Neutered
- Neuter event
  - Sterilized risk of non-age related mortality confined
  - Sterilized risk of non-age related mortality unconfined

Death

Adult annual risk of non-age related mortality confined

Young annual risk of non-age related mortality unconfined

Puppy annual risk of non-age related mortality unconfined

Adult annual risk of non-age related mortality unconfined

Adult annual risk of non-age related mortality confined

Young annual risk of non-age related mortality unconfined

Puppy annual risk of non-age related mortality confined

Sterilized male risk of age related mortality

Male risk of age related mortality
State chart
Life cycle for female dogs

- **Birth**
- **Puppy**
  - Time to weaning
- **Young**
  - Time to sexual maturity female
- **Adopted**
  - Duration of heat
  - Time to new proestrus
- **In Heat (Reproductive)**
  - Risk of pregnancy confined
  - Risk of pregnancy unconfined
- **Pregnant**
  - Gestation period
- **Not in Heat**
  - Sterilized risk of non-age related mortality confined
  - Sterilized risk of non-age related mortality unconfined
  - Sterilized female risk of age related mortality
  - Female risk of age related mortality
- **Spayed**
  - Spay event
  - Spay event
- **Death**

- **Immigration**
- **Emigration**
State chart
Life cycle for female dogs

- **Puppy**
  - Time to weaning
  - Puppy annual risk of non-age related mortality confined
  - Puppy annual risk of non-age related mortality unconfined

- **Young**
  - Time to sexual maturity female
  - Young annual risk of non-age related mortality confined
  - Young annual risk of non-age related mortality unconfined

- **Adult**
  - Duration of heat
  - Time to new proestrus
  - Spay event

- **Spayed**
  - Sterilized risk of non-age related mortality confined
  - Sterilized risk of non-age related mortality unconfined

- **Not in Heat**
  - Sterilized female risk of age related mortality
  - Female risk of age related mortality

- **Pregnant**
  - Gestation period
  - Risk of pregnancy confined
  - Risk of pregnancy unconfined

- **Death**

- Immigration
- Emigration
State chart
Life cycle for female dogs

- Birth
  - Puppy
    - Time to weaning
    - Puppy annual risk of non-age related mortality confined
    - Puppy annual risk of non-age related mortality unconfined
  - Young
    - Time to sexual maturity female
    - Young annual risk of non-age related mortality confined
    - Young annual risk of non-age related mortality unconfined
  - Adult
    - In Heat (Reproductive)
      - Duration of heat
      - Time to new proestrus
      - Risk of pregnancy confined
      - Risk of pregnancy unconfined
      - Gestation period
      - Pregnant
    - Not in Heat
      - Sterilized female risk of age related mortality
      - Sterilized risk of non-age related mortality confined
      - Sterilized risk of non-age related mortality unconfined
      - Female risk of age related mortality
      - Spay event
    - Spayed
      - Adult annual risk of non-age related mortality confined
      - Adult annual risk of non-age related mortality unconfined
  - Death
    - Immigration
    - Emigration
State chart
Life cycle for female dogs

Immigration

Emigration

Birth

Puppy

Puppy annual risk of non-age related mortality confined

Time to weaning

Young

Young annual risk of non-age related mortality confined

Young annual risk of non-age related mortality unconfined

Time to sexual maturity female

Adult

In Heat (Reproductive)

