# MAXIMIZING THE EFFECTIVENESS OF FERAL CAT CONTROL THROUGH WITHIN-YEAR DISTRIBUTION OF CAPTURE EFFORTS


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# BACKGROUND

- Feral cats pose significant risk to native wildlife, human health, and the health of other domestic animals
- Multiple methods are suggested to control feral cat populations (lethal control or removal, trap-neuter-release, and less commonly, trap vasectomy/ hysterectomy release).
- Appropriate use of finite resources is critical

# HYPOTHESIS

- Cats in temperate zones are seasonal breeders, so time of year a control program is applied will have different effects on population size.

# METHODS

- Individual-based stochastic simulation model previously used to compare the effectiveness of each method of control (McCarthy, R.J., Reed, J.M., Levine, S.H., (2013). Estimation of effectiveness of three methods or feral cat population control by use of a simulation model. *JAVMA, 243(4).*)

# VITAL RATE PARAMETERS

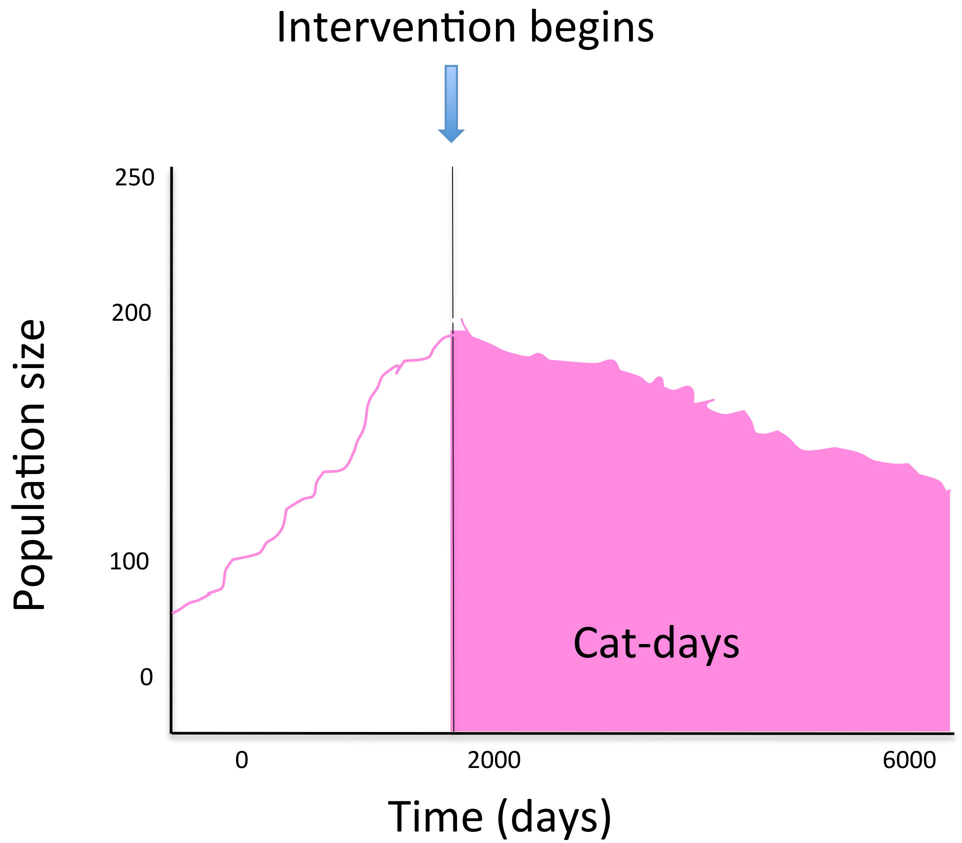
- In a population of cats undergoing control there are many different classes of cat each with a different likelihood of daily survival
  - Predicted daily survival of kittens less than adults
  - Predicted daily survival increases after neutering
  - Predicted daily survival of kittens and young juveniles increases as a greater % of the entire population is neutered (Gunther I, Finkler H, Terkel J. *J Am Vet Med Assoc* 2011;238:1134-1140)
    - 32% of kittens survive to 6 months of age in colonies with no intervention
    - 76% of kittens survive to 6 months of age in matched colonies after 75% are neutered
    - b=0 is no effect, b=0.6 is a moderate effect
- Density dependent effects
  - Predicted daily survival of an individual decreases as the population nears the carrying capacity

# MODEL INPUT

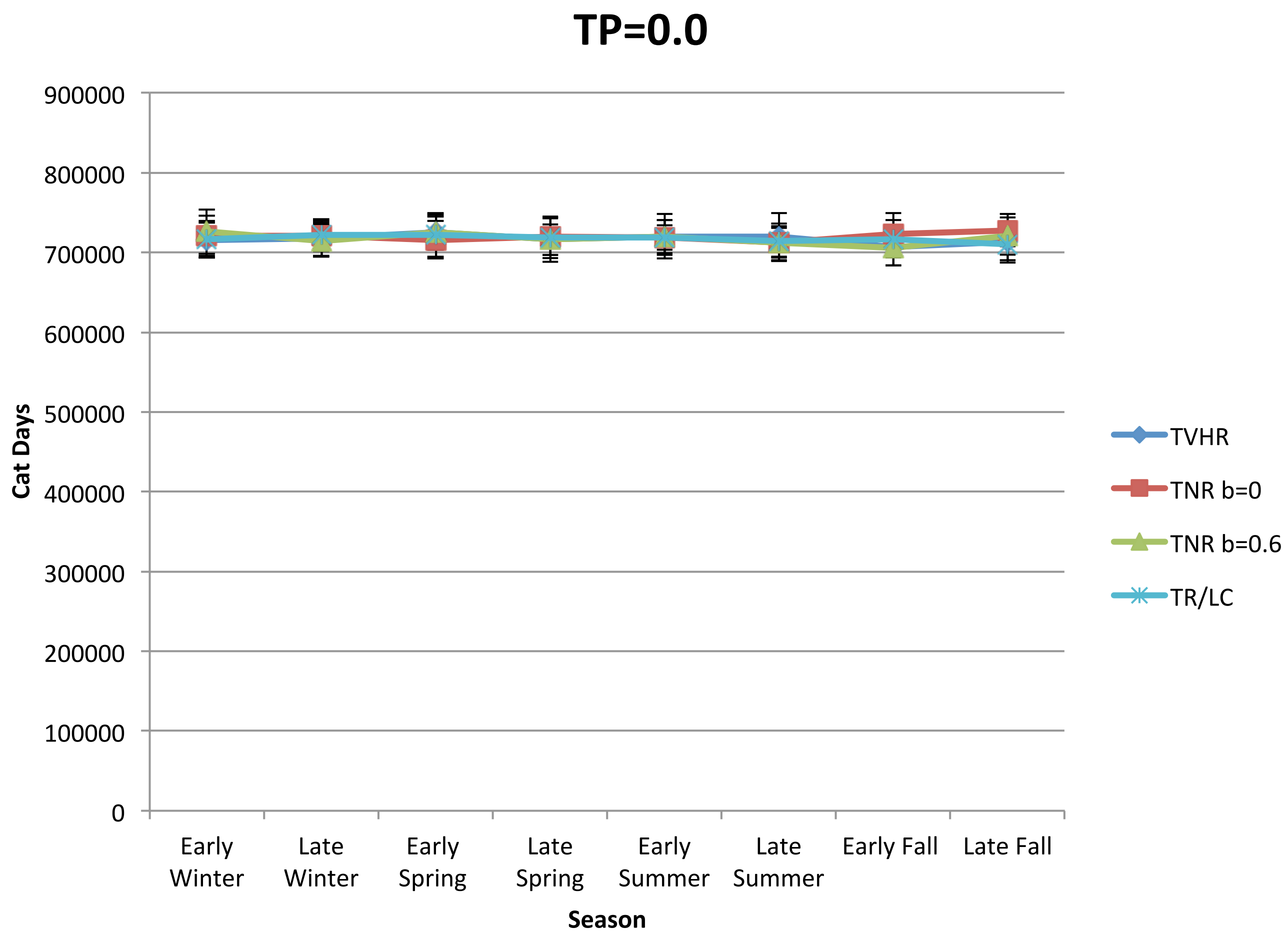
| Parameter | Value |
|---|---|
| | |
| Population size | 200 cats |
| Number days simulated | 6000 |
| Intervention day | 2000 |
| Consecutive trapping days | 30 |
| Annual trapping program frequency | 1 |
| Annual trapping probability | 0%, 19%, 35%, 57%, 82%, 97% |
| Seasonality | Early winter, late winter, early spring, late spring, early summer, late summer, early fall, late fall |
| Immigration/emigration | No |
| Management method | TNR, TR/LC, TVHR |
| Treatment of pregnant and pseudopregnant cats | No |
| “b” for TNR | 0, 0.6 |
| Treatment of kittens | Begins at 42 days of age |

