Age structure effects and population control in urban/suburban white-tailed deer, Chicago, IL 1992-2006

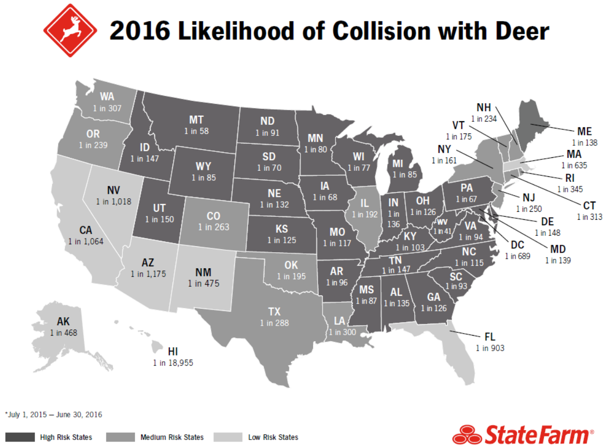
Yunyi Shen, Dwayne R. Etter and Tim R. VanDeelen

UW Madison
Department of Forest and Wildlife Ecology

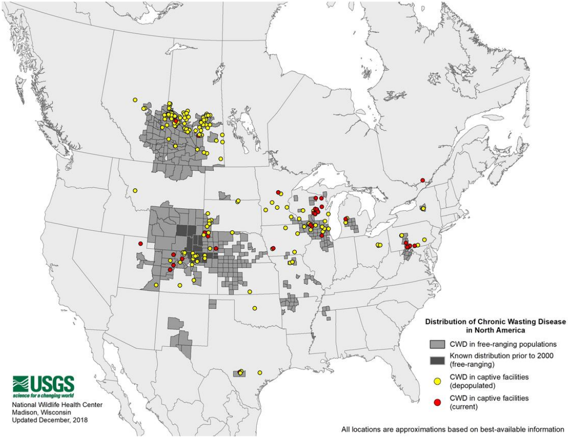
January 27, 2020

Introduction

Overabundant Deer is a Problem: Collision



Overabundant Deer is a Problem: CWD



Paradigm Shift of Population Control

Paradigms	**Sustainable Harvest**	**Low Densities**

Paradigm Shift of Population Control

Paradigms	**Sustainable Harvest**	**Low Densities**
Growth goal	~ 1	< 1 to reduce

Paradigm Shift of Population Control

Paradigms	**Sustainable Harvest**	**Low Densities**
Growth goal	~ 1	< 1 to reduce
Density	Various	Low

Paradigm Shift of Population Control

Paradigms	**Sustainable Harvest**	**Low Densities**
Growth goal	~ 1	< 1 to reduce
Density	Various	Low
Age structure	Stationary	Non-stationary

Paradigm Shift of Population Control

Paradigms	**Sustainable Harvest**	**Low Densities**
Growth goal	~ 1	< 1 to reduce
Density	Various	Low
Age structure	Stationary	Non-stationary

Requires a further evaluation!

Research Objective

- Evaluate intensive harvest as a method of population control with a goal of maintain low density:
  Is intensive harvest effective?

Research Objective

- Evaluate intensive harvest as a method of population control with a goal of maintain low density:
  Is intensive harvest effective?
- Understanding the dynamics of suburb deer population under such control:
  What is the best way to control it?

Research Objective

- Evaluate intensive harvest as a method of population control with a goal of maintain low density:
  Is intensive harvest effective?
- Understanding the dynamics of suburb deer population under such control:
  What is the best way to control it?
- Evaluate the effect of shifted age structure after intensive harvest:
  Can we skip a harvest year?

Research Objective

- Evaluate intensive harvest as a method of population control with a goal of maintain low density:

  Is intensive harvest effective?

- Understanding the dynamics of suburb deer population under such control:

  What is the best way to control it?

