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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[5] Rabies and Zoonoses Prevention Program, Servicios de Salud de Hidalgo

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

Livestock predation

FOR ANIMALS

Malnutrition

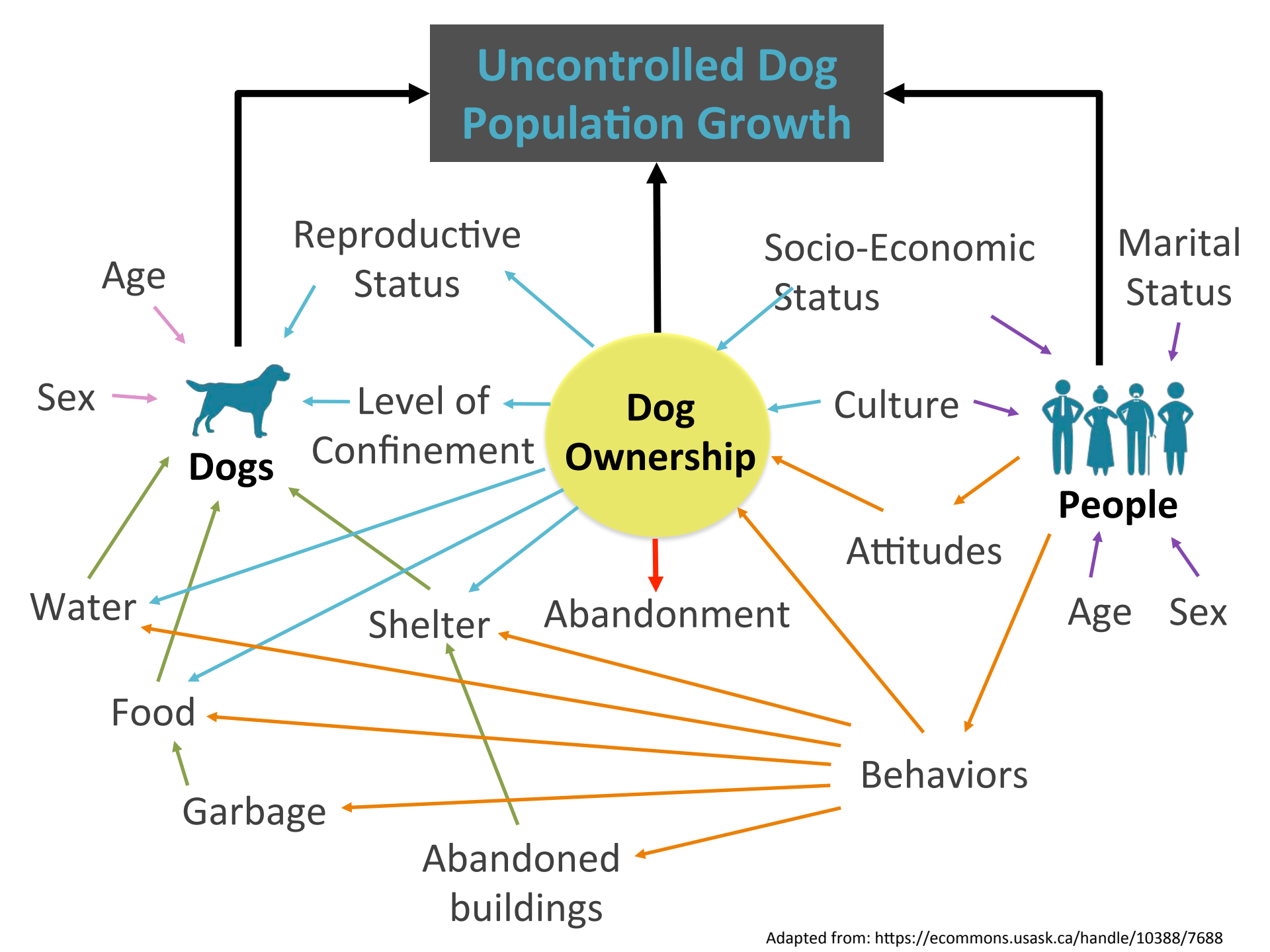
Untreated disease

Inhumane methods of control

Abusive treatment

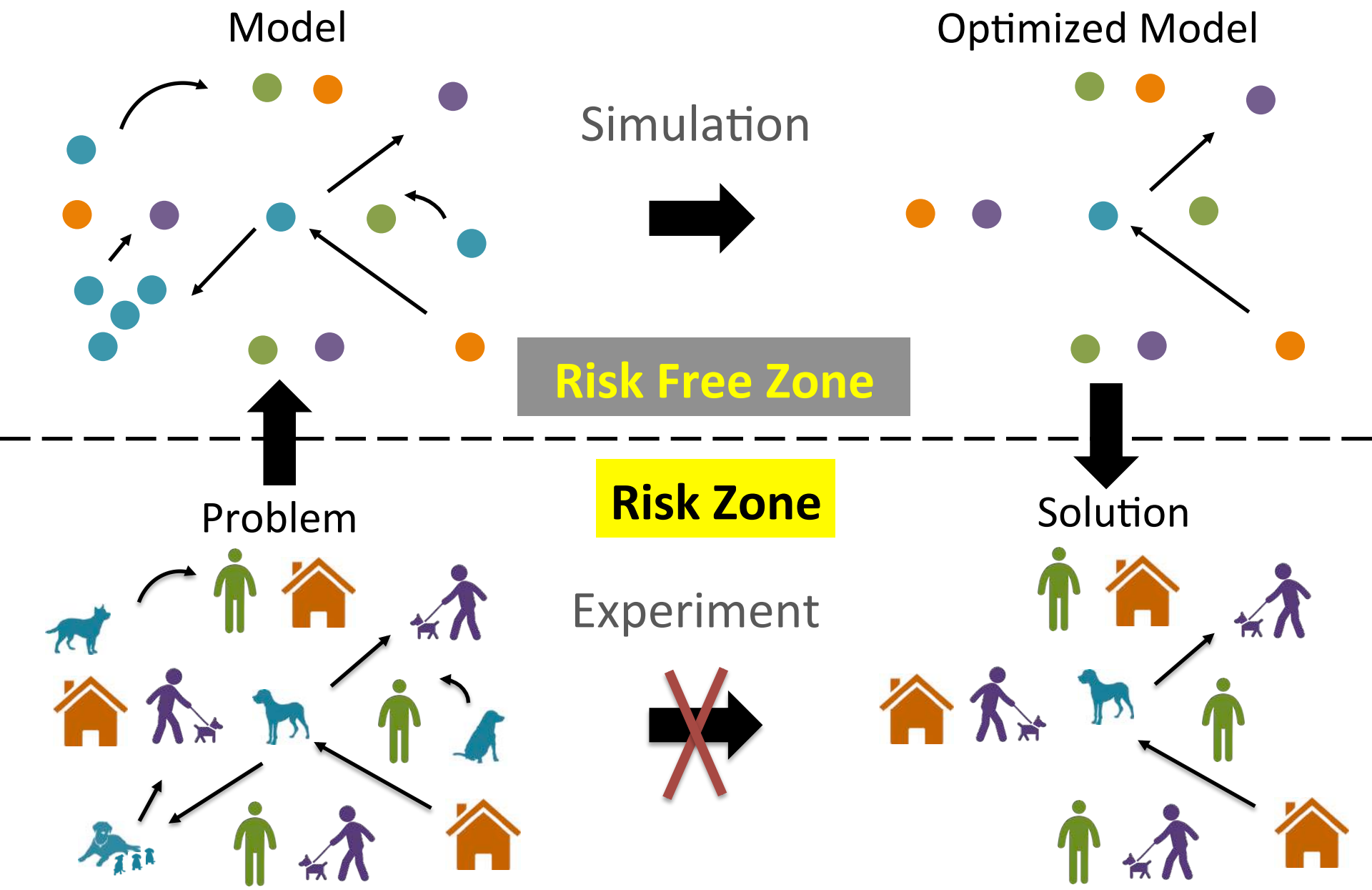
Wildlife predation

http://wagpetshop.blogspot.ca/2012/07/puppy-play-party.html



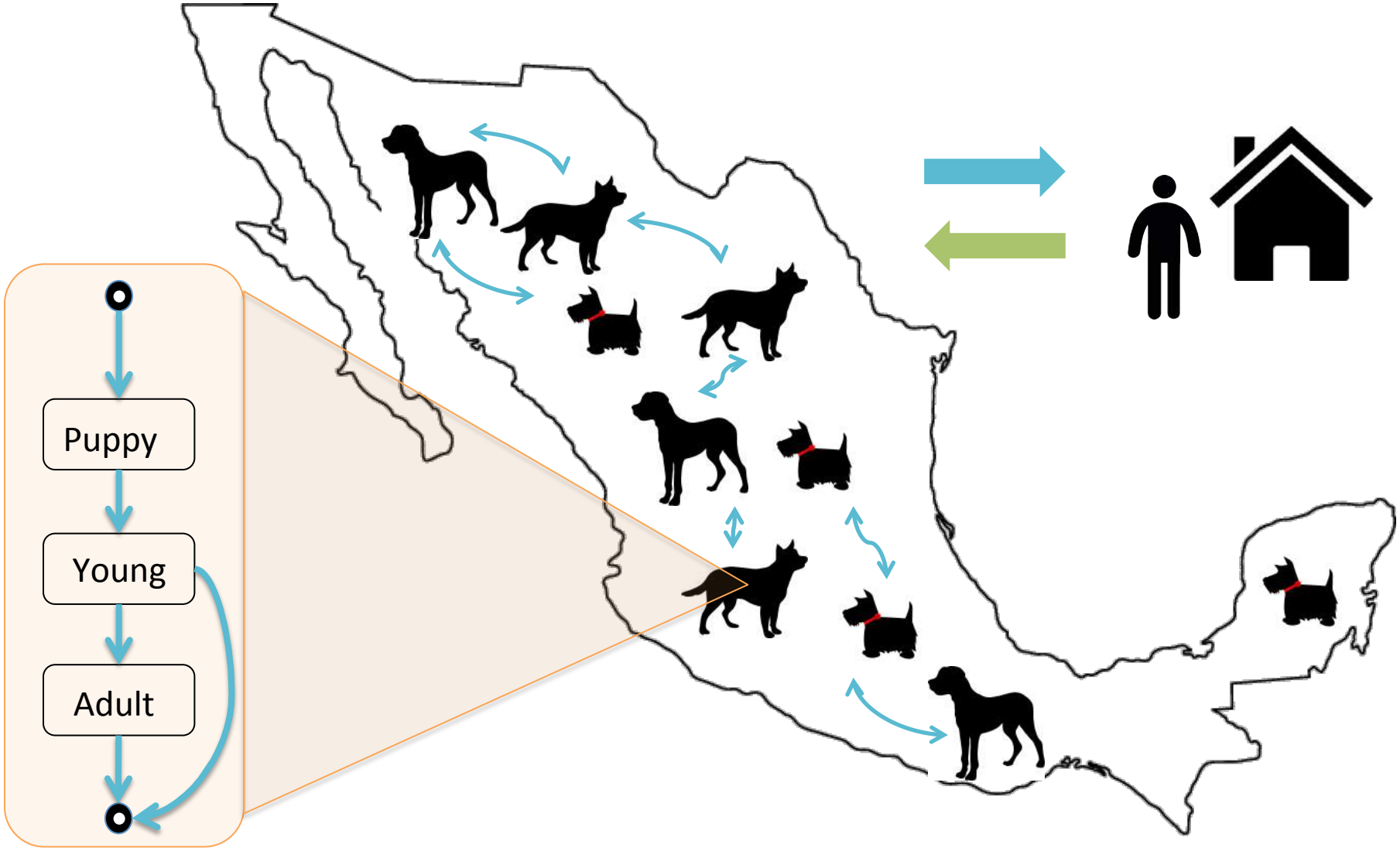
Adapted from: https://ecommons.usask.ca/handle/10388/7688

WHY SIMULATION MODELS?



Adapted from: http://www.anylogic.com/articles/from-system-dynamics-and-discrete-event-to-practical-agent-based-modeling-reasons-techniques-tools

INDIVIDUAL-BASED MODELS

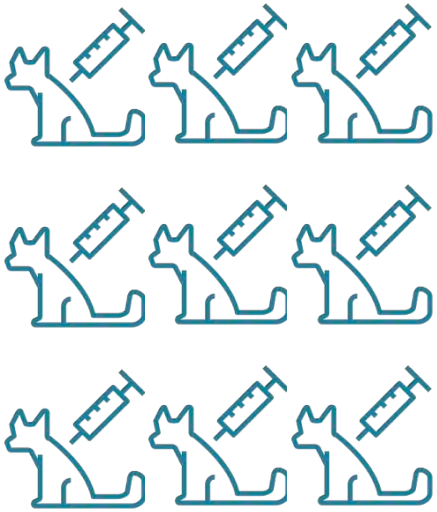


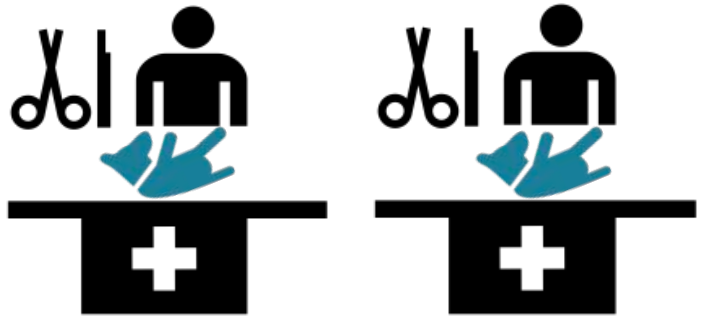
Adapted from: http://www.anylogic.com/upload/medialibrary/748/7481bdd58f16c6e67529d61c9f147aab.jpg

OVERVIEW

Owned Dog Population

Mexico





Subsidized rabies vaccination program

Subsidized surgical sterilization program

LOCATION

- **Villa de Tezontepec, Hidalgo, Mexico**

http://mapsof.net/mexico/mexico-states-hidalgo
http://intranet.e-hidalgo.gob.mx/enciclomuni/municipios/13066a.htm