# MODEL OUTPUT

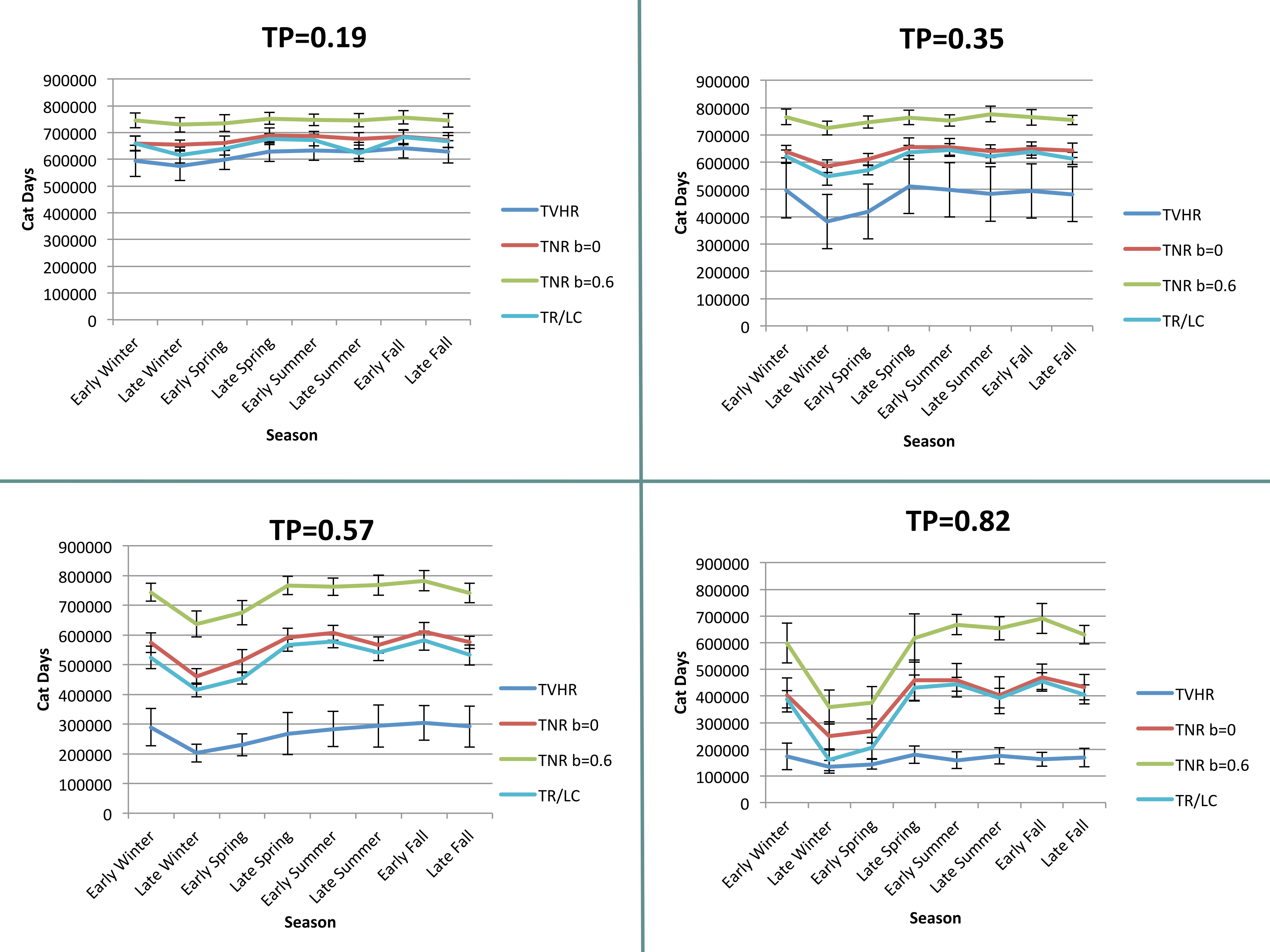
- Outcome measure defined as "cat days" (environmental impact)