Risk of pregnancy confined

Risk of pregnancy unconfined

Duration of heat

Time to new proestrus

Pregnant

Gestation period

Not in Heat

Sterilized female risk of age related mortality

Female risk of age related mortality

Spay event

Sterilized risk of non-age related mortality confined

Sterilized risk of non-age related mortality unconfined

Spay event

Death

Adult annual risk of non-age related mortality confined

Adult annual risk of non-age related mortality unconfined

Spayed

Sterilized risk of non-age related mortality unconfined

Sterilized risk of non-age related mortality confined

Immigration

Emigration

State chart
Life cycle for female dogs
State chart
Life cycle for female dogs

- Birth
- Spay event
- Duration of heat
- Time to new proestrus
- Gestation period
- Female risk of age related mortality
- Spayed female risk of non-age related mortality
- Sterilized female risk of age related mortality
- Sterilized risk of non-age related mortality
- Young annual risk of non-age related mortality
- Young annual risk of non-age related mortality
- Adult annual risk of non-age related mortality
- Spayed annual risk of non-age related mortality
- Adult annual risk of non-age related mortality
- Pregnancy annual risk of non-age related mortality
- Risk of pregnancy unconfined
- Risk of pregnancy confined
- Time to weaning
- Adult annual mortality
- Time to sexual maturity female
- Puppy annual risk of non-age related mortality unconfined
- Puppy annual risk of non-age related mortality confined
- Immigration
- Emigration
- Adult
- Not in Heat
- In Heat (Reproductive)
- Pregnant
- Death
SURGICAL STERILIZATION INTERVENTIONS (4)

- Sex
- Age
- Surgical capacity
Sex

Mixed sex
(Females and males)
SURGICAL STERILIZATION INTERVENTIONS (4)

Sex

- Mixed sex (Females and males)
- Female only
SURGICAL STERILIZATION INTERVENTIONS (4)

**Sex**
- Mixed sex (Females and males)
- Female only

**Age**
- Mixed age (Sexually mature and immature)
- Mixed age (Sexually mature and immature)
SURGICAL STERILIZATION INTERVENTIONS (4)

**Sex**
- Mixed sex (Females and males)
- Female only

**Age**
- Mixed age (Sexually mature and immature)
- Young age (Sexually immature)
- Mixed age (Sexually mature and immature)
- Young age (Sexually immature)
SURGICAL STERILIZATION INTERVENTIONS (4)

Sex

- Mixed sex (Females and males)
- Female only

Age

- Mixed age (Sexually mature and immature)
- Young age (Sexually immature)
- Mixed age (Sexually mature And immature)
- Young age (Sexually immature)

Surgical capacity

- ✓ 21 surgeries per month
- ✓ 42 surgeries per month
- ✓ 84 surgeries per month
SURGICAL STERILIZATION INTERVENTIONS (4)

Sex
- Mixed sex (Females and males)
- Female only

Age
- Mixed age (Sexually mature and immature)
- Young age (Sexually immature)
- Mixed age (Sexually mature and immature)
- Young age (Sexually immature)

Surgical capacity
- ✓ 21 surgeries per month
- ✓ 42 surgeries per month
- ✓ 84 surgeries per month
% Reduction in Population Size

Mixed sex
Mixed age sterilization

A

Base Case 0%

Community Capacity

B

Mixed sex
Young age sterilization

Number of Surgeries per Month

21 42 84 21 42 84

Community Capacity
Reduction in Population Size

Number of Surgeries per Month

Community Capacity

Mixed sex
Mixed age sterilization

Mixed sex
Young age sterilization

Base Case 0%

% Reduction in Population Size

21 42 84

21 42 84

A

B

Mixed sex
Sterilization

Community Capacity

Base Case

Number of Surgeries per Month
CONCLUSION

Computer simulation models

Optimize resources for dog population management programs

Robust dog population numbers and attributes

Models to evaluate dog population control interventions

Sterilization of sexually immature female owned dogs

Reduce the owned dog population size overtime

ACKNOWLEDGEMENTS

• University of Guelph

• Hidalgo Ministry of Health

• MITACS Globalink

• Canada Research Chairs
THANK YOU FOR LISTENING

• Any Questions?