MEAN AGE

2.9 years

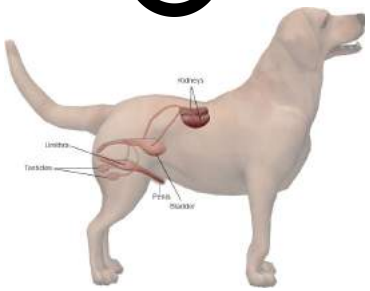
55.2% under **3 years** of age

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

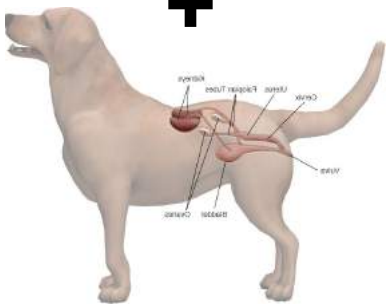
SEX RATIO

1.4 : 1

Male Dog ♂



Female Dog ♀



http://level2animalcare.weebly.com/uploads/2/6/5/3/26533862/9319307_orig.jpg

CONFINEMENT STATUS

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

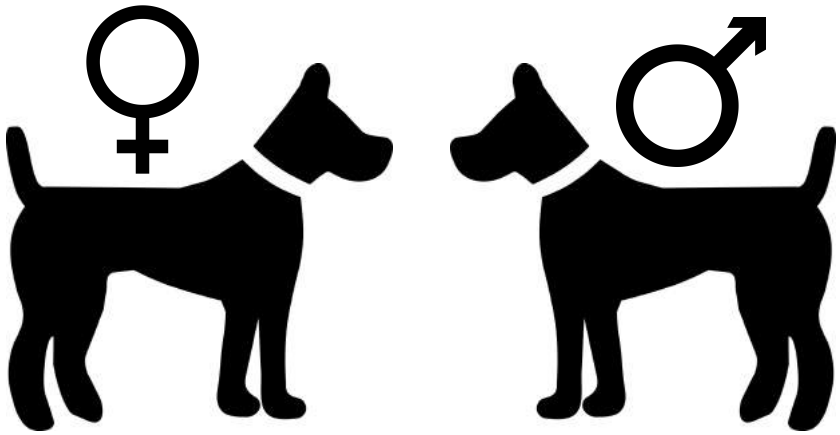
55.1%

http://vistaridgekennels.homestead.com

SPAY AND NEUTER STATUS

SPAYED
36.9%

NEUTERED
14.1%



80.0%
sterilized in
government subsidized
spay/neuter clinics

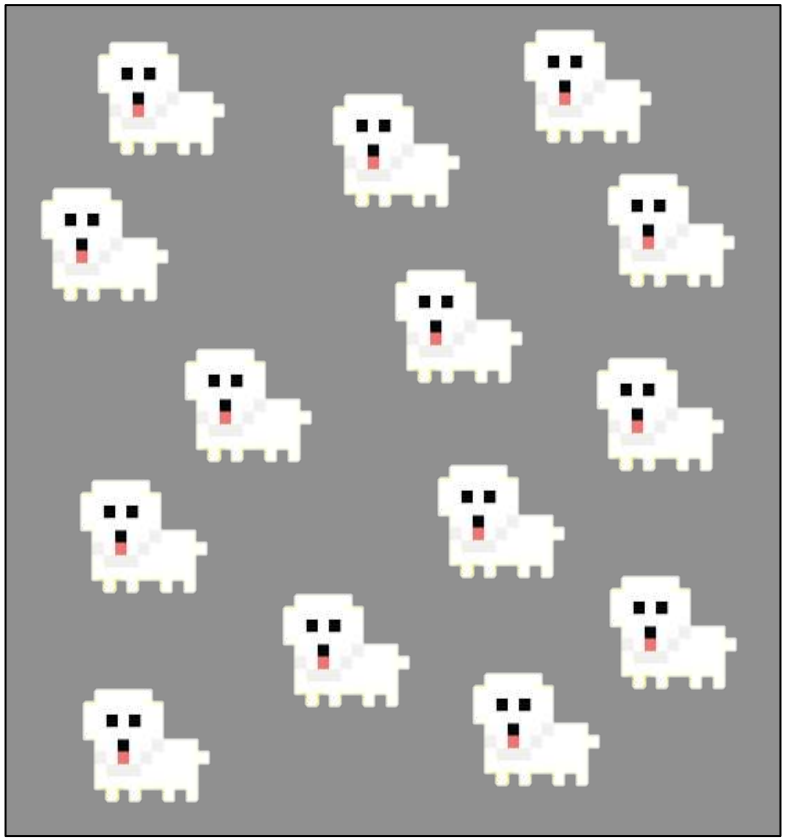
http://etc.usf.edu/clipart/70400/70422/70422_262_rg-240_s.htm

METHODS

A stochastic, **individual-based model** (Anylogic 7.2.0)

Model parameterization:

- Empirical data from **Kisiel et al., 2016**
- Peer reviewed literature



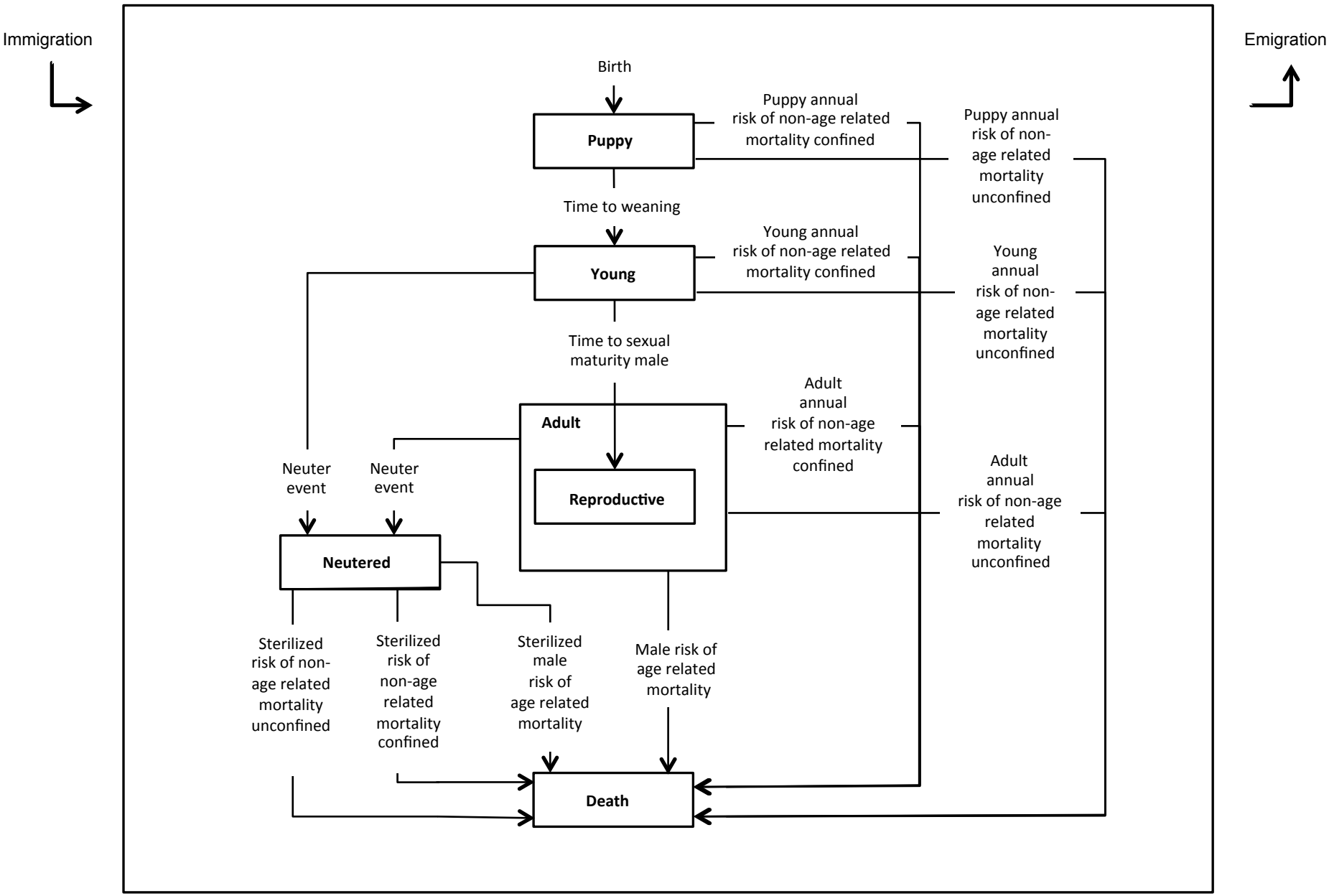
The primary outcome of interest: **final population size** (mean population size, standard deviation, median, and absolute range)

Model time horizon = **20 years**

Each model scenario was run **1000 times**

https://www.designspiration.net/save/1256346062468/

State chart
Life cycle for male dogs



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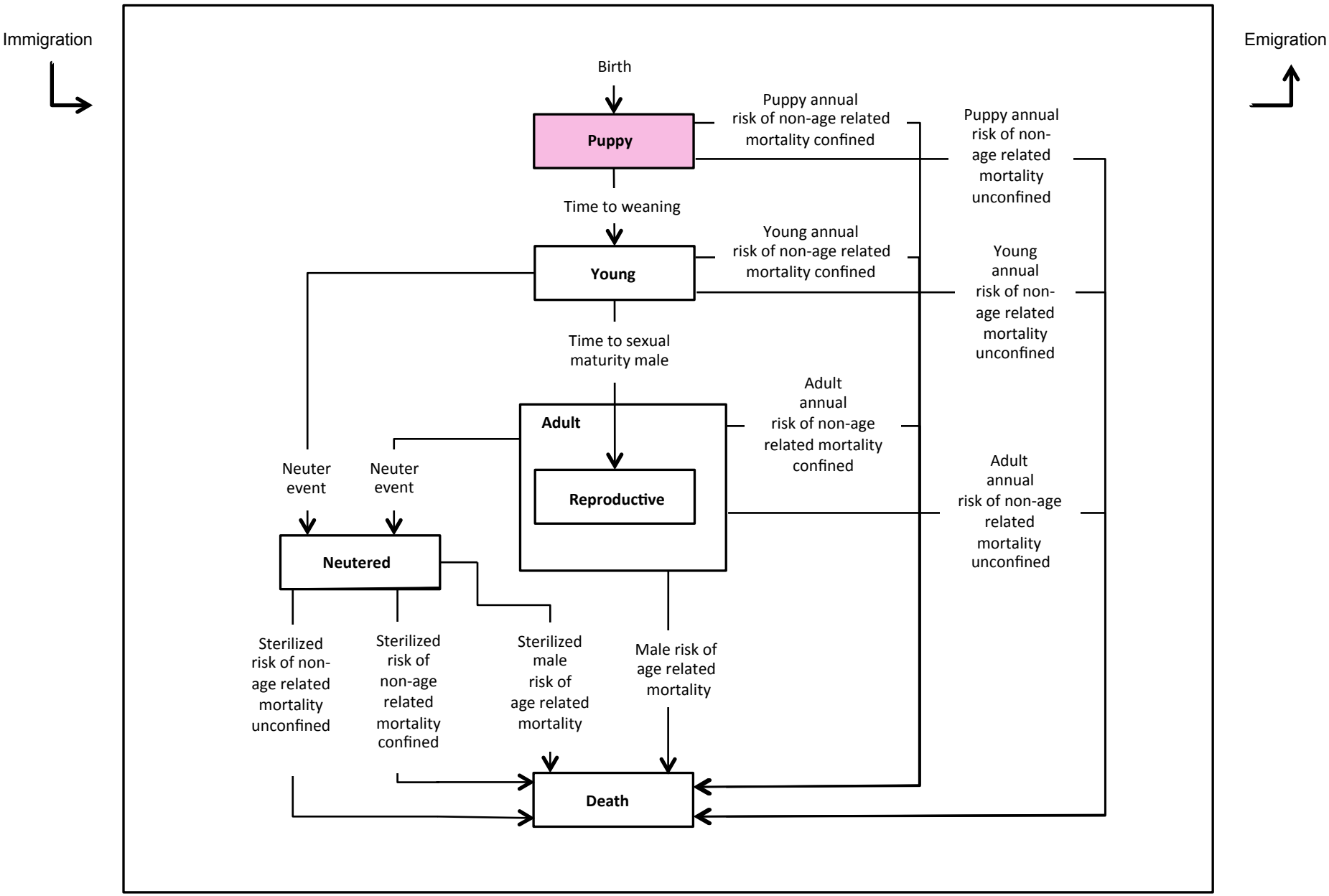

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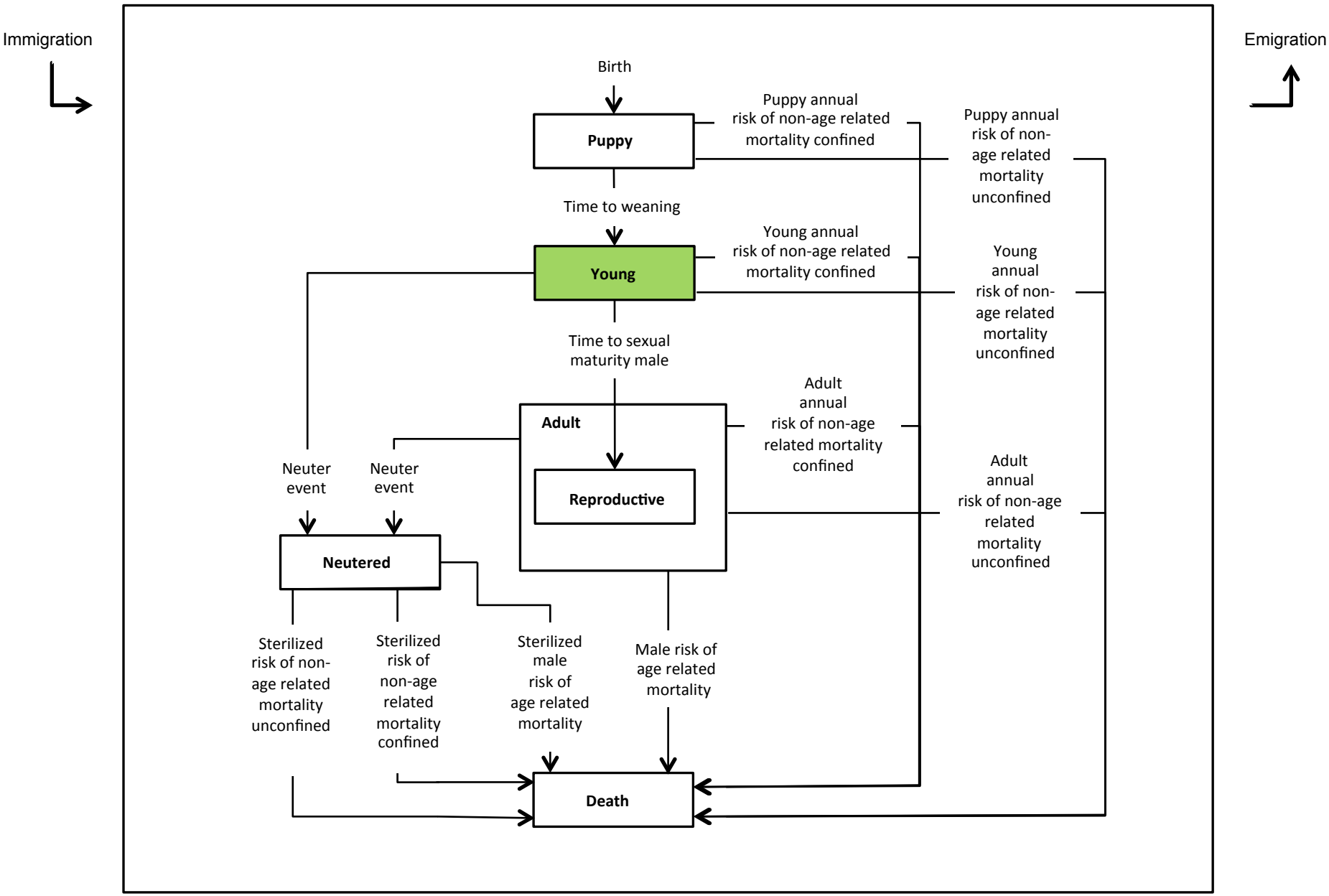