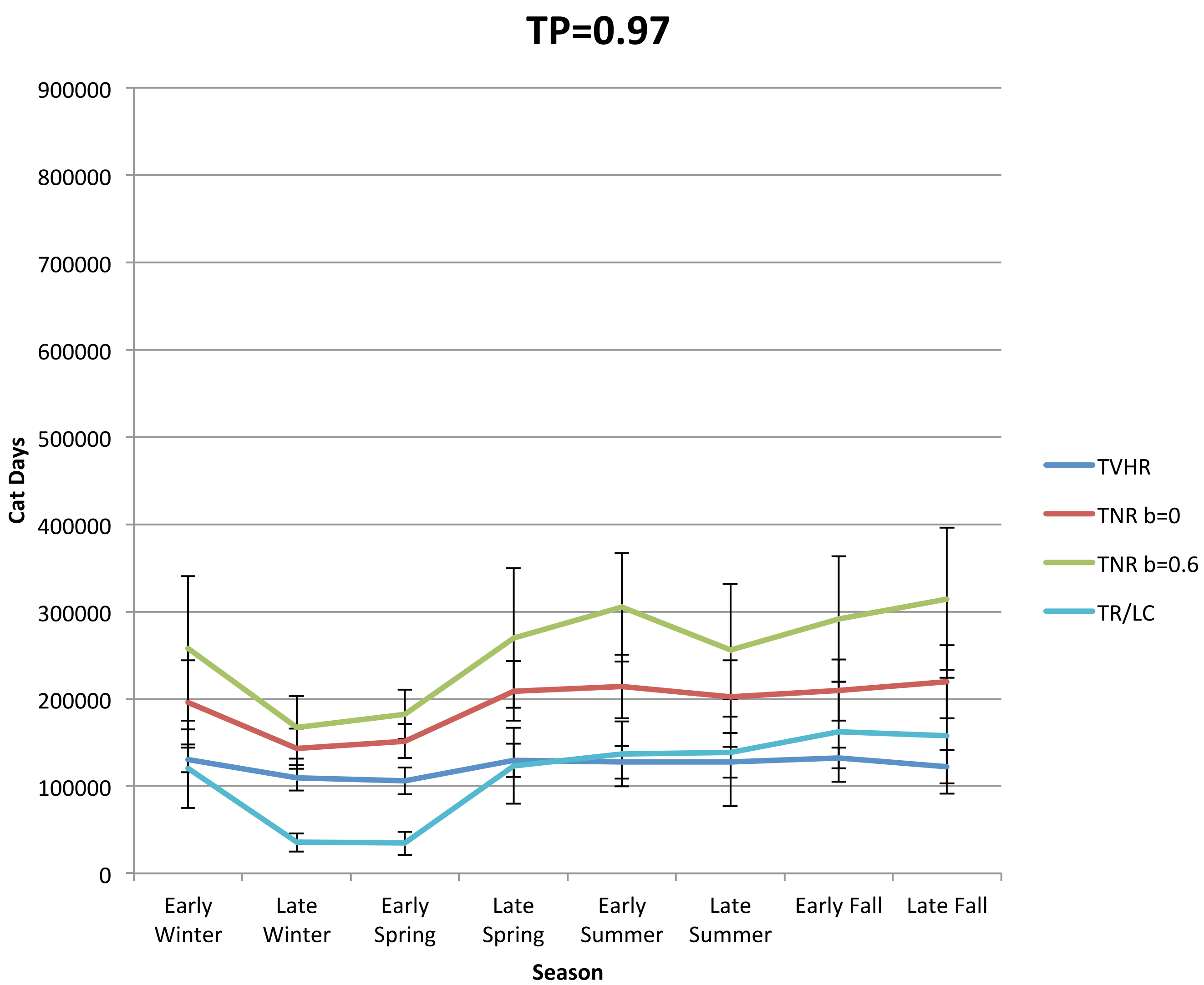


# RESULTS



TP=0.0
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Cat Days
Early Winter
Late Winter
Early Spring
Late Spring
Early Summer
Late Summer
Early Fall
Late Fall
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC


TP=0.19
Cat Days
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Early Winter
Late Winter
Early Spring
Late Spring
Early Summer
Late Summer
Early Fall
Late Fall
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC
TP=0.35
Cat Days
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC
TP=0.57
Cat Days
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC
TP=0.82
Cat Days
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC



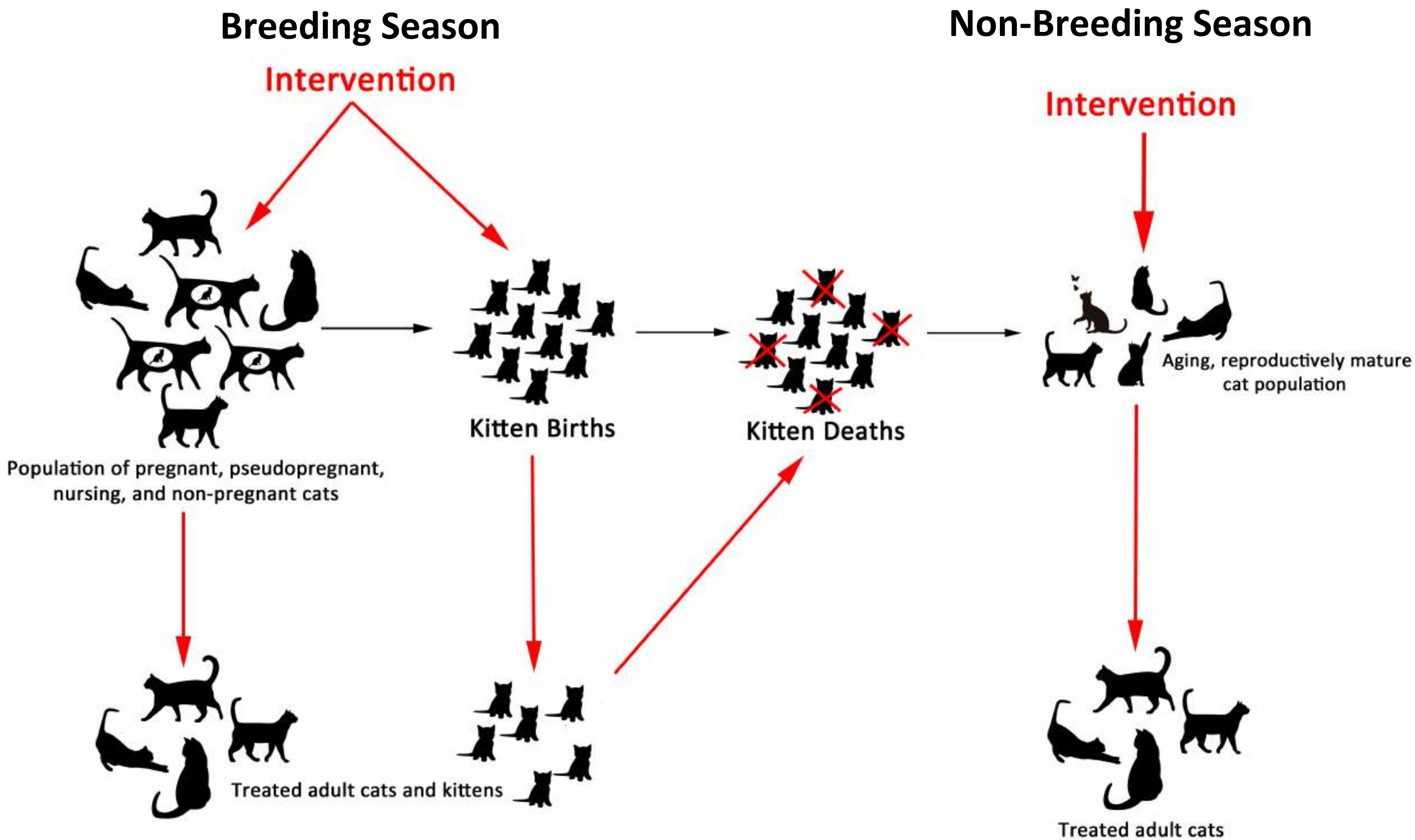
TP=0.97
Cat Days
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
Early Winter
Late Winter
Early Spring
Late Spring
Early Summer
Late Summer
Early Fall
Late Fall
Season
TVHR
TNR b=0
TNR b=0.6
TR/LC

# DISCUSSION

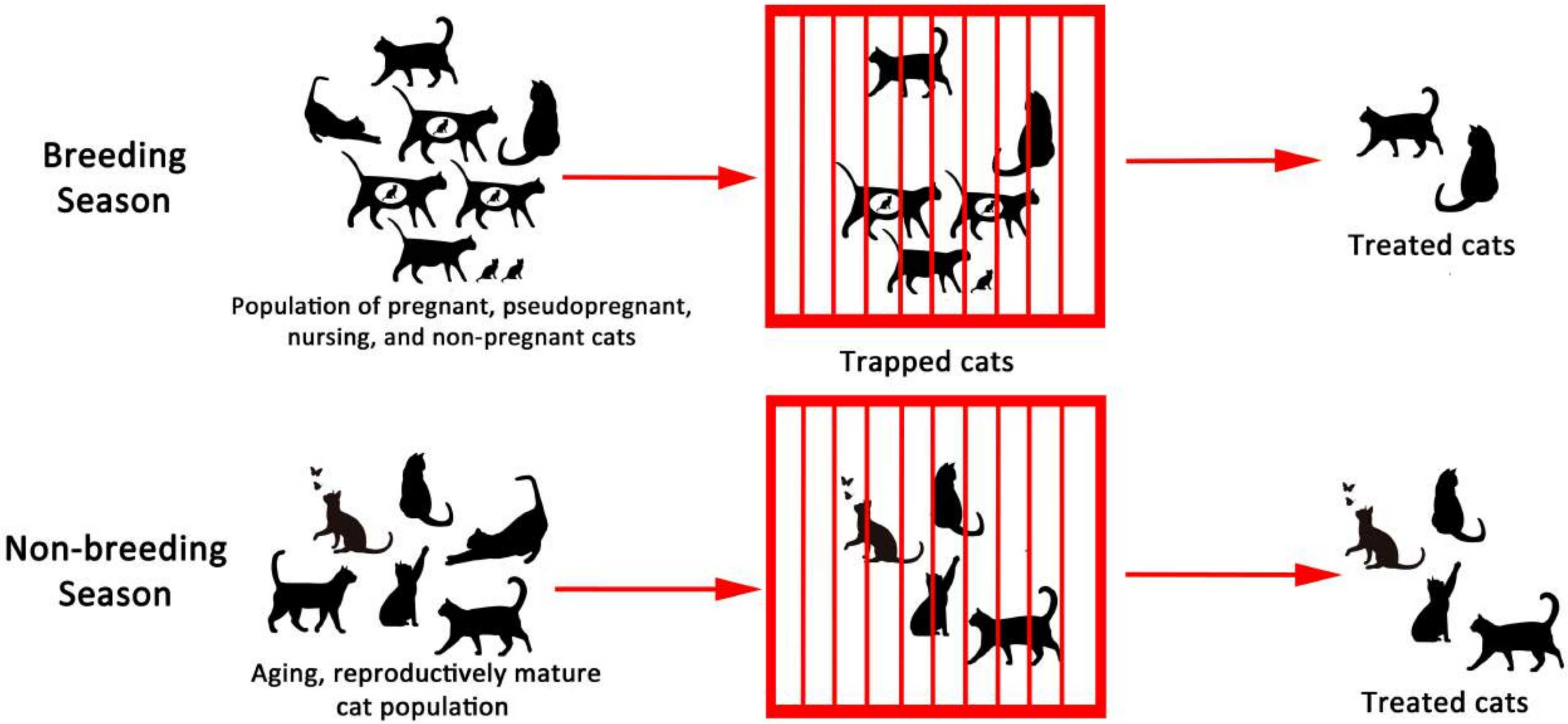
- When pseudopregnant, pregnant, and nursing females are left untreated, late winter and early spring are the most efficacious seasons during which to trap feral cats living in temperate zones.