http://v2.elpensular.mx/semana-nacional-de-vacunacion-antirrabica-canina-y-felina-2018/
## Model initial conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL PARAMETERS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of confined dogs</td>
<td>45.00%</td>
<td>Kisiel et al., 2016</td>
</tr>
<tr>
<td><strong>FEMALE DOGS INITIAL CONDITIONS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population size</td>
<td>1222 dogs</td>
<td>Kisiel et al., 2016</td>
</tr>
<tr>
<td>Proportion puppy</td>
<td>4.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion young</td>
<td>11.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion reproductive</td>
<td>21.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion pregnant</td>
<td>6.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion not in heat</td>
<td>21.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion regular spayed</td>
<td>37.00%</td>
<td>Kisiel et al., 2016</td>
</tr>
</tbody>
</table>
# Model initial conditions (Continue)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MALE DOGS INITIAL CONDITIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population size</td>
<td>1702 dogs</td>
<td>Kisiel et al., 2016</td>
</tr>
<tr>
<td>Proportion puppy</td>
<td>6.00%</td>
<td>Kisiel et al., 2016</td>
</tr>
<tr>
<td>Proportion young</td>
<td>16.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion reproductive</td>
<td>64.00%</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Proportion regular neutered</td>
<td>14.00%</td>
<td>Kisiel et al., 2016</td>
</tr>
</tbody>
</table>
Model parameters describing the transition rates and/or times for individual dogs to move between the different model states

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Distribution (parameter values)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GENERAL PARAMETERS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to weaning</td>
<td>8 weeks</td>
<td>N/A</td>
<td>Kustritz, 2010</td>
</tr>
<tr>
<td>Time to sexual maturity female</td>
<td>Average 6 to 10 months</td>
<td>Uniform (Min. 6 months Max. 10 months)</td>
<td>Kustritz, 2010</td>
</tr>
<tr>
<td>Time to sexual maturity male</td>
<td>Average 10 months</td>
<td>N/A</td>
<td>Kustritz, 2010</td>
</tr>
<tr>
<td>Puppy annual risk of non-age-related mortality confined</td>
<td>0.10 per year (Sensitivity analysis range from 0.05 to 0.3)</td>
<td>N/A</td>
<td>Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)</td>
</tr>
<tr>
<td>Puppy annual risk of non-age-related mortality unconfined</td>
<td>0.20 per year</td>
<td>N/A</td>
<td>Assumption (2 X Puppy annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>Young annual risk of non-age-related mortality confined</td>
<td>0.20 per year (Sensitivity analysis range from 0.1 to 0.3)</td>
<td>N/A</td>
<td>Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)</td>
</tr>
<tr>
<td>Young annual risk of non-age-related mortality unconfined</td>
<td>0.40 per year</td>
<td>N/A</td>
<td>Assumption (2 X Young annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>Adult annual risk of non-age-related mortality confined</td>
<td>0.03 per year (Sensitivity analysis range from 0.015 to 0.075)</td>
<td>N/A</td>
<td>Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)</td>
</tr>
<tr>
<td>Adult annual risk of non-age-related mortality unconfined</td>
<td>0.06 per year</td>
<td>N/A</td>
<td>Assumption (2 X Adult annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
</tbody>
</table>
Model parameters describing the transition rates and/or times for individual dogs to move between the different model states (Continue)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>GENERAL PARAMETERS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sterilized risk of non-age-related mortality confined</td>
<td>0.027 per year</td>
<td>N/A</td>
<td>Assumption (90.00% of Adult annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>Sterilized risk of non-age-related mortality unconfined</td>
<td>0.054 per year</td>
<td>N/A</td>
<td>Assumption (2 X Sterilized risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>Male risk of age related mortality</td>
<td></td>
<td>Exponential (Min. 0.08 years, Max. 14.00 years, Skewness 2.27 and Kurtosis 10.24)</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Female risk of age related mortality</td>
<td></td>
<td>Exponential (Min. 0.50 years, Max. 12.00 years, Skewness 1.58 and Kurtosis 5.13)</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Sterilized male risk of age related mortality</td>
<td></td>
<td>Exponential (Min. 0.88 years, Max. 15.40 years, Skewness 2.27 and Kurtosis 10.24)</td>
<td>Assumption (90.00% of Male age-related mortality) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>Sterilized female risk of age related mortality</td>
<td></td>
<td>Exponential (Min. 0.55 years, Max. 13.20 years, Skewness 1.58 and Kurtosis 5.13)</td>
<td>Assumption (90.00% Female age-related mortality) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
</tbody>
</table>
Model parameters describing the transition rates and/or times for individual dogs to move between the different model states (Continue)