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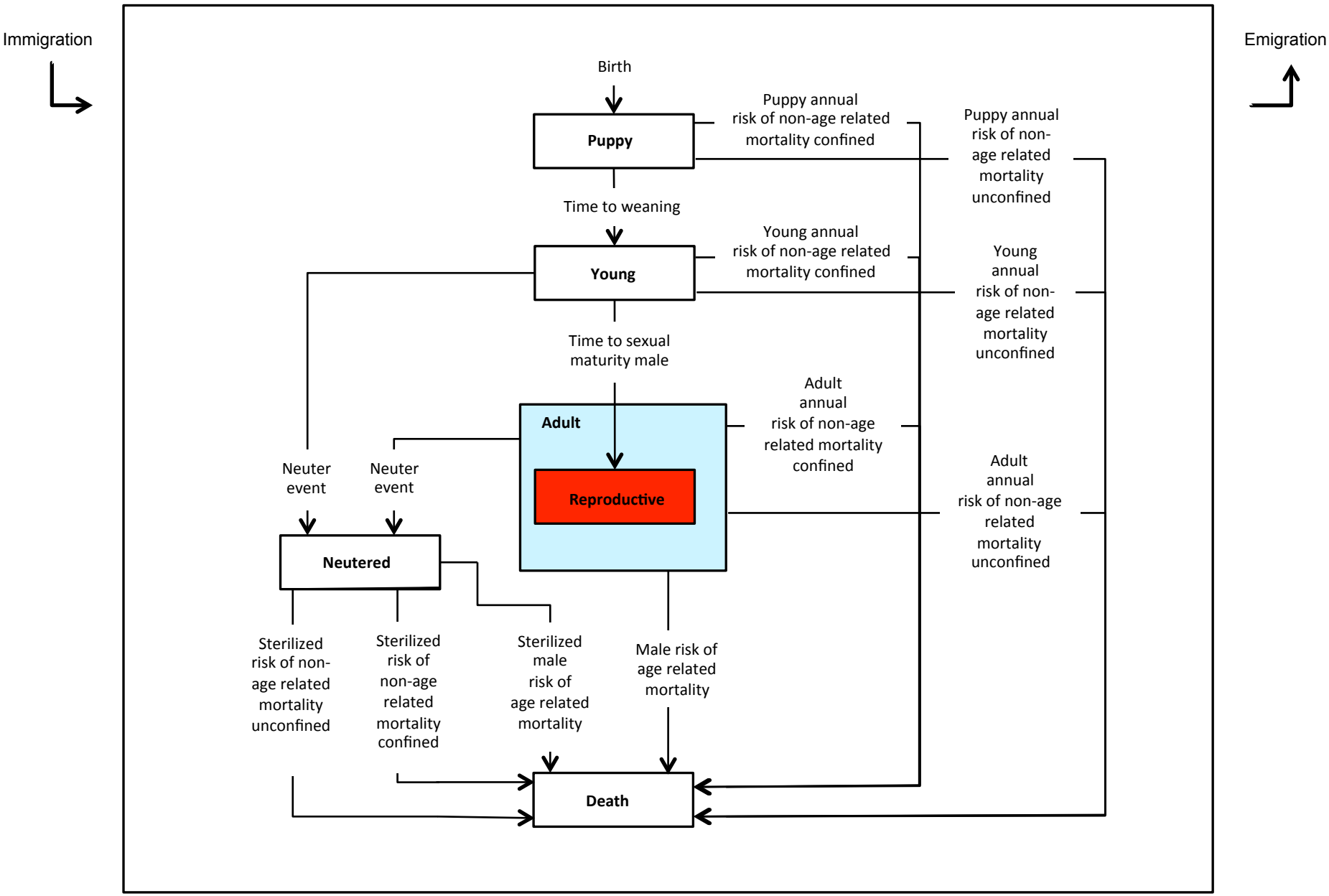

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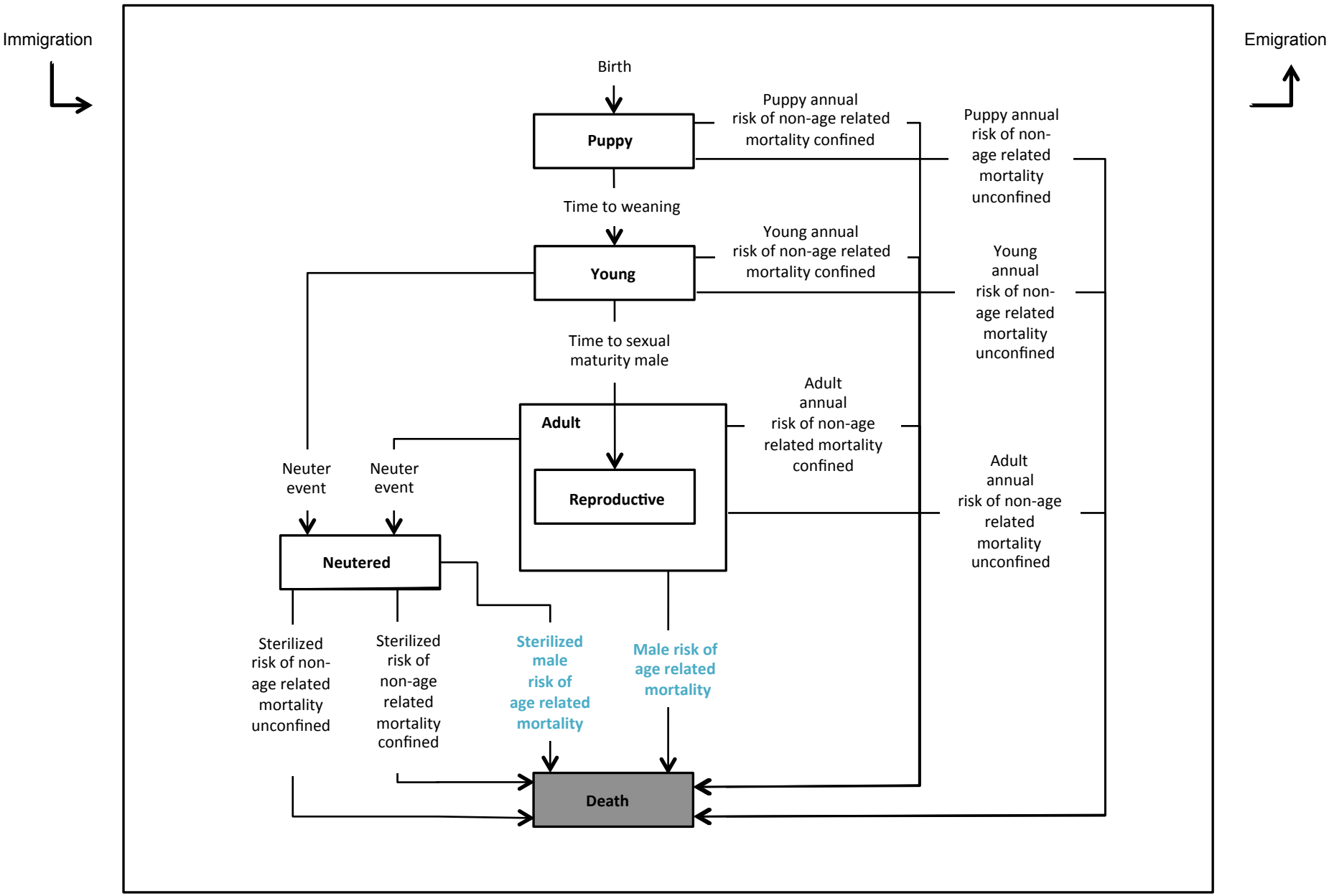

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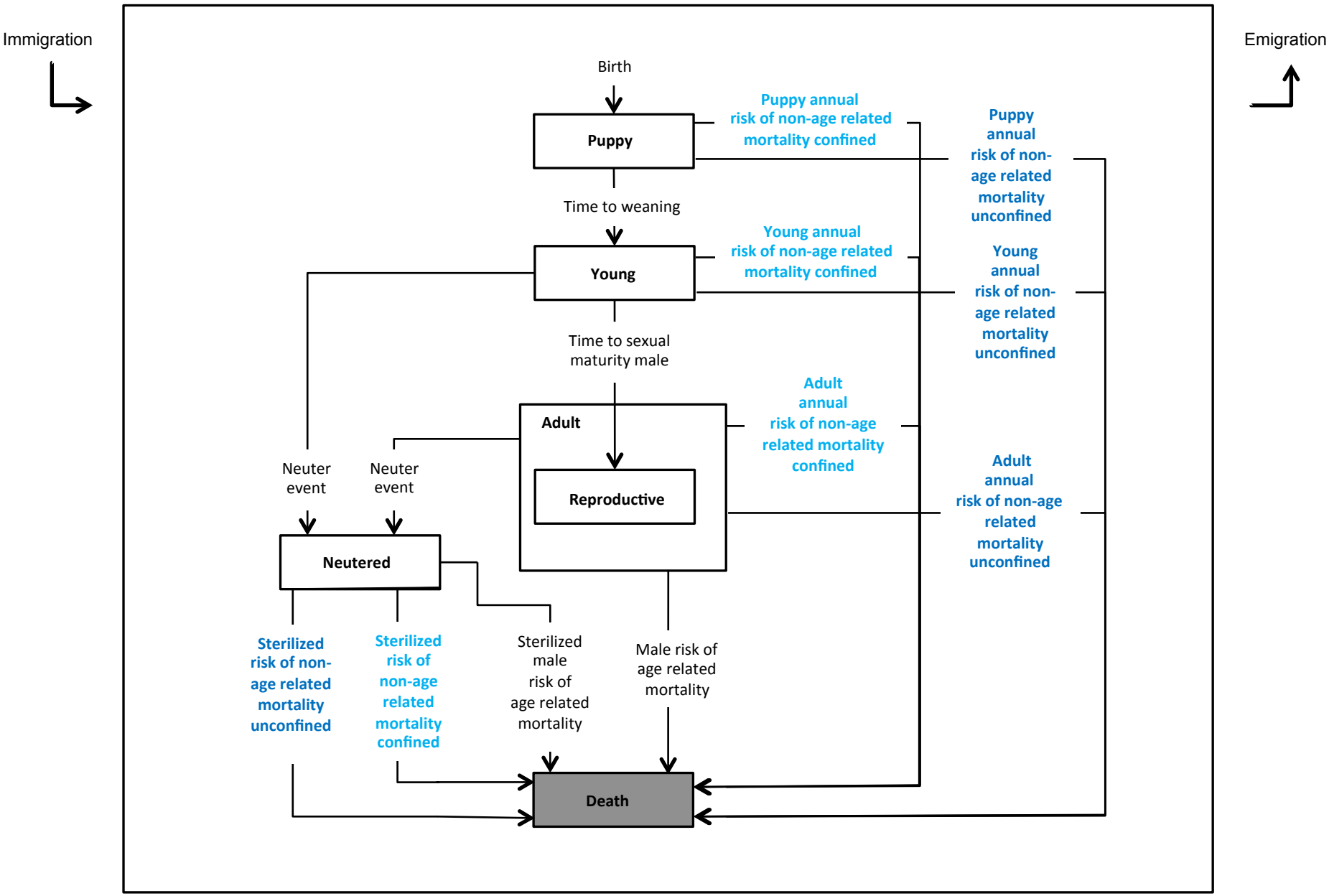

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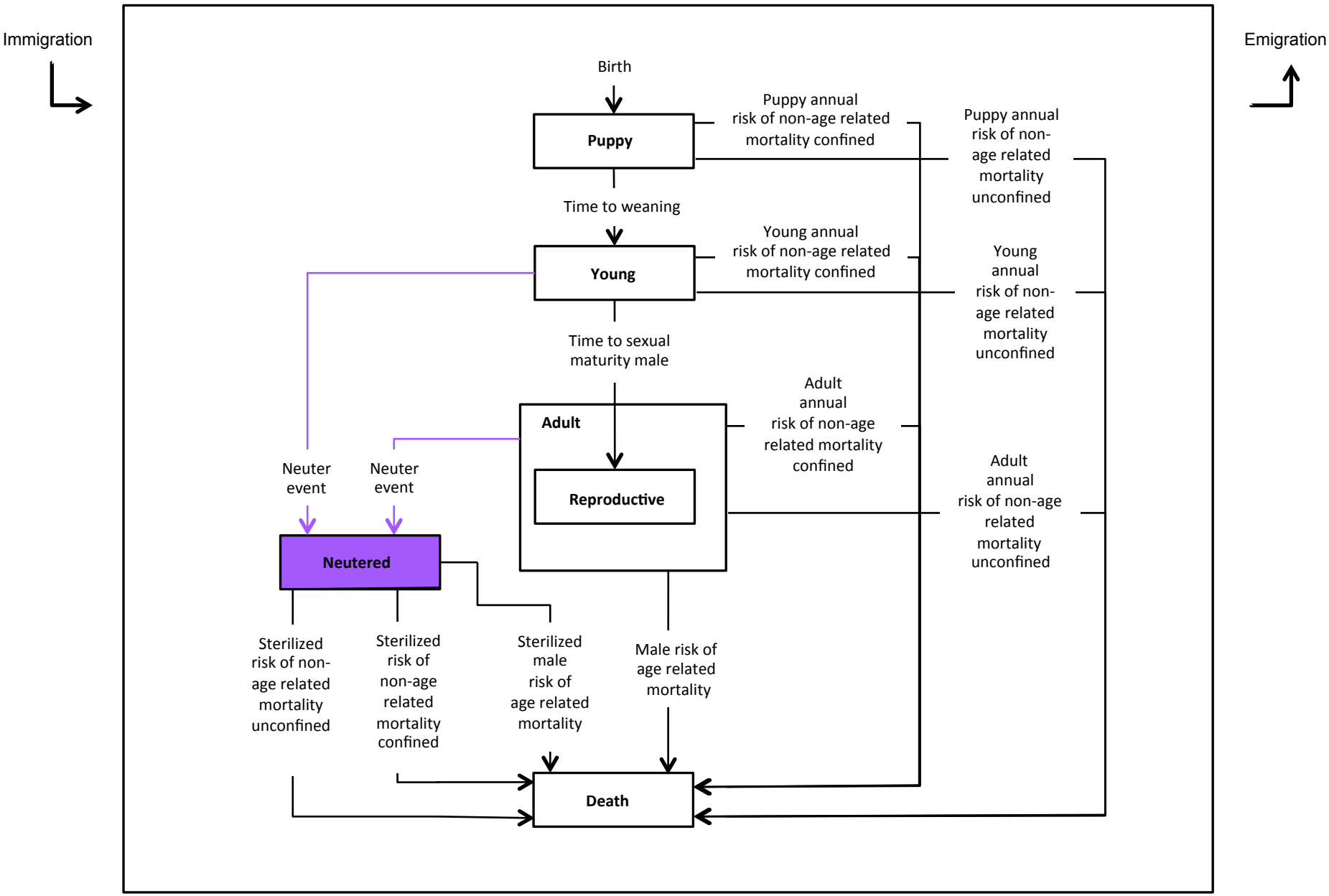
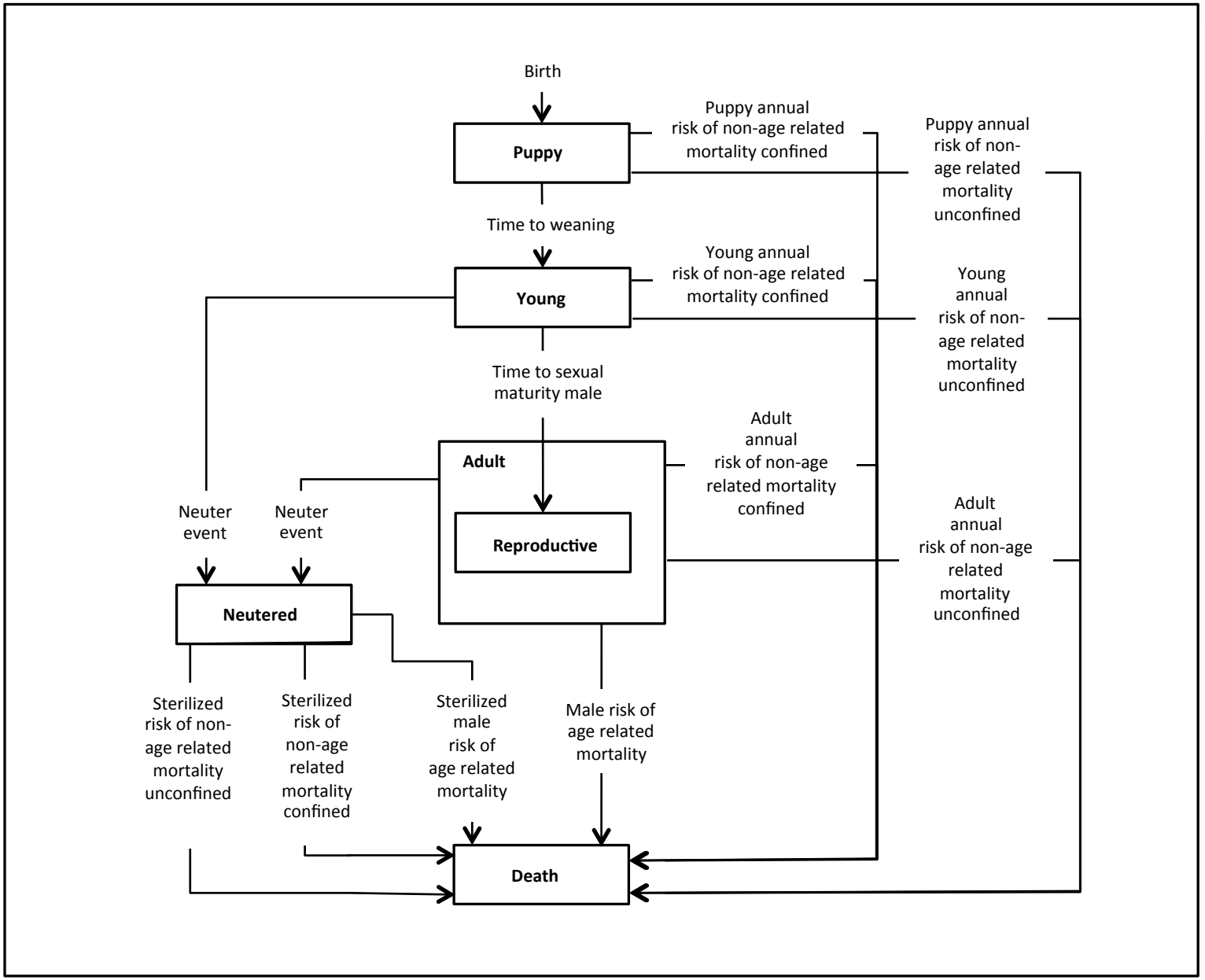