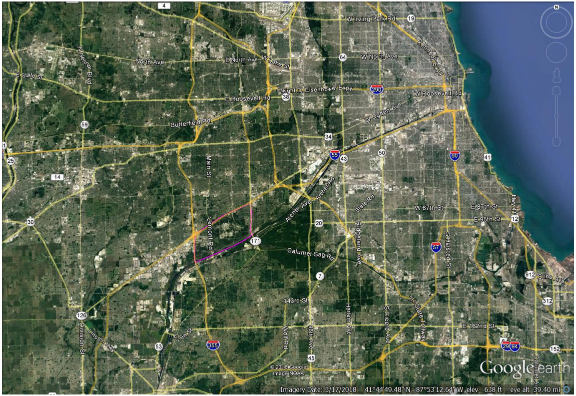
- Evaluate the effect of shifted age structure after intensive harvest:

  Can we skip a harvest year?

Chicago Suburb Deer: a Case Study

Study area: Complex 1

- $30.6 km^2$
- Isolated by highways

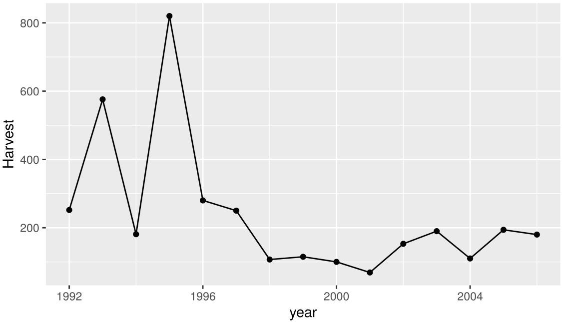


Intensive harvest

- 15 years

Intensive harvest

- 15 years
- 3,827 records



Questions to ask

- Did this method work in Chicago?

Questions to ask

- Did this method work in Chicago?
- What was the effect of shifted age structure after culling here?

Questions to ask

- Did this method work in Chicago?
- What was the effect of shifted age structure after culling here?
- Can we control by knock population down and then keep harvest a **fixed quota** or we have to be adaptive, i.e. try harvest a **fixed proportion**?

Questions to ask

- Did this method work in Chicago?
- What was the effect of shifted age structure after culling here?
- Can we control by knock population down and then keep harvest a **fixed quota** or we have to be adaptive, i.e. try harvest a **fixed proportion**?
- Which age should we focus on?

Questions to ask

- Did this method work in Chicago?
- What was the effect of shifted age structure after culling here?
- Can we control by knock population down and then keep harvest a **fixed quota** or we have to be adaptive, i.e. try harvest a **fixed proportion**?
- Which age should we focus on?

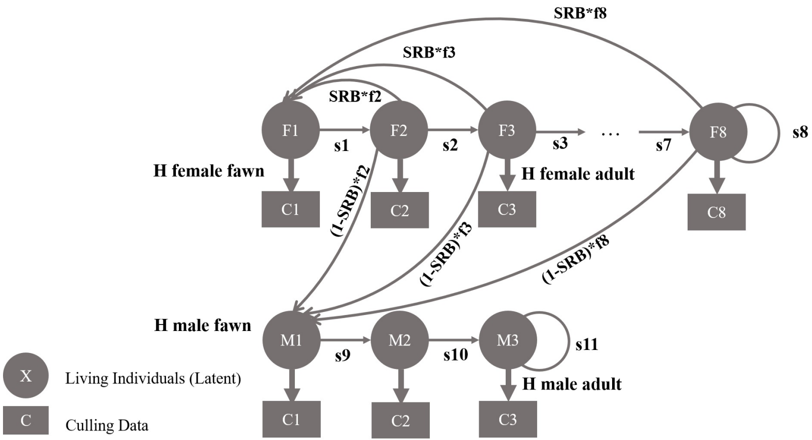
To Answer These Questions:

Reconstruct the Dynamics and find the posterior distribution of population growth under different schemes!