- These conclusions are also applicable to non-surgical methods of control.
    - TNR is equivalent to non-surgical methods of control (GnRH agonist implants and GnRH vaccines) that do not leave reproductive hormones intact.
    - TVHR is equivalent to non-surgical methods of control (zona pellucida vaccines and anti-sperm vaccines) that leave reproductive hormones intact.

# WHY DOES TRAPPING IN LATE WINTER AND EARLY SPRING RESULT IN FEWER CAT DAYS?



# WHY DOES TRAPPING IN LATE WINTER AND EARLY SPRING RESULT IN FEWER CAT DAYS?



# LIMITATIONS

- A computer model is a controlled representation of reality
  - We account for as many realistic biologic parameters as possible, but once those parameters are set, they cannot be changed while the model is running
- Immigration/emmigration that occurs in feral cat populations is not included in this model
- Psuedopregnant, pregnant, and nursing cats are not treated

# FUTURE OPPORTUNITIES FOR INVESTIGATION

1. Treat pregnant and pseudopregnant cats

2. Investigate multiple annual interventions

3. Investigate mixed method interventions

4. Add immigrating/emigrating cats into the model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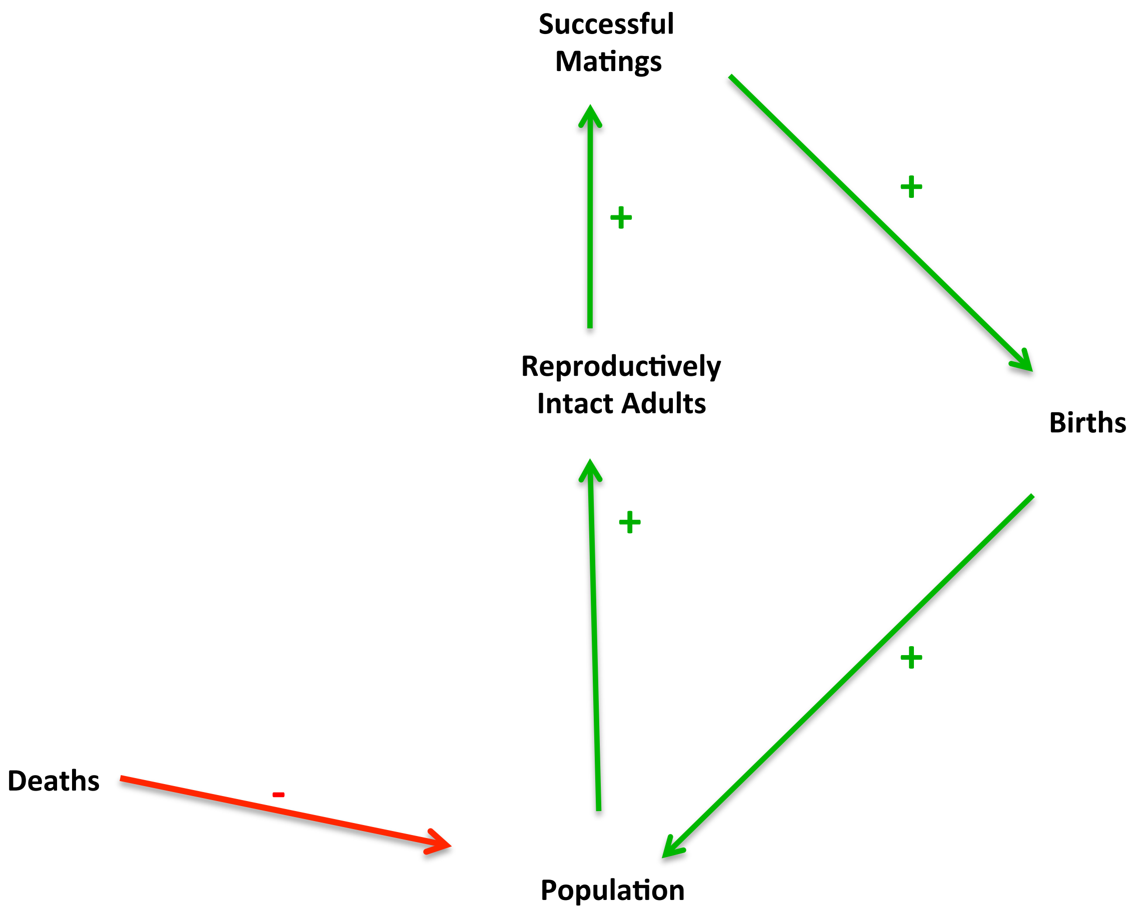
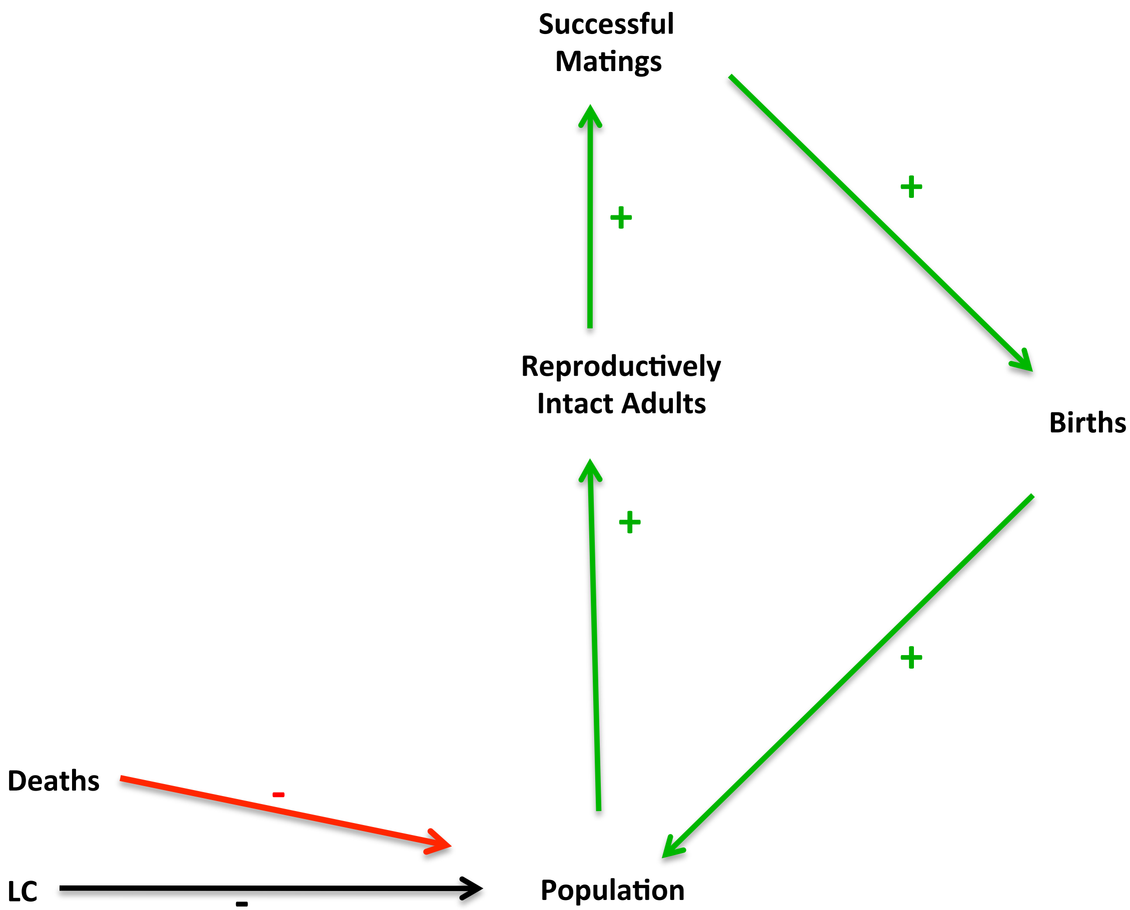
# Discussion