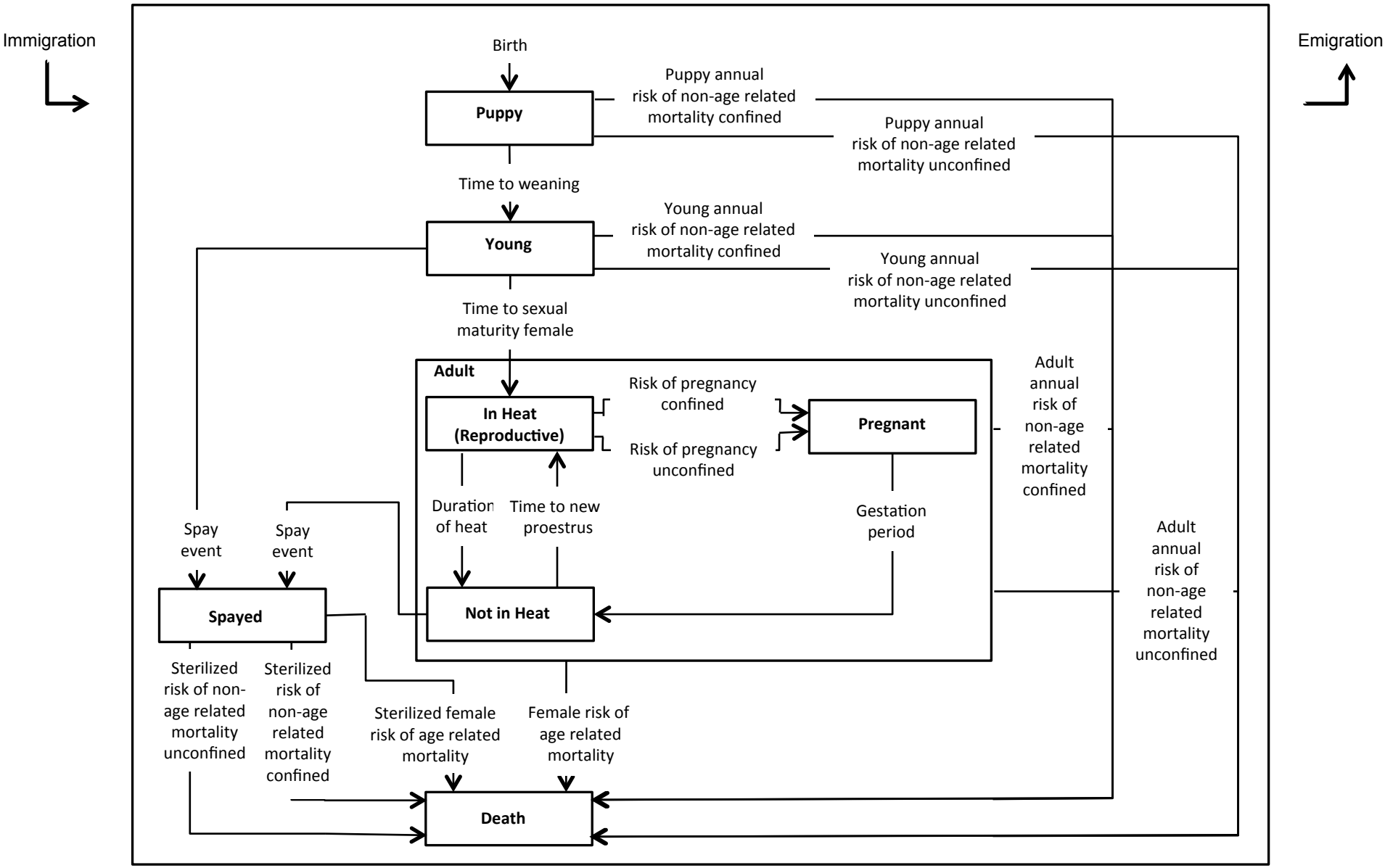
State chart
Life cycle for male dogs

Immigration

Emigration



State chart
Life cycle for female dogs



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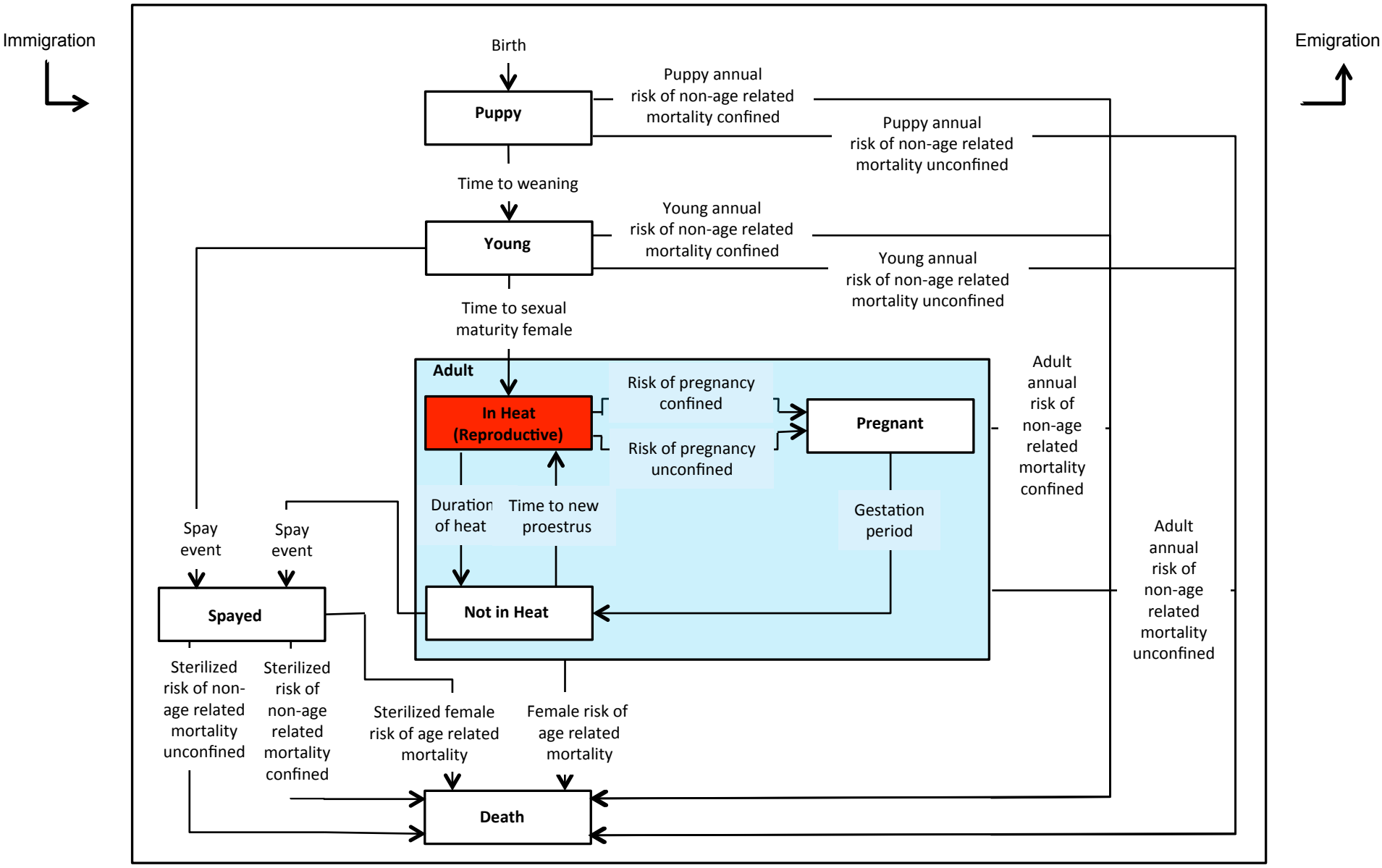

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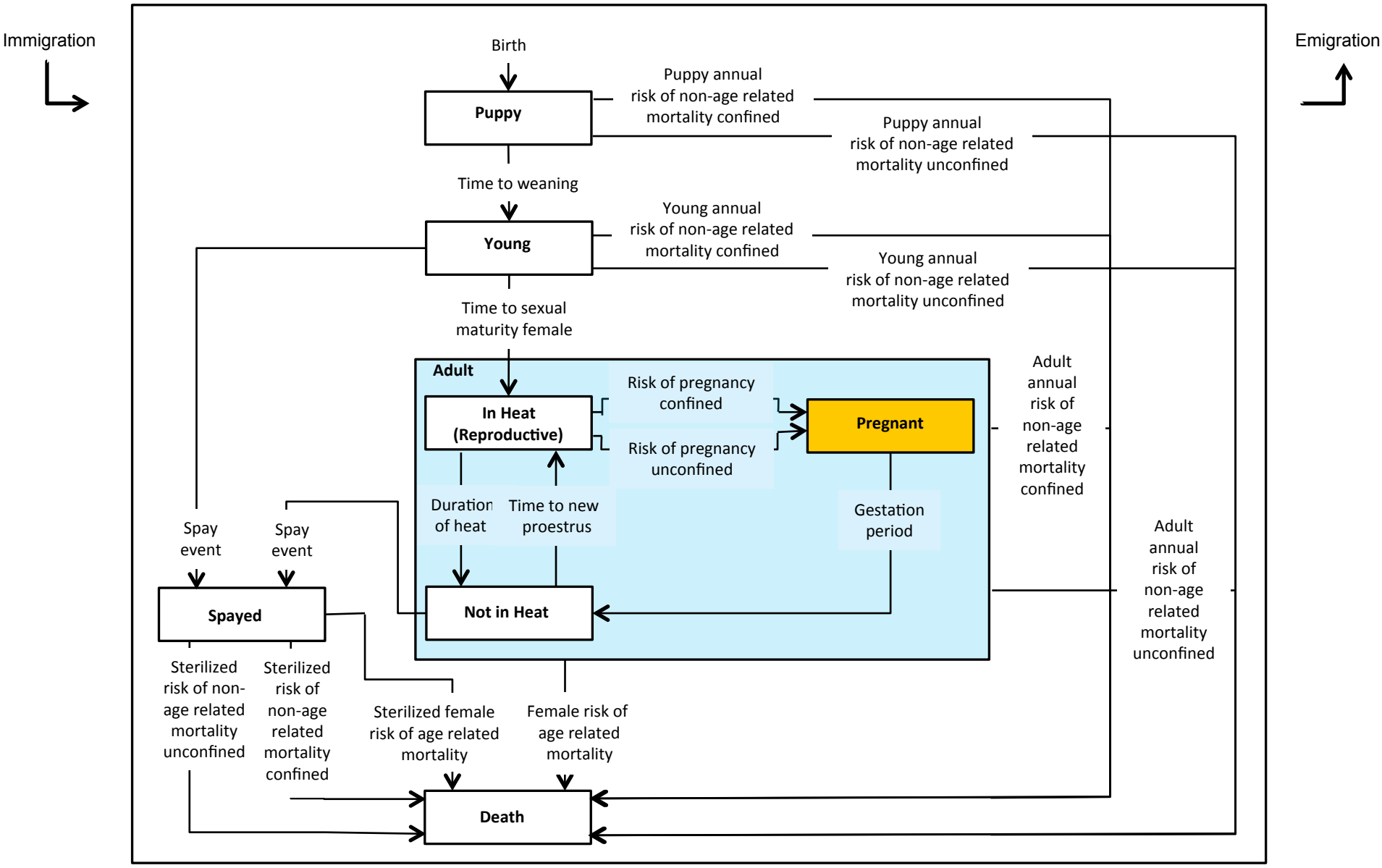

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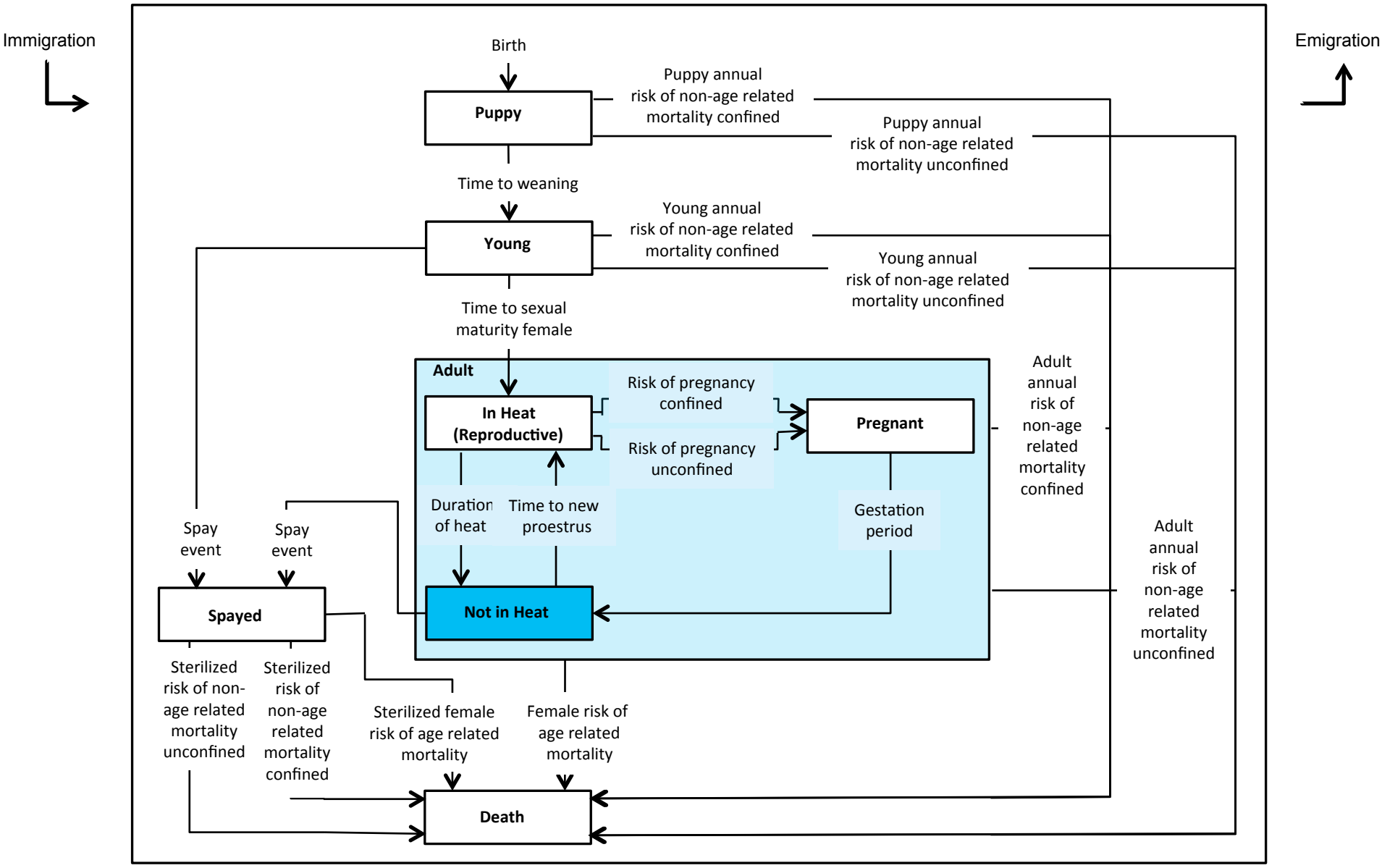