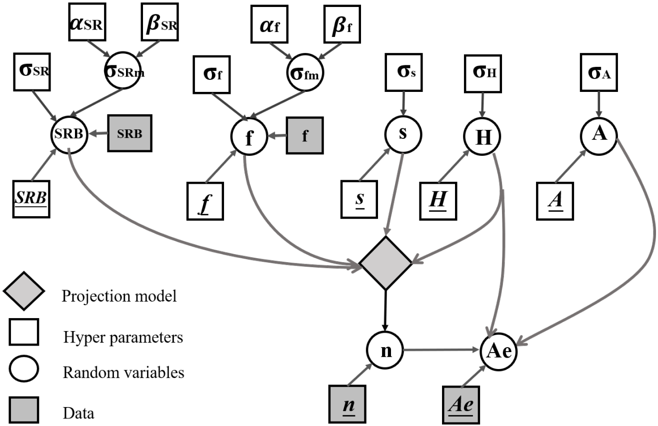
Data Collected

- Age-at-harvest
- Post-harvest aerial count
- Fecundity was surveyed annually
- Prior knowledge from Etter et al. 2002 on survival rate

Process Model: Leslie Matrix Projection



Reconstruction: A Bayesian (Filter) Framework



Algorithm Modified from Weldon et al. 2013 and implemented in R and C++

Model Selection Based on DIC

- There are multiple assumptions considered vital rates: e.g. whether fecundity changing through time and age?
- Model was selected based on **Deviation Information Criterion** (DIC), a Bayesian extension of AIC (Gelman et al. 2013).

Making Predictions on Different Schemes

- Stochastic Leslie matrix model with vital rates follow posterior distribution estimated by reconstruction: a retrospect
- i.e., estimating the conditional distribution of population **given scheme and data**

$$Population|Data, Scheme$$

Model Selection

Fecundity	Survival	Harvest	error	P_d	DIC
age, time	age, sex, time	F/A, sex, time	homo	224.6	1245
F/Y/A, time	age, sex, time	F/A, sex, time	time	205.0	1297
F/Y/A, time	age, sex, time	F/A, sex, time	homo	206.3	1304
F/Y/A, time	F/A, sex, time	F/A, sex, time	time	182.4	1307

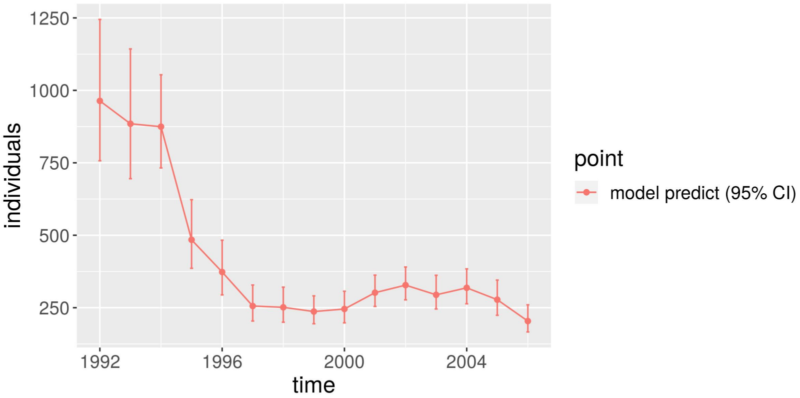
Model Selection

Fecundity	Survival	Harvest	error	P_d	DIC
age, time	age, sex, time	F/A, sex, time	homo	224.6	1245
F/Y/A, time	age, sex, time	F/A, sex, time	time	205.0	1297
F/Y/A, time	age, sex, time	F/A, sex, time	homo	206.3	1304
F/Y/A, time	F/A, sex, time	F/A, sex, time	time	182.4	1307