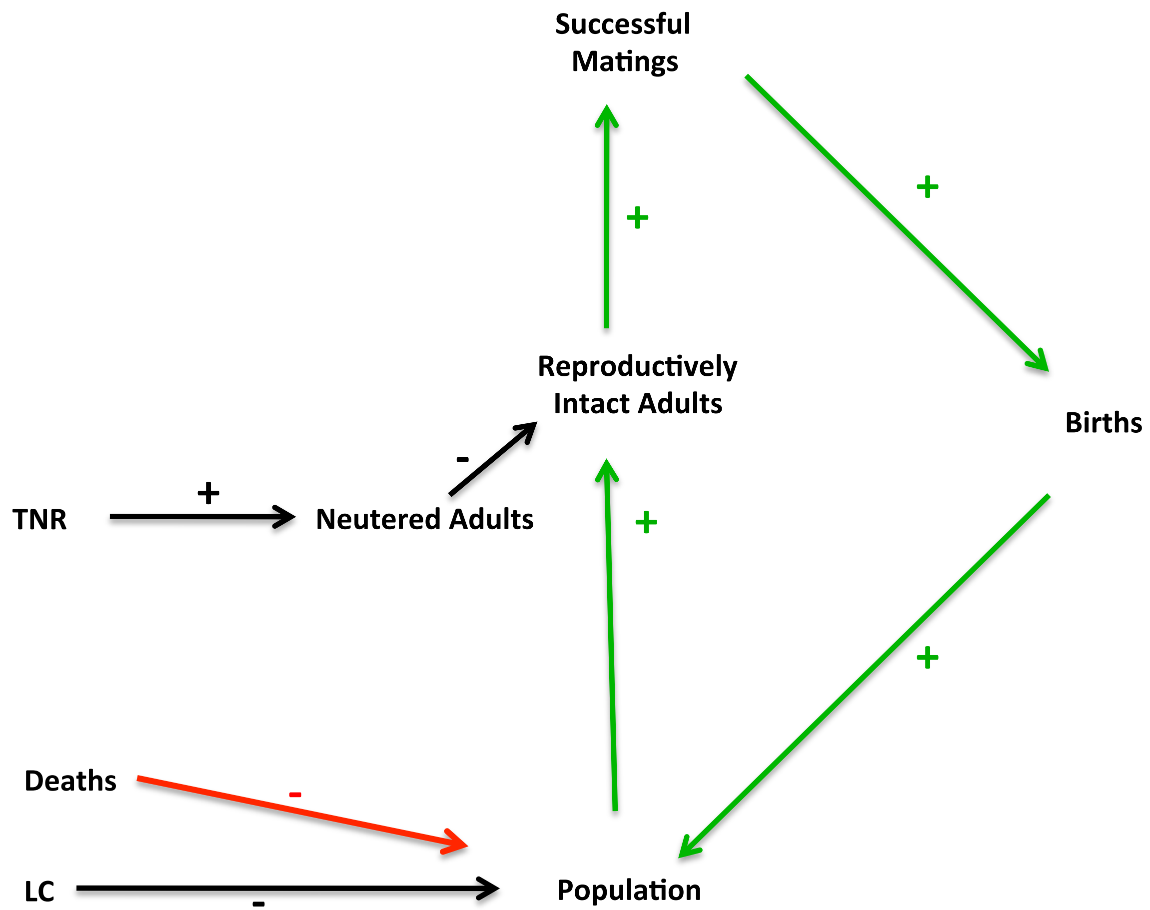
Successful Matings
+
+
Reproductively Intact Adults
Births
+
+
Deaths
-
Population

# Discussion



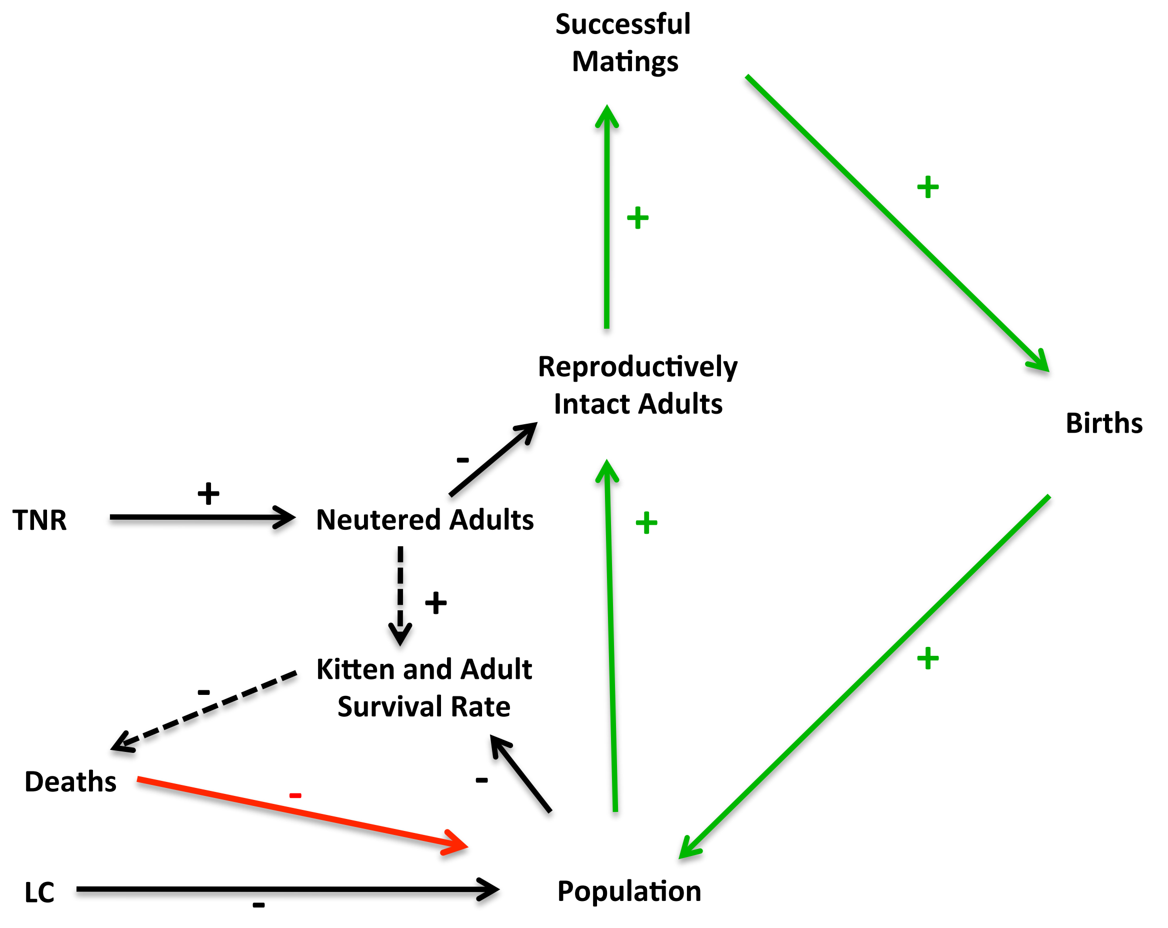
Successful Matings
+
+
Reproductively Intact Adults
Births
+
+
Deaths
-
LC
-
Population