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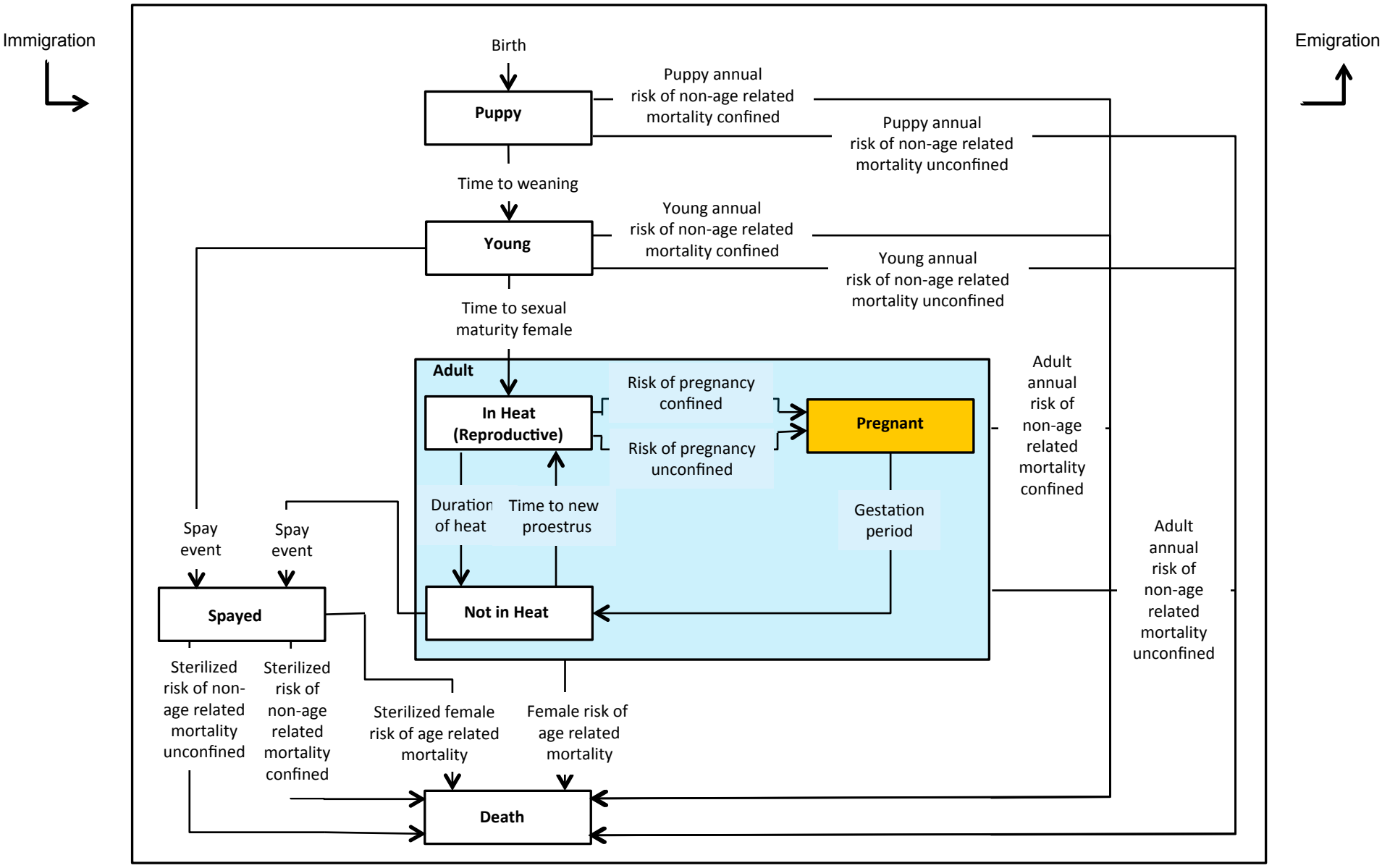

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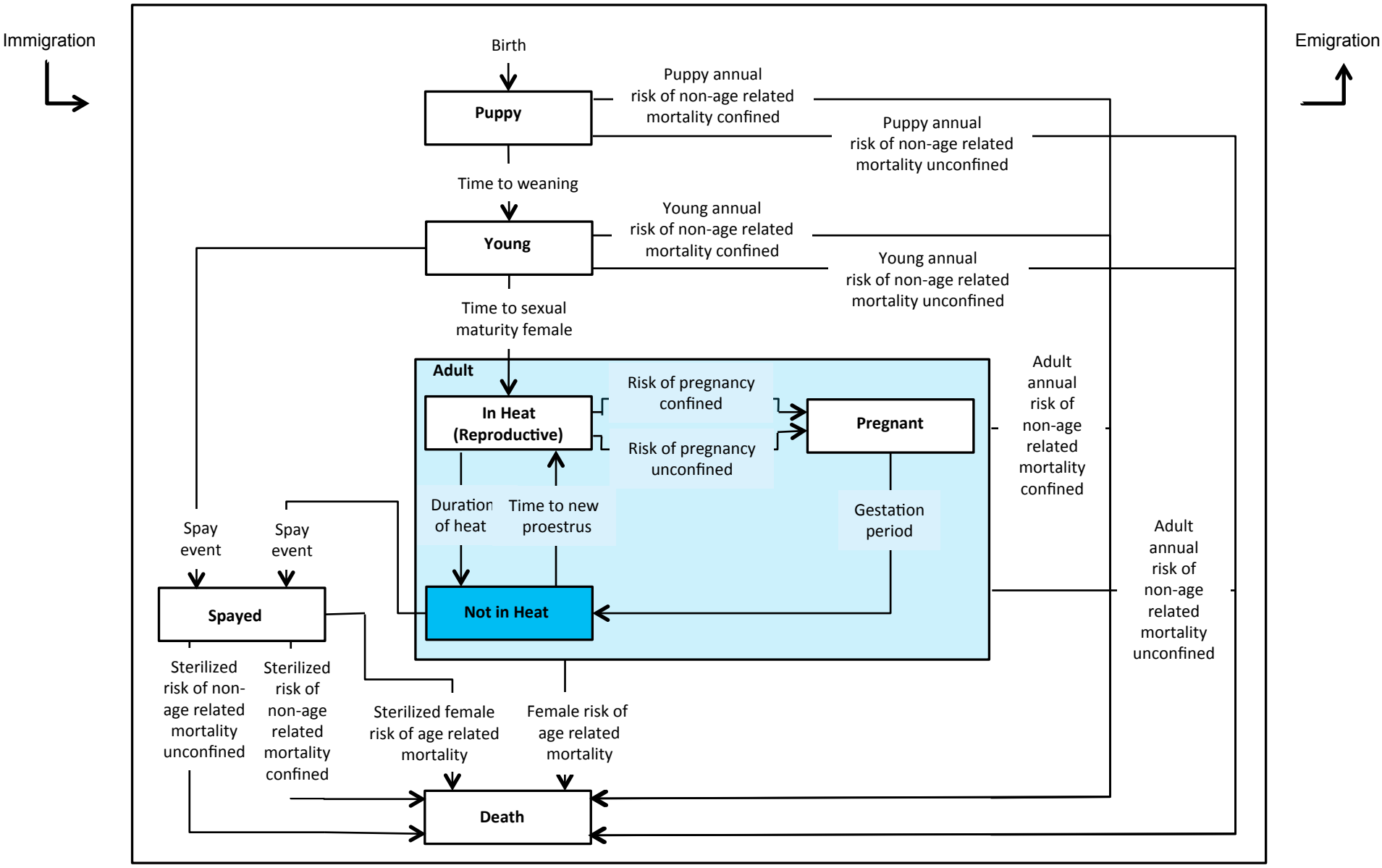

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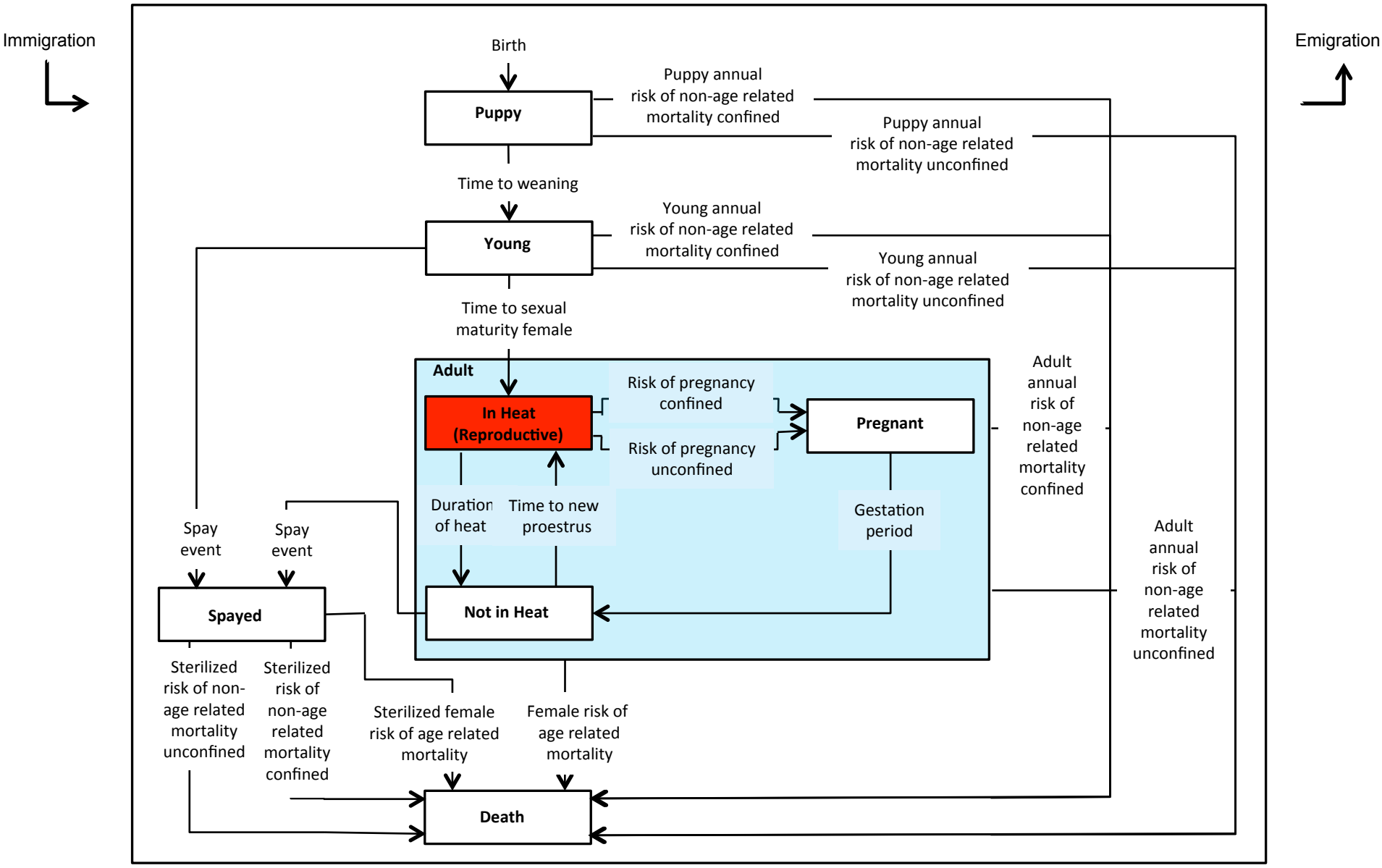

SURGICAL STERILIZATION INTERVENTIONS (4)

- Sex
- Age
- Surgical capacity

SURGICAL STERILIZATION INTERVENTIONS (4)