Model 1 were chosen for predictions

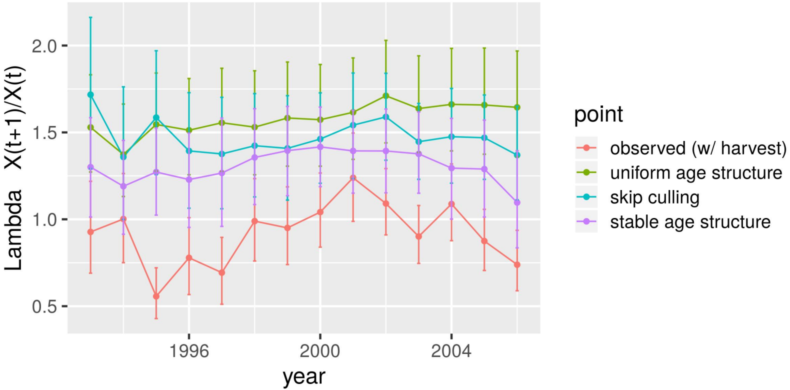
Reconstructed Post-harvest Population

We successfully control the population size to ~ 300



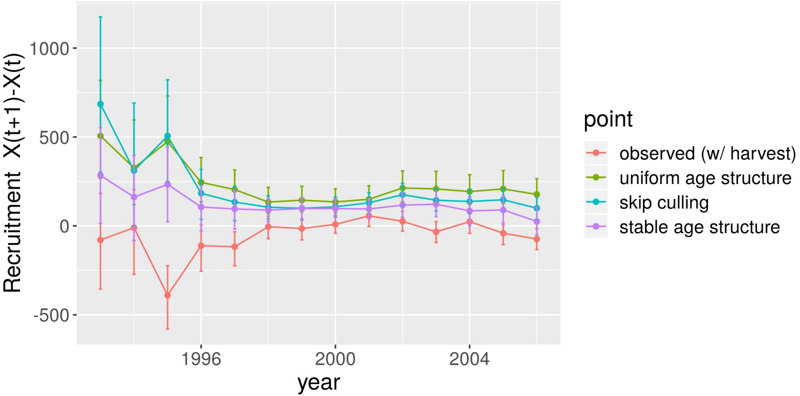
Can Shifted Age Structure be an Insurance?

In terms of growth rate: **No**



Can Shifted Age Structure be an Insurance?

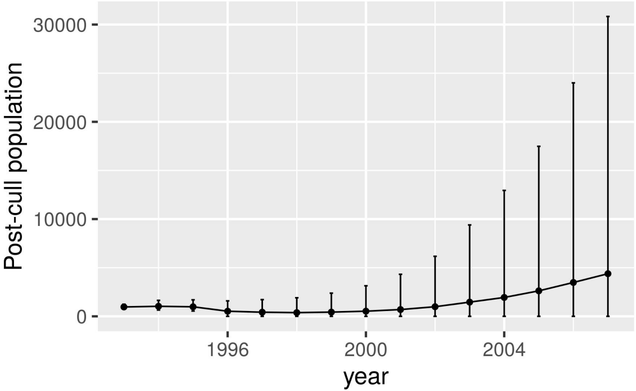
But low population size itself can be one in terms of recruitment



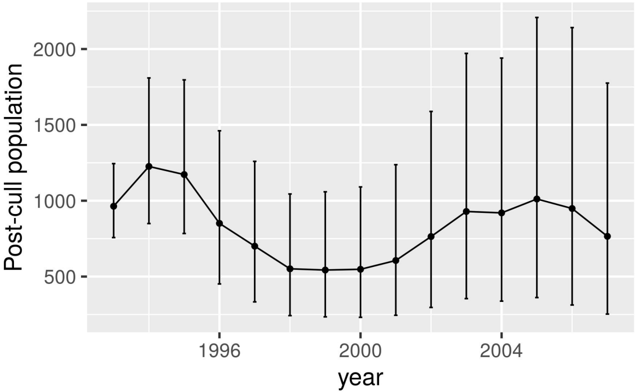
Culling amount: Fix quota vs Fix Proportion