# Discussion



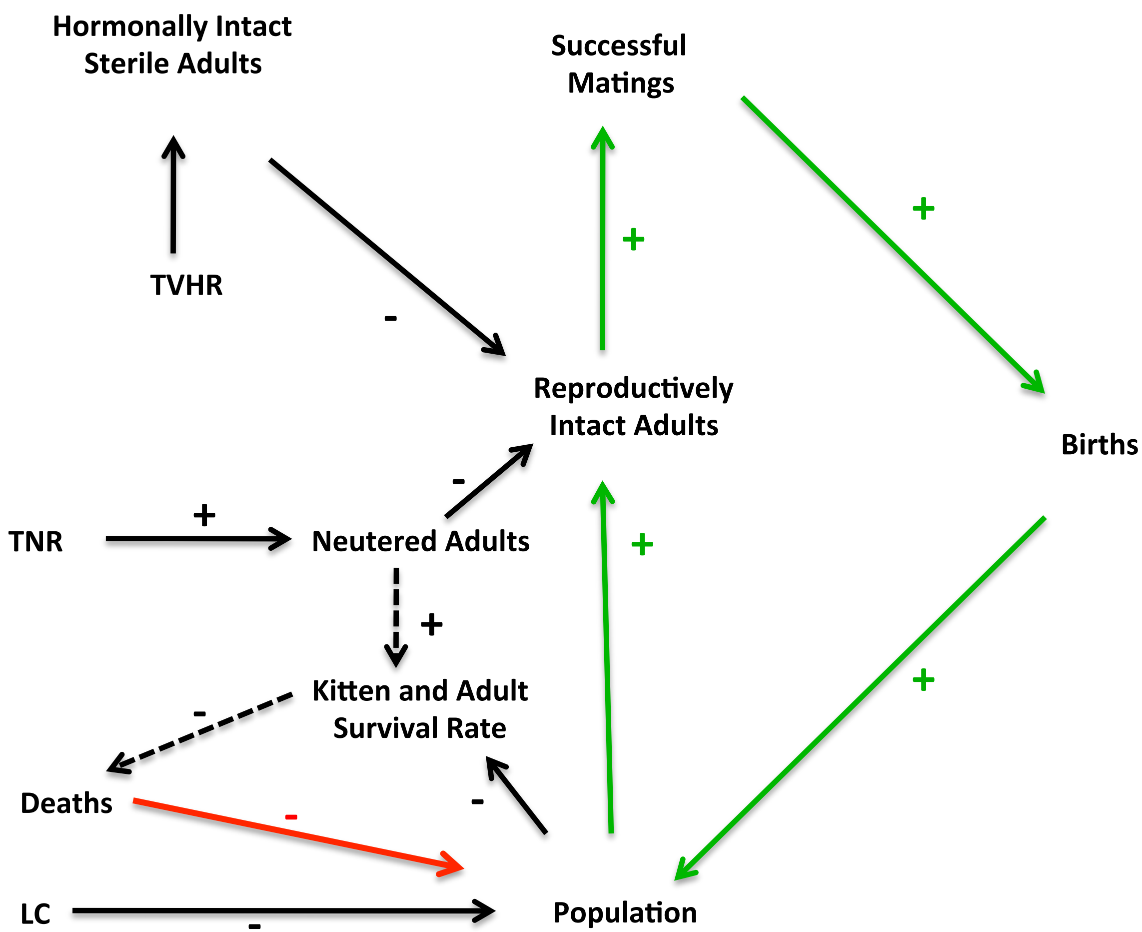
Successful Matings
+
+
Reproductively Intact Adults
Births
-
+
TNR
Neutered Adults
+
+
Deaths
-
LC
-
Population

# Discussion



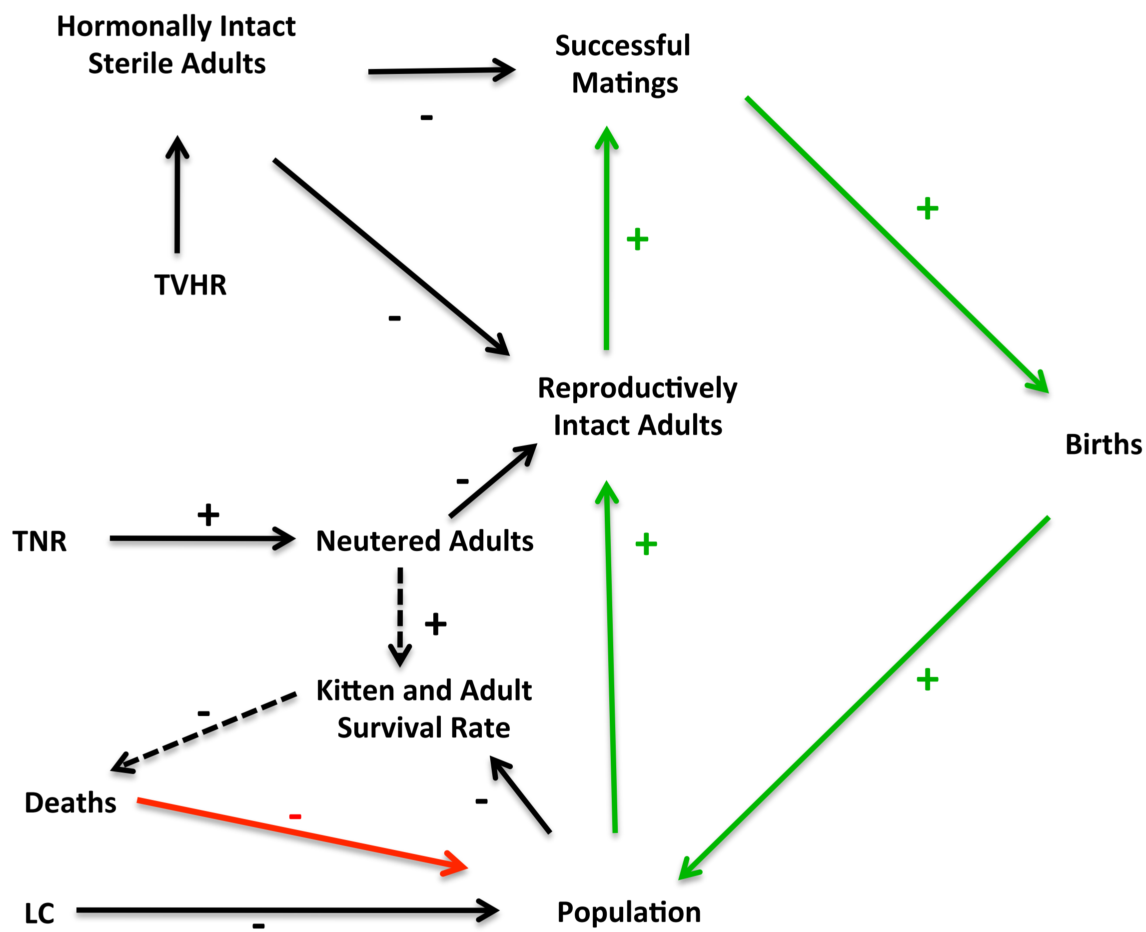
Successful Matings
+
+
Reproductively Intact Adults
Births
-
+
TNR
Neutered Adults
+
+
+
Kitten and Adult Survival Rate
-
Deaths
-
-
LC
-
Population