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Distribution (parameter values)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE DOG ONLY PARAMETERS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of heat</td>
<td>18 days (Proestrus Average 9 days + Estrus Average 9 days)</td>
<td>N/A</td>
<td>(Kustritz, 2010, Kustritz, 2012)</td>
</tr>
<tr>
<td>Gestation duration</td>
<td>65 days</td>
<td>N/A</td>
<td>Kutzler, 2010</td>
</tr>
<tr>
<td>Time to New proestrus</td>
<td>Average 7 months</td>
<td>N/A</td>
<td>Kustritz, 2010</td>
</tr>
<tr>
<td>Litter size</td>
<td>4 puppies</td>
<td>N/A</td>
<td>Kisiel et al., 2016</td>
</tr>
<tr>
<td>Risk of pregnancy confined</td>
<td>0.26 per year (Sensitivity analysis range from 0.10 to 0.40)</td>
<td>N/A</td>
<td>Kisiel et al., 2016 (Sensitivity analysis: based on researchers hypothesis)</td>
</tr>
<tr>
<td>Risk of pregnancy unconfined</td>
<td>0.52 per year</td>
<td>N/A</td>
<td>Assumption (2 X risk of pregnancy confined) (Sensitivity analysis: based on researchers’ hypothesis)</td>
</tr>
<tr>
<td>POPULATION PARAMETERS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual probability of immigration</td>
<td>0.23 per year</td>
<td>N/A</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Annual probability of emigration</td>
<td>0.04 per year</td>
<td>N/A</td>
<td>Kisiel et al., 2018</td>
</tr>
<tr>
<td>Community capacity</td>
<td>2924 dogs</td>
<td>N/A</td>
<td>Kisiel et al., 2016</td>
</tr>
</tbody>
</table>
Minimum, maximum, mean, standard deviation and total number of owned dogs in the young, pregnant, and adult age group categories

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total # of Owned Dogs # (%)(^\text{e})</th>
<th>Percent from Total Population(^\text{f})</th>
<th>Owned Dogs Median Age (range)</th>
<th>Owned Dogs Mean Age (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female young</td>
<td>11 (18.64)</td>
<td>11.22 (0.19*0.59)</td>
<td>0.5 (0.21 - 0.75)</td>
<td>0.50 (SD = 0.19)</td>
</tr>
<tr>
<td>Female Pregnant</td>
<td>6 (10.17)</td>
<td>6.12 (0.10*.059)</td>
<td>1.75 (0.67 – 6.00)</td>
<td>2.28 (SD = 1.89)</td>
</tr>
<tr>
<td>Female Adult(^\text{ab})</td>
<td>42 (71.19)</td>
<td>41.13 (0.71*0.59)</td>
<td>3.00 (1.00 – 11.00)</td>
<td>3.37 (SD = 2.11)</td>
</tr>
<tr>
<td><strong>Total Female(^\text{c})</strong></td>
<td><strong>59 (100.00)</strong></td>
<td><strong>59.20 (1.00*0.59)</strong></td>
<td><strong>2.00 (0.21 – 11.00)</strong></td>
<td><strong>2.70 (SD = 2.17)</strong></td>
</tr>
<tr>
<td>Male young</td>
<td>23 (19.83)</td>
<td>15.92 (0.20*0.80)</td>
<td>0.5 (0.25 - 0.83)</td>
<td>0.51 (SD = 0.17)</td>
</tr>
<tr>
<td>Male Adult</td>
<td>93 (80.17)</td>
<td>64.39 (0.80*0.80)</td>
<td>3.00 (0.92 – 15.00)</td>
<td>3.34 (SD = 2.47)</td>
</tr>
<tr>
<td><strong>Total Male(^\text{d})</strong></td>
<td><strong>116 (100.00)</strong></td>
<td><strong>80.30 (1.00*0.80)</strong></td>
<td><strong>2.00 (0.25 – 15.00)</strong></td>
<td><strong>2.78 (SD = 2.48)</strong></td>
</tr>
</tbody>
</table>

a. Includes In heat and Not in heat
b. Excludes female adult pregnant dogs
c. Excludes female puppies and spayed dogs
d. Excludes male puppies and neutered dogs
e. Includes only owned dog data where numerical age values were provided
f. Based on total dog population (n=428). Calculation= Total number of dogs in age group divided by total number of dogs per gender, multiplied by percentage of total population per gender
Minimum, maximum, mean, standard deviation and total number of owned dogs older than one year. Population distribution skewness and kurtosis also included