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

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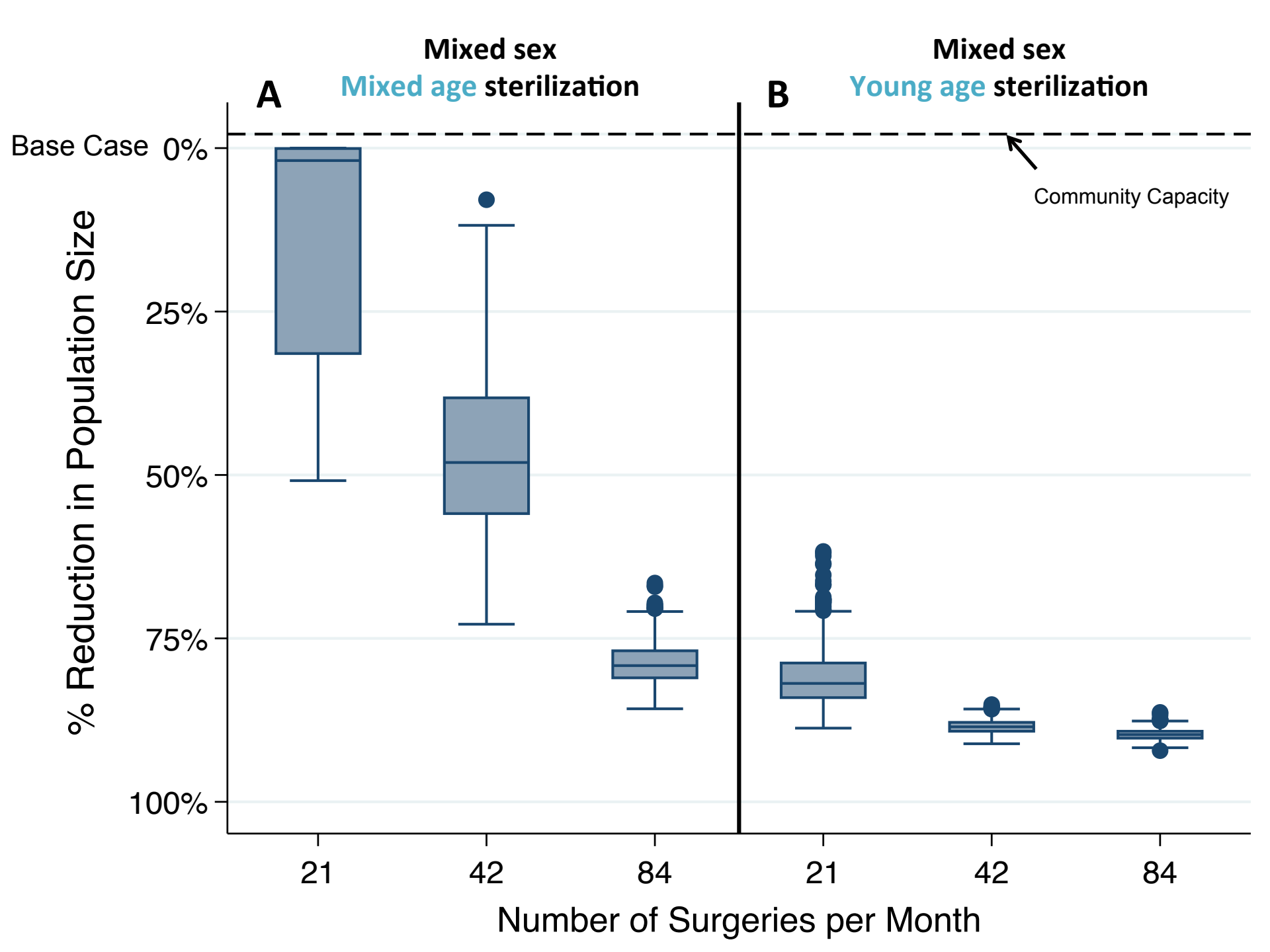
Mixed sex
Mixed age sterilization
A
Mixed sex
Young age sterilization
B
Base Case
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Community Capacity
% Reduction in Population Size
21
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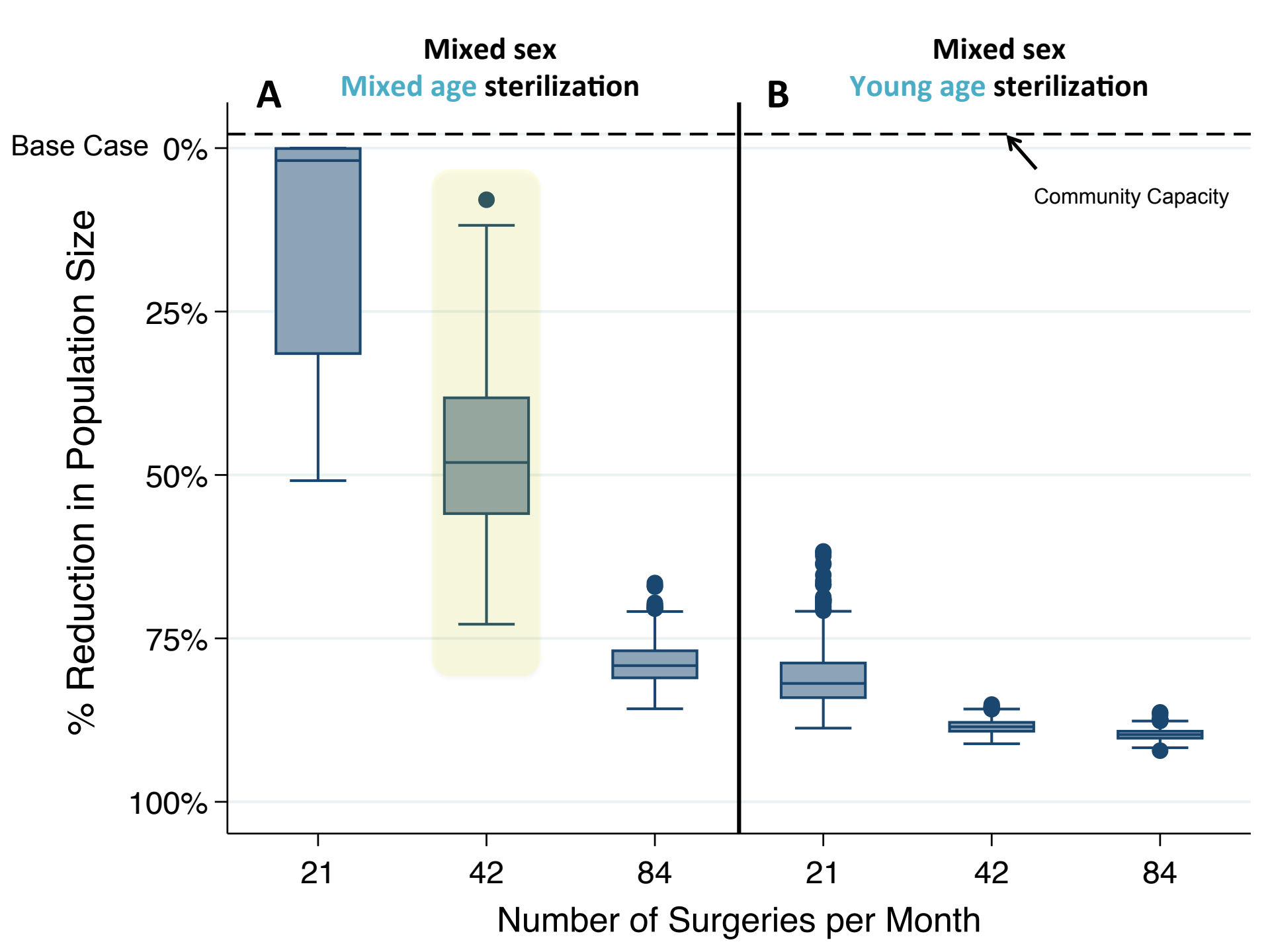
Number of Surgeries per Month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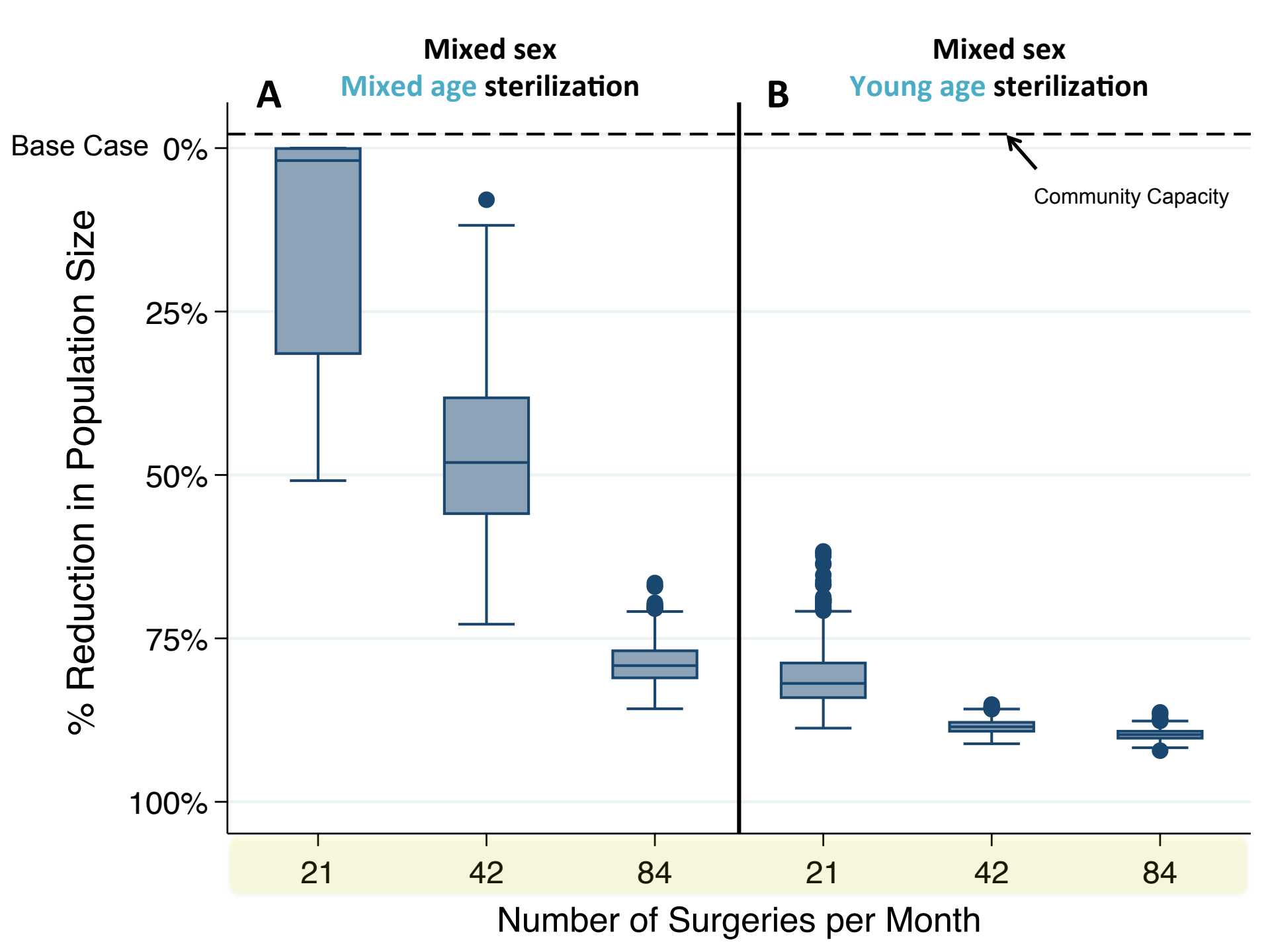
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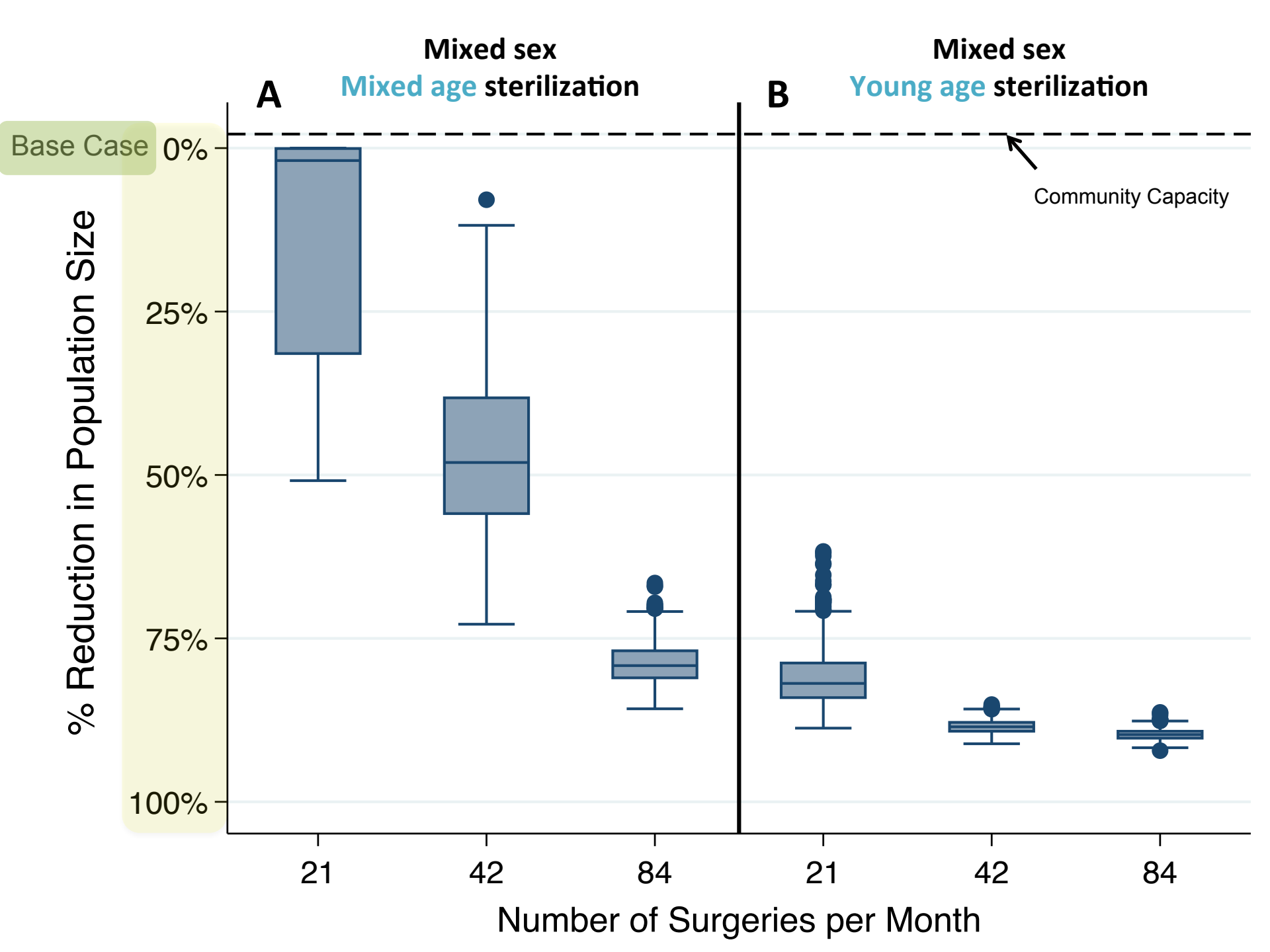
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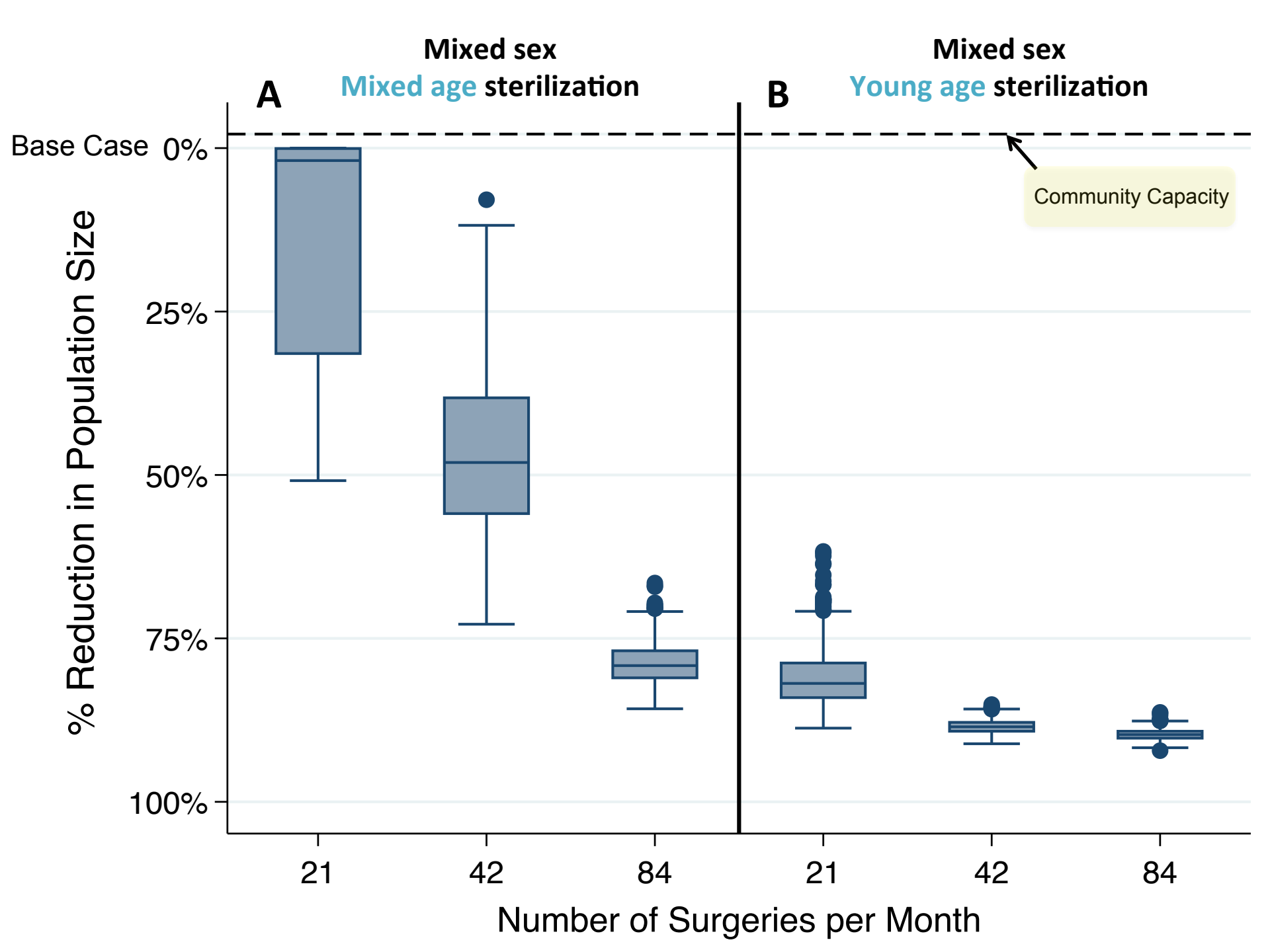