# Discussion



Hormonally Intact
Sterile Adults
Successful
Matings
+
+
TVHR
-
Reproductively
Intact Adults
Births
-
+
TNR
Neutered Adults
+
+
+
Kitten and Adult
Survival Rate
-
Deaths
-
-
LC
-
Population

# Discussion


Hormonally Intact Sterile Adults
Successful Matings
TVHR
Reproductively Intact Adults
Births
TNR
Neutered Adults
Kitten and Adult Survival Rate
Deaths
LC
Population

# Conclusions

- If decrease in population size and effects on local wildlife is the goal, TVHR superior to TNR and LC
- The model allows many parameters to be altered to fit the population of interest so should  be useful for planning by individuals, organizations, and government agencies

# Immigration

- Being investigated
- Has a large effect, but less so in populations undergoing TVHR
- Introduce sterile males?

# Trapping pattern

- Being investigated
- In general, patterns with more yearly episodes more effective even if same annual trapping probability.

# Validity checks

- Number of males and females in population
- Relative number of adults and kittens
- Percent females pregnant in the breeding season
- Steady state population when no intervention performed

# Medical contraception

- Great for domestic animals, limitations for feral cats.
- Baits attract indigenous species
- Injections still require trapping
- Specific products target zona pellucida, sperm antigens and GnRH
  - Zona pellucida only affects females
  - Sperm antigens only affect males
  - GnRH affects both, but will eliminate reproductive hormones

# Mathematical justification

For a given population size, TVHR does not affect the number of matings, but the fraction of matings that can produce offspring is $(1-m)(1-m)=1-2m+m^2$ where m is the fraction of feral cats trapped previously

For TNR and LC, as long as an adequate number of intact males exist, the number of matings (all of which can produce offspring) depends on the fraction of intact females and is thus proportional to $(1-m)$

Between $m = 0$ and $m = 1$ the curve $1-2m + m^2$ always lies below $1-m$.

When m is small the impact of TNR and LC on reducing productive matings is proportional to m, while the impact of TVHR is proportional to 2m.

Furthermore, the difference between $(1-m)$ and $(1-m)^2$ is greatest at $m = 0.5$; so all things being equal we predict superiority of TVHR over TNR and LC would be greatest in the mid-range of trapping rates.

# Negative aspects of TVHR

- Maintenance of undesirable behaviors
- Increased difficulty of surgical procedure
- Intact females may be more efficient hunters
- Cystic endometrial hyperplasia/pyometra complex

# Male survival

| Parameter | | Value |
|---|---|---|
| | | |
| Daily survival at carrying capacity $s_K$ | | |
| Adult (>319 days) | Intact | 0.997406 |
| | Castrated | 0.999051 |
| | Vasectomy | 0.997406 |
| Old juvenile (184-319 days) | Intact | 0.997406 |
| | Castrated | 0.999051 |
| | Vasectomy | 0.997406 |
| Young juvenile (43-183 days) | Intact | 0.991244 |
| | Castrated | 0.991244 |
| | Vasectomy | 0.991244 |
| Kitten (0-42 days) | Intact | 0.991244 |

**Actual daily survival rate adult and older juveniles**

$$s(p) = s_0 - \frac{s_0 - s_K}{K} p$$

Where $s_0$=daily survival at low density

**Actual daily survival rate kittens and young juveniles**

$$s^*(p,f) = s_0 - (1 - bf)\frac{s_0 - s_K}{K} p$$

Where $s_0$=daily survival at low density, f= fraction of cats neutered and b= estimate of effect of neutering on survival

# Calculation of "b"

- Kitten and young juvenile survival increases as % of a population castrated or spayed
  - 80% survive to 6 months if 75% neutered whereas 32% survive to 6 months if not neutered
    - (Gunther I, Finkler H, Terkel J. Demographic differences between urban feeding groups of neutered and sexually intact free-roaming cats following a trap-neuter-return procedure. *J Am Vet Med Assoc* 2011;238:1134-1140.)

s*(p,f)=daily survival at population p accounting for impact of neutering

s*(p,0)=daily survival at population p with no neutering

f=fraction of population neutered

$$b = \frac{s^*(p,f) - s^*(p,0)}{f(s_0 - s^*(p,0))}$$

$$s^*(p,0)^{180} = 0.32 \text{ or } s^*(p,0) = 0.9937$$

$$s^*(p,0) = (s_0 + s^*(K,0)/2 = (0.9991 + 0.9912)/2 = 0.9952$$

$$s^*(p,0) = (0.9937 + 0.9952)/2 = 0.9945$$

$$(s^*(p,0.75))^{180} = 0.76 = 0.9985$$

$$b = \frac{0.9985 - 0.9945}{0.75(0.9991 - 0.9945)} = 1.16$$

# Female survival

| Parameter | | | Value |
|---|---|---|---|
| | | | |
| Daily survival at carrying capacity $s_K$ | | Receptive | |
| Adult | Intact | +/- | 0.998832 |
| (>319 days) | Intact pseudopregnant | - | 0.998832 |
| | Intact pregnant or nursing | - | 0.998832 |
| | Hysterectomy | +/- | 0.998832 |
| | Hysterectomy pseudopregnant | - | 0.998832 |
| | Spayed | - | 0.999051 |
| Older Juvenile | Intact | - | 0.998832 |
| (184-319 days) | Hysterectomy | - | 0.998832 |
| | Spayed | - | 0.998832 |
| Young Juvenile | Intact | - | 0.991244 |
| (43-183 days) | Hysterectomy | - | 0.991244 |
| | Spay | - | 0.991244 |
| Kitten (0-42 days) | Intact | - | 0.991244 |

**Actual daily survival rate adult and older juveniles**

$$s(p) = s_0 - \frac{s_0 - s_K}{K} p$$

**Actual daily survival rate kittens and young juveniles**

$$s^*(p,f) = s_0 - (1 - bf) \frac{s_0 - s_K}{K} p$$

# Model Input

| Parameter | Value |
|---|---|
| | |
| Carrying capacity (K) | 200 |
| Number days simulated | 6000 |
| Intervention day | 2000 |
| Daily trapping probability | 0.03 |
| Consecutive trapping days | 14 |
| Trapping program frequency | 3 |
| Annual trapping probability | P (calculated) |
| Seasonality | Yes |
| Immigration/emigration | No |
| Management method | None, LC, TNR, TVHR |