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total # of Owned Dogs # (%)</th>
<th>Owned Dogs Median Age (range)</th>
<th>Owned Dogs Mean Age (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female &gt; 1 year old</td>
<td>72 (41.62)</td>
<td>3.00 (1.5 – 13.00)</td>
<td>3.87 (SD = 2.56)</td>
<td>1.59</td>
<td>5.14</td>
</tr>
<tr>
<td>Males &gt; 1 year old</td>
<td>101 (58.38)</td>
<td>3.00 (1.08 – 15.00)</td>
<td>3.70 (SD = 2.30)</td>
<td>2.27</td>
<td>10.24</td>
</tr>
<tr>
<td>Total</td>
<td>173 (100.00)</td>
<td>3.00 (1.08 – 15.00)</td>
<td>3.77 (SD = 2.41)</td>
<td>1.95</td>
<td>7.64</td>
</tr>
</tbody>
</table>

Percentage and total number of owned dogs that immigrated and emigrate to and from Villa de Tezontepec, Hidalgo Mexico, 2015

<table>
<thead>
<tr>
<th>Category</th>
<th>Total per Category # (%)</th>
<th>Percentage from Total Populationa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of dogs purchased outside the population</td>
<td>39 (40.21)</td>
<td>9.11 (39/428)</td>
</tr>
<tr>
<td>Number of dogs that were a gift from outside the population</td>
<td>58 (59.79)</td>
<td>13.55 (58/428)</td>
</tr>
<tr>
<td><strong>Total number of dog that came from outside the population</strong></td>
<td><strong>97 (100.00)</strong></td>
<td><strong>22.66 (97/428)</strong></td>
</tr>
<tr>
<td>Number of dogs given away</td>
<td>9 (50.00)</td>
<td>2.10 (9/428)</td>
</tr>
<tr>
<td>Number of dogs sold away</td>
<td>9 (50.00)</td>
<td>2.10 (9/428)</td>
</tr>
<tr>
<td><strong>Total number of dog that left the population</strong></td>
<td><strong>18 (100.00)</strong></td>
<td><strong>4.21 (9/428)</strong></td>
</tr>
</tbody>
</table>

a. Calculate based on the total population size (n=428)
Percentage and total number of owned dogs that died in the past 12 months in Villa de Tezontepec, Hidalgo Mexico, in 2015

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total # of Owned Dogs that Died in the Past 12 Months # (%)</th>
<th>Total # of Owned Dogs per Age Groupa</th>
<th>Percentage from Total Population per age group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puppies</td>
<td>2 (8.70)</td>
<td>21</td>
<td>9.52 (2/21)</td>
</tr>
<tr>
<td>Young</td>
<td>13 (56.52)</td>
<td>80</td>
<td>16.25 (13/80)</td>
</tr>
<tr>
<td>Adultb</td>
<td>8 (34.78)</td>
<td>294</td>
<td>2.72 (8/294)</td>
</tr>
<tr>
<td>Total</td>
<td>23 (100.00)</td>
<td>395</td>
<td>5.82 (23/395)</td>
</tr>
</tbody>
</table>

a. Includes only owned dog data where age range values were provided
b. Excludes adult dogs older than 5 years
Percentage and total number of female owned dogs that got pregnant in the past 12 months per level of confinement in Villa de Tezontepec, Hidalgo Mexico, in 2015a

<table>
<thead>
<tr>
<th>Category</th>
<th>Total # of Female Owned Dogs that got Pregnant in the Past 12 Months per Category</th>
<th>Percentage of Female Owned Dogs per category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always Confined</td>
<td>13</td>
<td>38.24 (13/34)</td>
</tr>
<tr>
<td>Partially Confined</td>
<td>21</td>
<td>61.76 (21/34)</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>100.00 (34/34)</td>
</tr>
</tbody>
</table>

a. Table does not include 3 missing responses.
b. Partially confined Includes: 1) Never confined 71.43% (15/21), 2) Sometimes confined 23.81% (5/21), 3) Confined only at night 4.76% (1/21).
Model outcomes for the surgical interventions examined using the individual-based model describing dog population dynamics in Villa de Tezontepec, Hidalgo Mexico.