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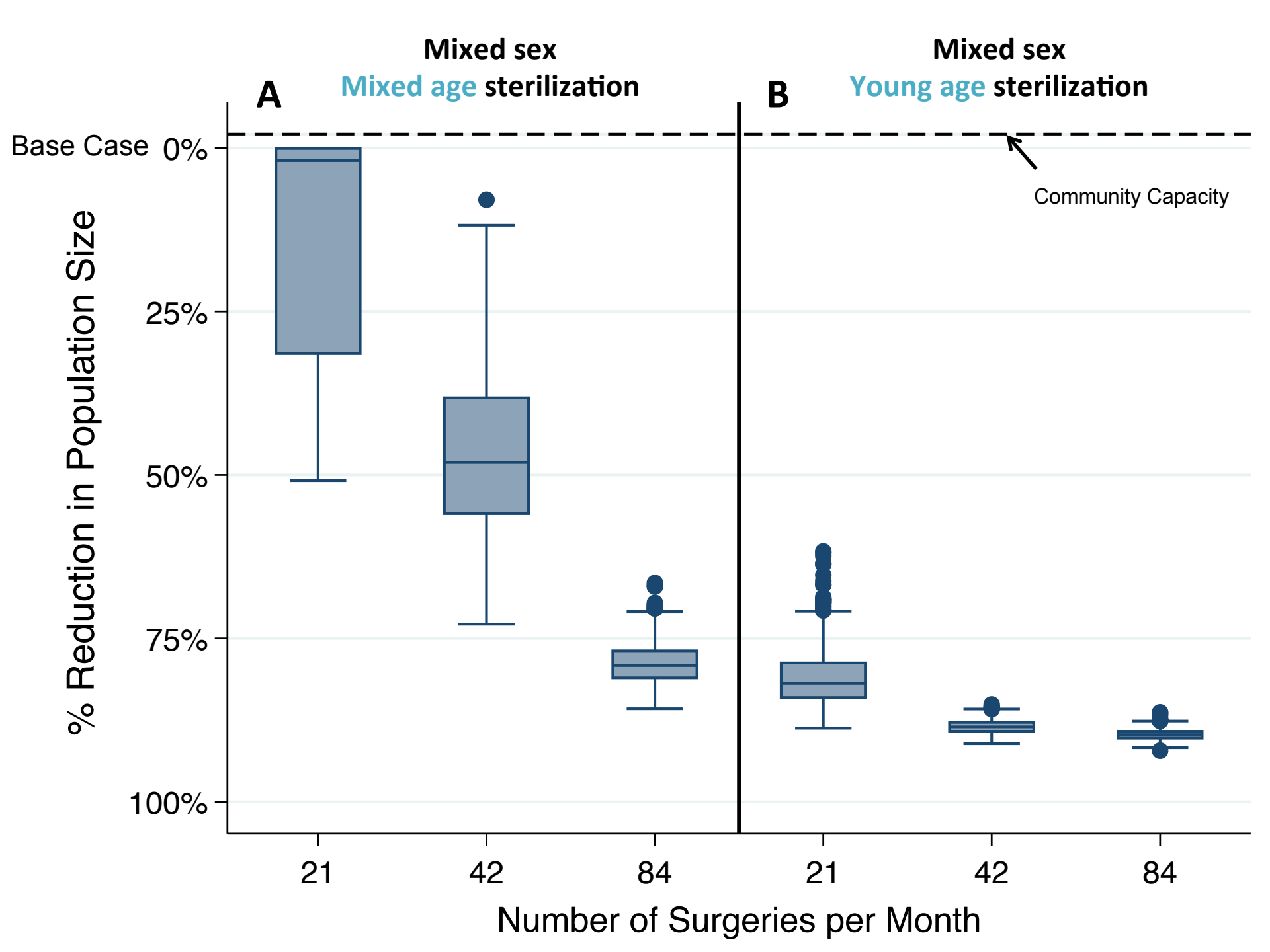
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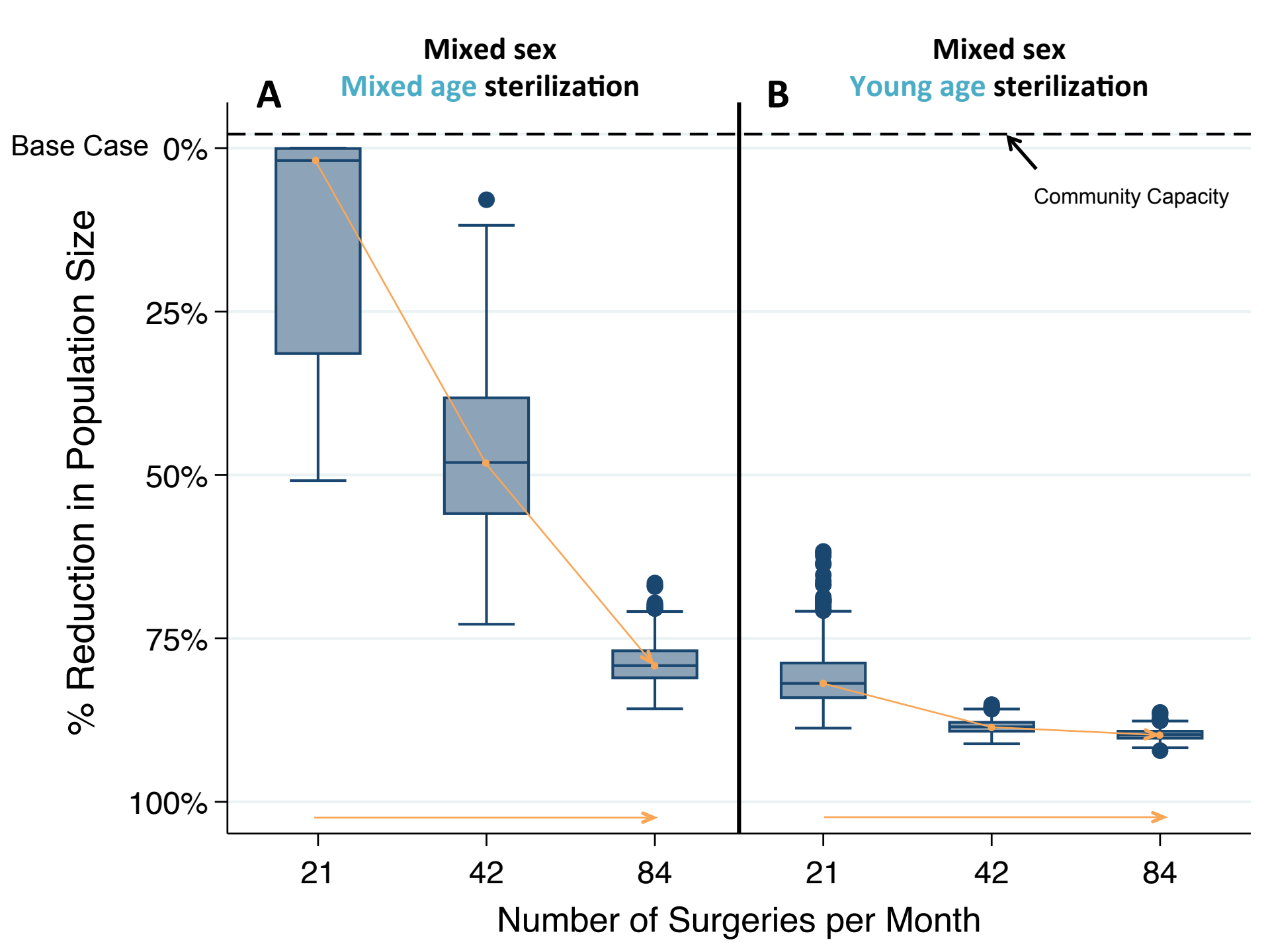
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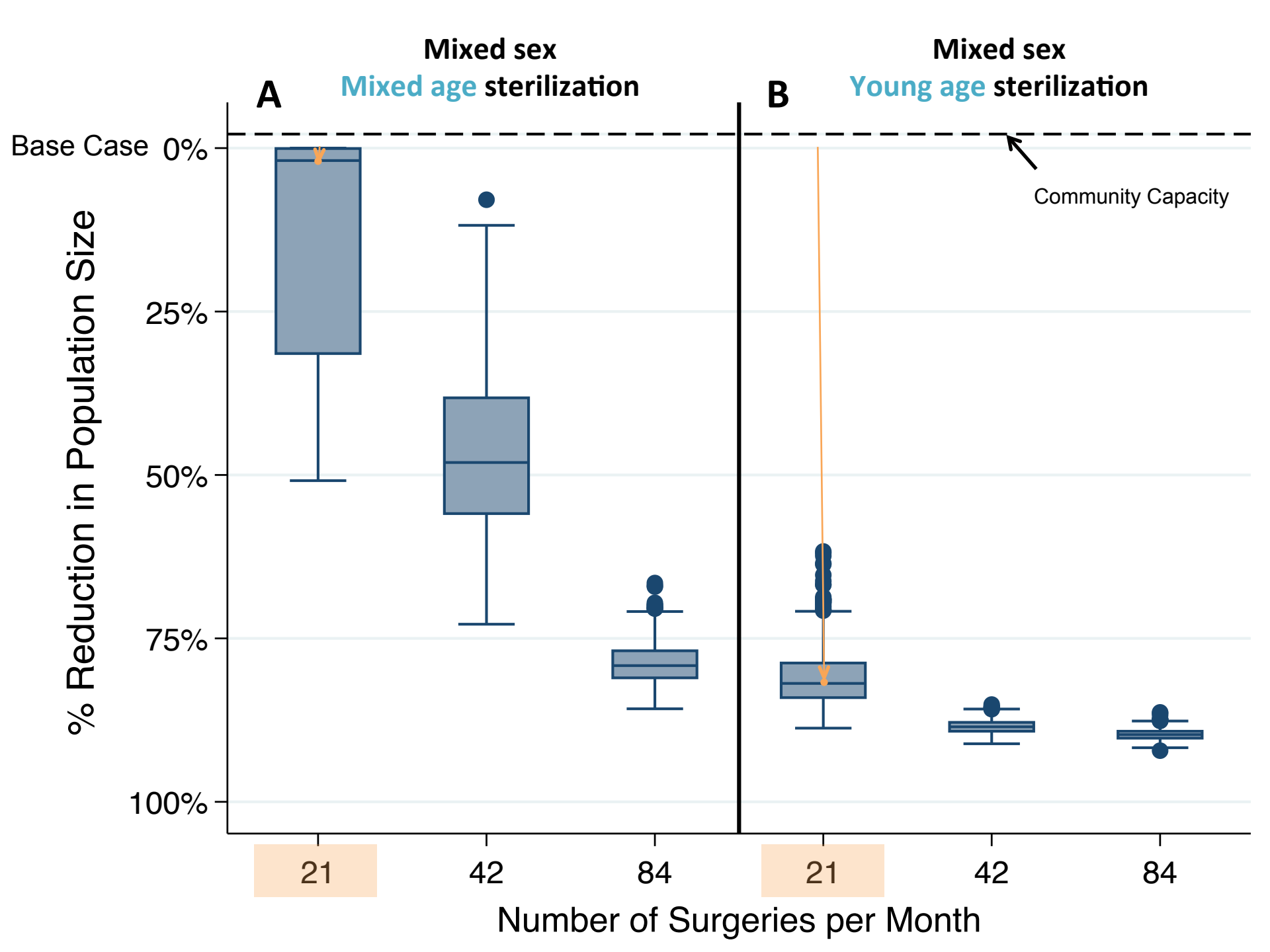
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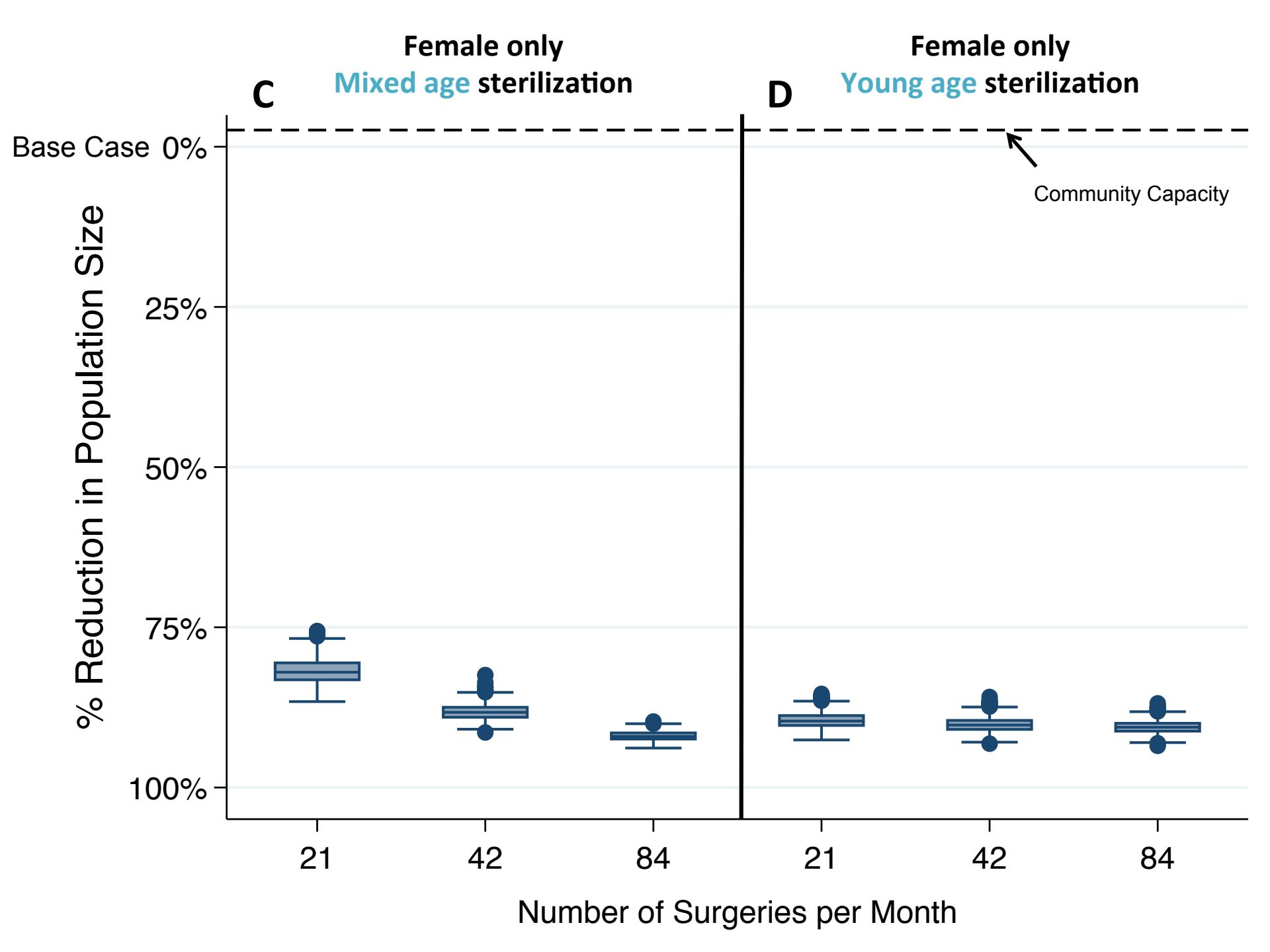
C
Female only
Mixed age sterilization
D
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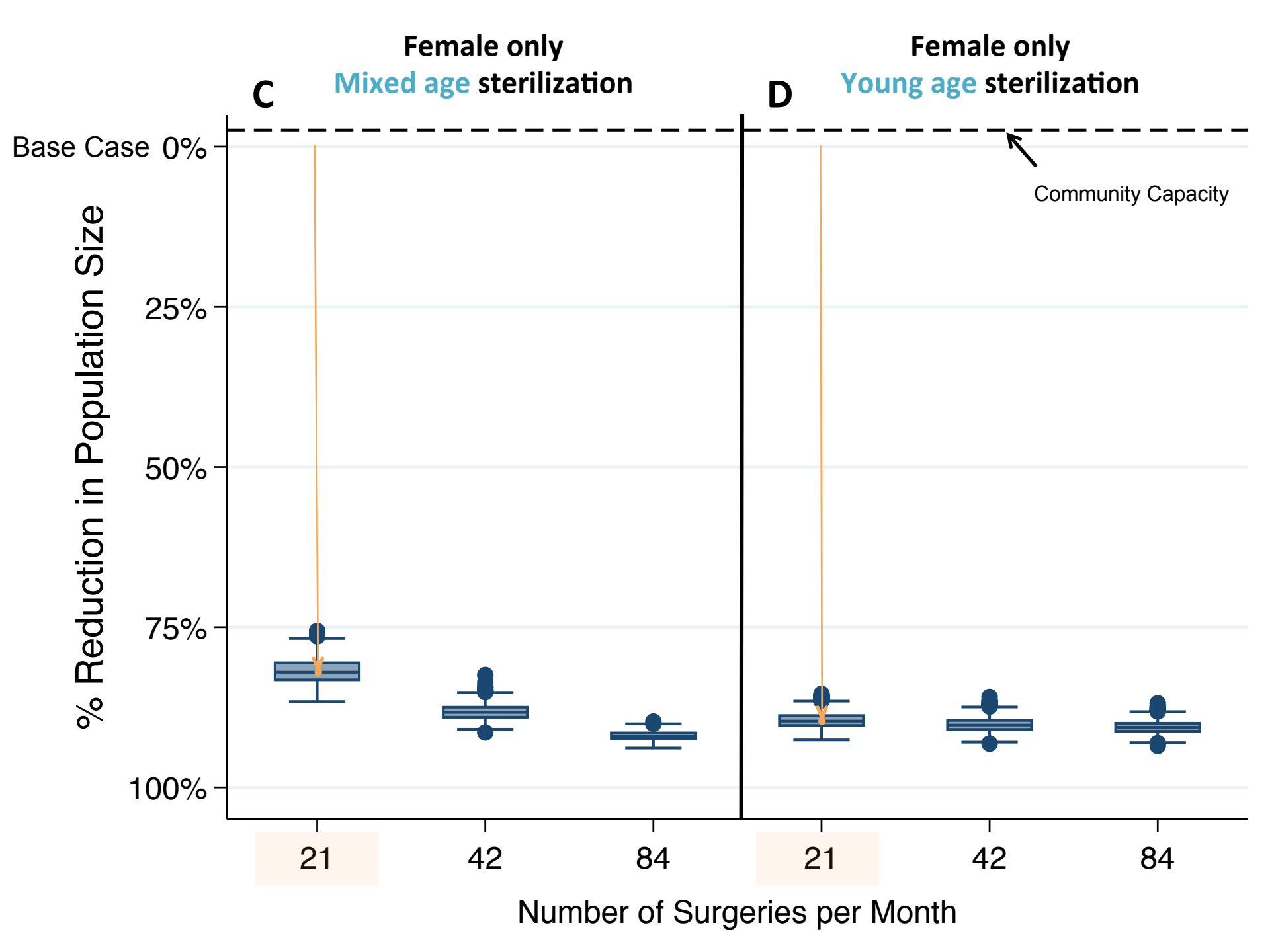
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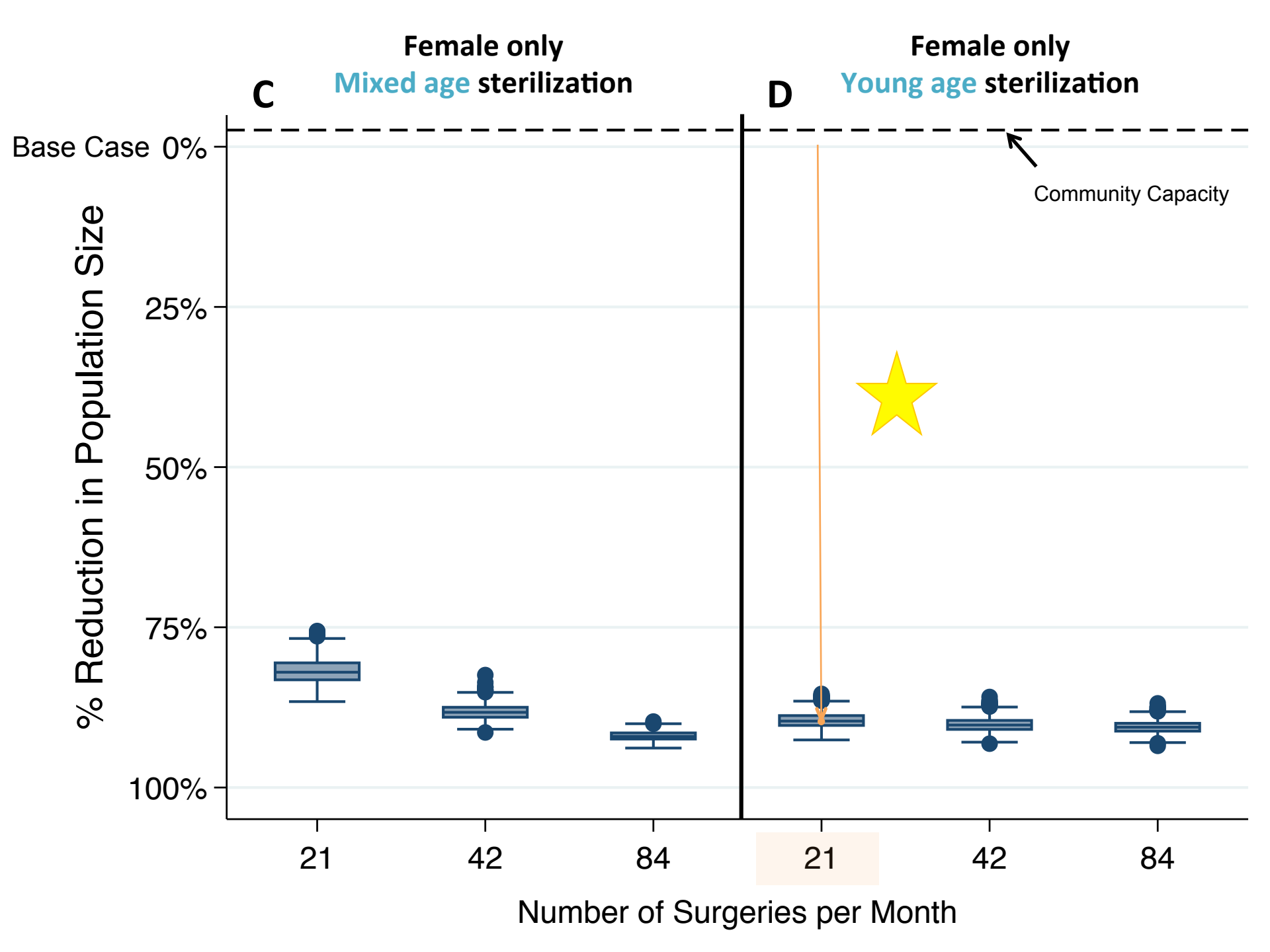
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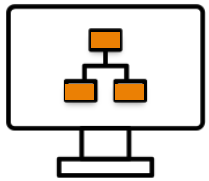
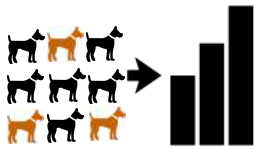
CONCLUSION