Annual trapping probability

$$P = 1-(1-d)^{cf}$$

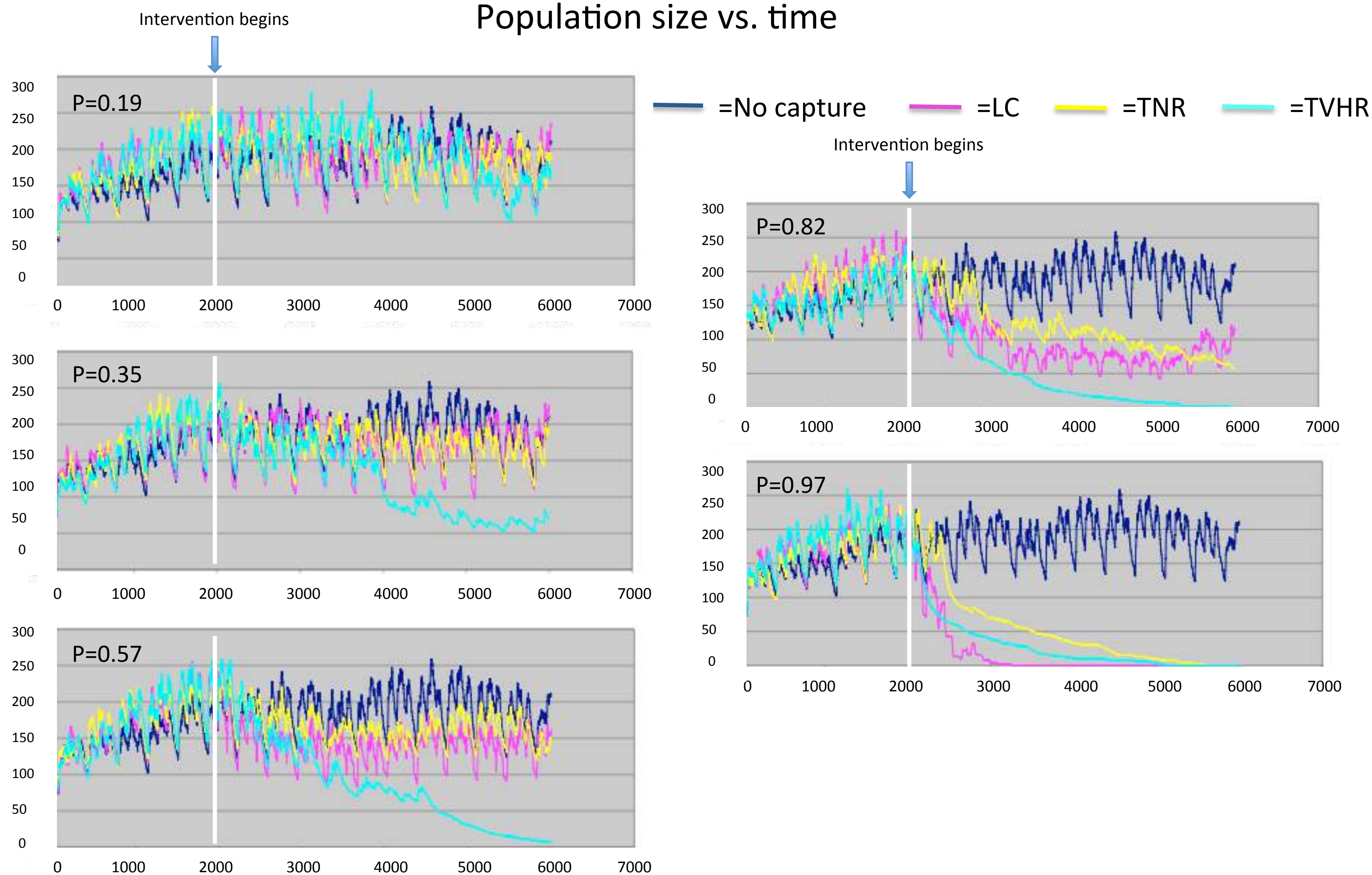
$$P = 1-(1-0.03)^{14x3} = 0.72$$

# Vital rate parameters

- In a population of cats undergoing control there are many different classes of cat each with a different likelihood of daily survival
  - Predicted daily survival of kittens less than adults
  - Predicted daily survival increases after neutering
  - Predicted daily survival of kittens and young juveniles increases as a greater % of the entire population is neutered (Gunther I, Finkler H, Terkel J. *J Am Vet Med Assoc* 2011;238:1134-1140)
    - 32% of kittens survive to 6 months of age in colonies with no intervention
    - 76% of kittens survive to 6 months of age in matched colonies after 75% are neutered
    - b=0 is no effect, b=1.2 is predicted effect
- Density dependent effects
  - Predicted daily survival of an individual decreases as the population nears the carrying capacity

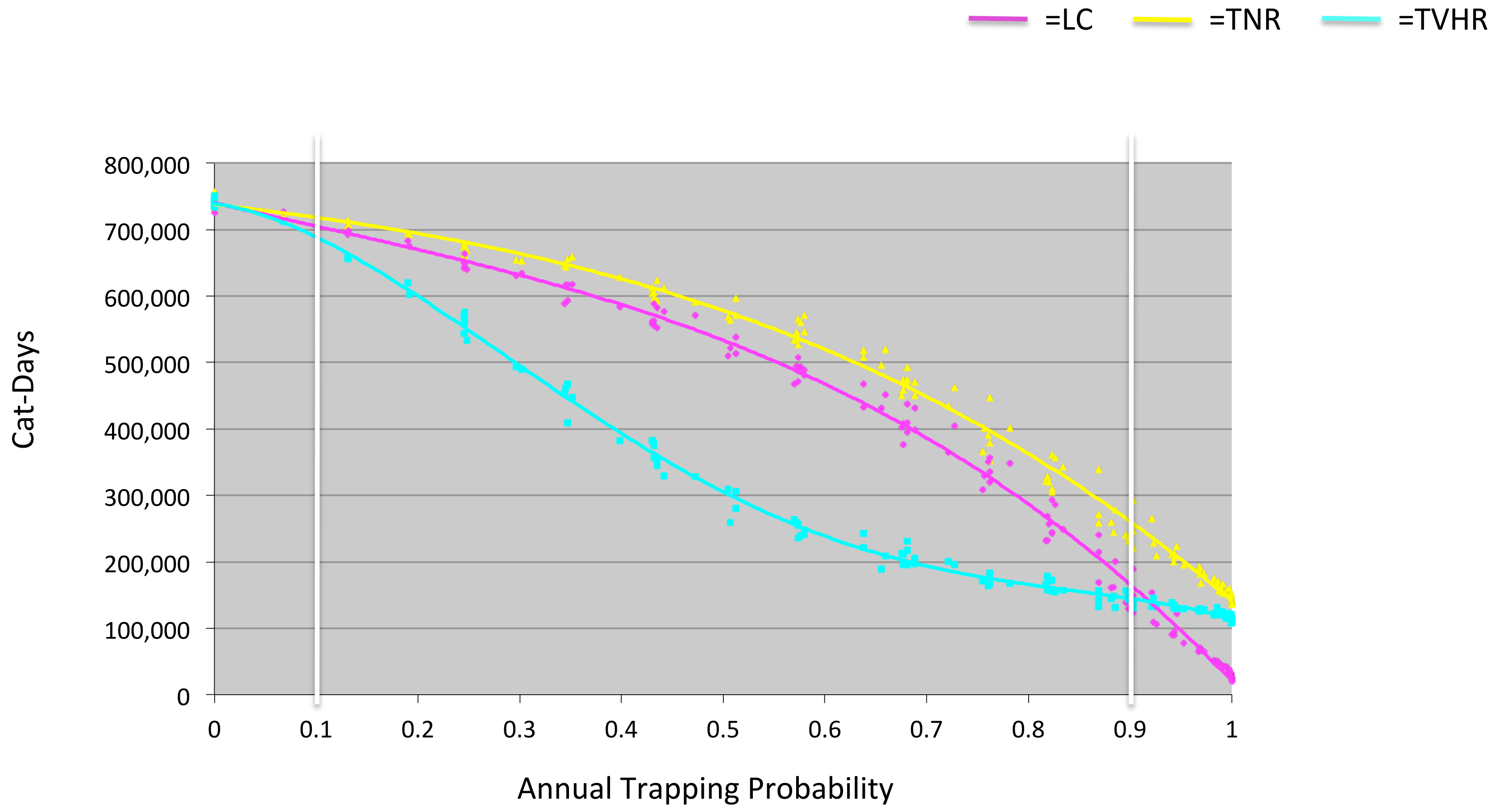
# Results

## Population size vs. time



# Results

Cat days vs. annual trapping probability



# Results

Effect of “b” on cat days for TNR