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Intervention number</th>
<th>Surgical capacity</th>
<th>Mean population size (# of dogs)</th>
<th>Standard deviation</th>
<th>Median population size (# of dogs)</th>
<th>Range (min – max)</th>
<th>% relative change compare to base case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>N/A</td>
<td>N/A</td>
<td>2934</td>
<td>6.20</td>
<td>2936</td>
<td>2878 – 2945</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Surgical sterilization</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Mixed age surgical sterilization</td>
<td>A.1</td>
<td>Level 1 - 21 surgeries per month</td>
<td>2519</td>
<td>496.71</td>
<td>2881</td>
<td>1443 – 2937</td>
<td>-14.14%</td>
</tr>
<tr>
<td></td>
<td>A.2</td>
<td>Level 2 - 42 surgeries per month</td>
<td>1564</td>
<td>341.09</td>
<td>1525</td>
<td>798 - 2705</td>
<td>-46.69%</td>
</tr>
<tr>
<td></td>
<td>A.3</td>
<td>Level 3 - 84 surgeries per month</td>
<td>624</td>
<td>91.13</td>
<td>612</td>
<td>418 - 983</td>
<td>-78.73%</td>
</tr>
<tr>
<td>B. Young age surgical sterilization</td>
<td>B.1</td>
<td>Level 1 - 21 surgeries per month</td>
<td>558</td>
<td>122.06</td>
<td>532</td>
<td>331 - 1125</td>
<td>-80.98%</td>
</tr>
<tr>
<td></td>
<td>B.2</td>
<td>Level 2 - 42 surgeries per month</td>
<td>339</td>
<td>29.81</td>
<td>337</td>
<td>261 - 437</td>
<td>-88.44%</td>
</tr>
<tr>
<td></td>
<td>B.3</td>
<td>Level 3 - 84 surgeries per month</td>
<td>303</td>
<td>23.72</td>
<td>302</td>
<td>230 - 402</td>
<td>-89.67%</td>
</tr>
<tr>
<td>C. Female only mixed age surgical sterilization</td>
<td>C.1</td>
<td>Level 1 - 21 surgeries per month</td>
<td>532</td>
<td>55.29</td>
<td>526</td>
<td>392 - 714</td>
<td>-81.87%</td>
</tr>
<tr>
<td></td>
<td>C.2</td>
<td>Level 2 - 42 surgeries per month</td>
<td>345</td>
<td>34.37</td>
<td>343</td>
<td>251 - 513</td>
<td>-88.24%</td>
</tr>
<tr>
<td></td>
<td>C.3</td>
<td>Level 3 - 84 surgeries per month</td>
<td>235</td>
<td>19.82</td>
<td>233</td>
<td>180 - 301</td>
<td>-91.99%</td>
</tr>
<tr>
<td>D. Female only young age surgical sterilization (prior to sexual maturity)</td>
<td>D.1</td>
<td>Level 1 - 21 surgeries per month</td>
<td>307</td>
<td>34.71</td>
<td>303</td>
<td>217 - 427</td>
<td>-89.54%</td>
</tr>
<tr>
<td></td>
<td>D.2</td>
<td>Level 2 - 42 surgeries per month</td>
<td>287</td>
<td>31.86</td>
<td>285</td>
<td>200 - 413</td>
<td>-90.22%</td>
</tr>
<tr>
<td></td>
<td>D.3</td>
<td>Level 3 - 84 surgeries per month</td>
<td>276</td>
<td>28.96</td>
<td>275</td>
<td>190 - 384</td>
<td>-90.59%</td>
</tr>
</tbody>
</table>