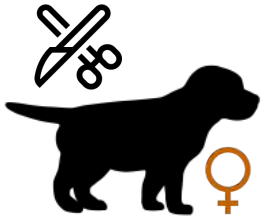
Computer simulation models

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

Kisiel LM, Jones-Bitton A, Sargeant JM, Coe JB, Flockhart DTT, Canales Vargas EJ, et al. (2018) **Modeling the effect of surgical sterilization on owned dog population size in Villa de Tezontepec, Hidalgo, Mexico, using an individual-based computer simulation model.** PLoS ONE 13(6): e0198209.

ACKNOWLEDGEMENTS

- University of Guelph

- Hidalgo Ministry of Health

- MITACS Globalink

- Canada Research Chairs

THANK YOU FOR LISTENING

- Any Questions?

http://v2.elpeninsular.mx/semana-nacional-de-vacunacion-antirrabica-canina-y-felina-2018/

Model initial conditions

Parameter	Values	Reference
GENERAL PARAMETERS		
Proportion of confined dogs	45.00%	Kisiel et al., 2016
FEMALE DOGS INITIAL CONDITIONS		
Population size	1222 dogs	Kisiel et al., 2016
Proportion puppy	4.00%	Kisiel et al., 2018
Proportion young	11.00%	Kisiel et al., 2018
Proportion reproductive	21.00%	Kisiel et al., 2018
Proportion pregnant	6.00%	Kisiel et al., 2018
Proportion not in heat	21.00%	Kisiel et al., 2018
Proportion regular spayed	37.00%	Kisiel et al., 2016

Model initial conditions (Continue)

Parameter	Values	Reference
MALE DOGS INITIAL CONDITIONS		
Population size	1702 dogs	Kisiel et al., 2016
Proportion puppy	6.00%	Kisiel et al., 2016
Proportion young	16.00%	Kisiel et al., 2018
Proportion reproductive	64.00%	Kisiel et al., 2018
Proportion regular neutered	14.00%	Kisiel et al., 2016

Model parameters describing the transition rates and/or times for individual dogs to move between the different model states

Parameter	Value	Distribution (parameter values)	Reference
GENERAL PARAMETERS			
Time to weaning	8 weeks	N/A	Kustritz, 2010
Time to sexual maturity female	Average 6 to 10 months	Uniform (Min. 6 months Max. 10 months)	Kustritz, 2010
Time to sexual maturity male	Average 10 months	N/A	Kustritz, 2010
Puppy annual risk of non-age-related mortality confined	0.10 per year (Sensitivity analysis range from 0.05 to 0.3)	N/A	Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)
Puppy annual risk of non-age-related mortality unconfined	0.20 per year	N/A	Assumption (2 X Puppy annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers' hypothesis)
Young annual risk of non-age-related mortality confined	0.20 per year (Sensitivity analysis range from 0.1 to 0.3)	N/A	Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)
Young annual risk of non-age-related mortality unconfined	0.40 per year	N/A	Assumption (2 X Young annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers' hypothesis)
Adult annual risk of non-age-related mortality confined	0.03 per year (Sensitivity analysis range from 0.015 to 0.075)	N/A	Kisiel et al., 2018 (Sensitivity analysis: Morales and Ibarra 1979; Ibarra et al., 1991; Morales et al., 1992; Ibarra et al., 1997)
Adult annual risk of non-age-related mortality unconfined	0.06 per year	N/A	Assumption (2 X Adult annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers' hypothesis)

Model parameters describing the transition rates and/or times for individual dogs to move between the different model states (Continue)

Parameter	Value	Distribution (parameter values)	Reference
GENERAL PARAMETERS			
Sterilized risk of non-age-related mortality confined	0.027 per year	N/A	Assumption (90.00% of Adult annual risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers' hypothesis)
Sterilized risk of non-age-related mortality unconfined	0.054 per year	N/A	Assumption (2 X Sterilized risk of non-age-related mortality confined) (Sensitivity analysis: based on researchers' hypothesis)
Male risk of age related mortality		Exponential (Min. 0.08 years, Max. 14.00 years, Skewness 2.27 and Kurtosis 10.24)	Kisiel et al., 2018
Female risk of age related mortality		Exponential (Min. 0.50 years, Max. 12.00 years, Skewness 1.58 and Kurtosis 5.13)	Kisiel et al., 2018
Sterilized male risk of age related mortality		Exponential (Min. 0.88 years, Max. 15.40 years, Skewness 2.27 and Kurtosis 10.24)	Assumption (90.00% of Male age-related mortality) (Sensitivity analysis: based on researchers' hypothesis)
Sterilized female risk of age related mortality		Exponential (Min. 0.55 years, Max. 13.20 years, Skewness 1.58 and Kurtosis 5.13)	Assumption (90.00% Female age-related mortality) (Sensitivity analysis: based on researchers' hypothesis)

Model parameters describing the transition rates and/or times for individual dogs to move between the different model states (Continue)

Parameter	Value	Distribution (parameter values)	Reference
FEMALE DOG ONLY PARAMETERS			
Duration of heat	18 days (Proestrus Average 9 days + Estrus Average 9 days)	N/A	(Kustritz, 2010, Kustritz, 2012)
Gestation duration	65 days	N/A	Kutzler, 2010
Time to New proestrus	Average 7 months	N/A	Kustritz, 2010
Litter size	4 puppies	N/A	Kisiel et al., 2016
Risk of pregnancy confined	0.26 per year (Sensitivity analysis range from 0.10 to 0.40)	N/A	Kisiel et al., 2016 (Sensitivity analysis: based on researchers hypothesis)
Risk of pregnancy unconfined	0.52 per year	N/A	Assumption (2 X risk of pregnancy confined) (Sensitivity analysis: based on researchers' hypothesis)
POPULATION PARAMETERS			
Annual probability of immigration	0.23 per year	N/A	Kisiel et al., 2018
Annual probability of emigration	0.04 per year	N/A	Kisiel et al., 2018
Community capacity	2924 dogs	N/A	Kisiel et al., 2016

Minimum, maximum, mean, standard deviation and total number of owned dogs in the young, pregnant, and adult age group categories

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

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

Age Group	Total # of Owned Dogs # (%)	Owned Dogs Median Age (range)	Owned Dogs Mean Age (SD)	Skewness	Kurtosis
Female > 1 year old	72 (41.62)	3.00 (1.5 – 13.00)	3.87 (SD = 2.56)	1.59	5.14
Males > 1 year old	101 (58.38)	3.00 (1.08 – 15.00)	3.70 (SD = 2.30)	2.27	10.24
Total	**173 (100.00)**	**3.00 (1.08 – 15.00)**	**3.77 (SD = 2.41)**	**1.95**	**7.64**

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

Category	Total per Category # (%)	Percentage from Total Population[a]
Number of dogs purchased outside the population	39 (40.21)	9.11 (39/428)
Number of dogs that were a gift from outside the population	58 (59.79)	13.55 (58/428)
Total number of dog that came from outside the population	**97 (100.00)**	**22.66 (97/428)**
Number of dogs given away	9 (50.00)	2.10 (9/428)
Number of dogs sold away	9 (50.00)	2.10 (9/428)
Total number of dog that left the population	**18 (100.00)**	**4.21 (9/428)**

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

Age Group	Total # of Owned Dogs that Died in the Past 12 Months # (%)	Total # of Owned Dogs per Age Group[a]	Percentage from Total Population per age group
Puppies	2 (8.70)	21	9.52 (2/21)
Young	13 (56.52)	80	16.25 (13/80)
Adult[b]	8 (34.78)	294	2.72 (8/294)
Total	**23 (100.00)**	**395**	**5.82 (23/395)**

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 2015[a]

Category	Total # of Female Owned Dogs that got Pregnant in the Past 12 Months per Category	Percentage of Female Owned Dogs per category
Always Confined	13	38.24 (13/34)
Partially Confined	21	61.76 (21/34)
Total	**34**	**100.00 (34/34)**

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.

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