- Retrospect: used quota/proportion and vital rates of 1992-2016
- Non-selective: Assuming we allocate the quota by age structure

Culling amount: Fix quota



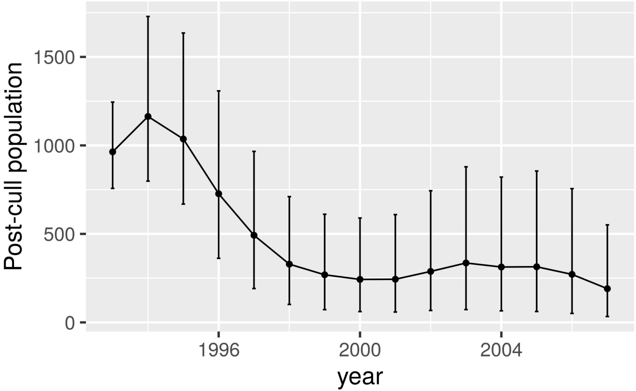
Culling amount: Fix proportion



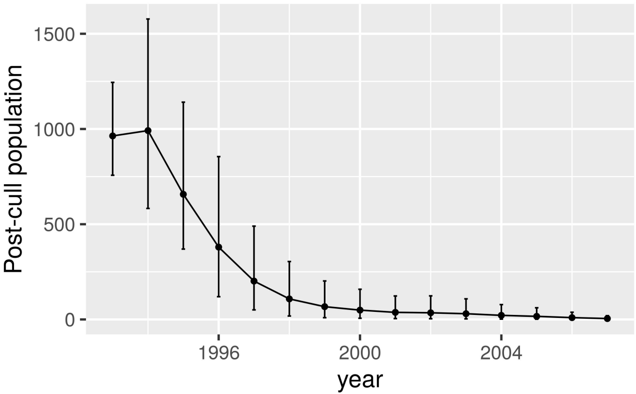
Selective Culling: Which age?

- Retrospect: used proportion and vital rates of 1992-2016
- Selective: added a weight to each age

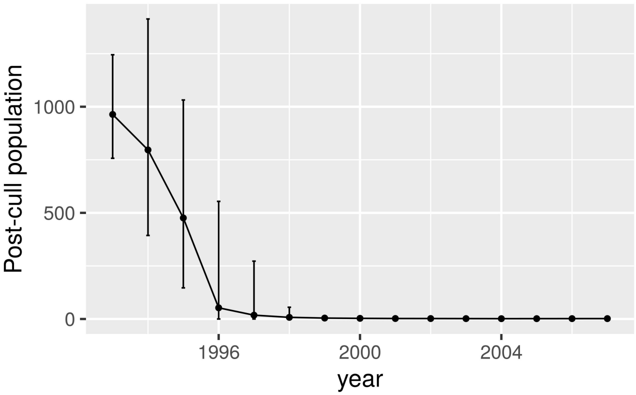
Selective Culling: Doe twice likely to be harvested



Selective Culling: Only doe



Selective Culling: Only doe, fix quota



Take Home Message for Management Based on This Case

- Intensive culling is a powerful tool for controlling overabundant deer

Take Home Message for Management Based on This Case

- Intensive culling is a powerful tool for controlling overabundant deer
- Continuous effort should be put in to control the population

Take Home Message for Management Based on This Case

- Intensive culling is a powerful tool for controlling overabundant deer
- Continuous effort should be put in to control the population
- After knocking the population down, the (adaptive) **fixed proportion** rather than fix quota harvest can help keeping the population low (this may means **similar effort** each year)

Take Home Message for Management Based on This Case

- Intensive culling is a powerful tool for controlling overabundant deer
- Continuous effort should be put in to control the population
- After knocking the population down, the (adaptive) **fixed proportion** rather than fix quota harvest can help keeping the population low (this may means **similar effort** each year)
- Be selective and focus on doe

References

- Etter, D. R., Hollis, K. M., Van Deelen, T. R., Ludwig, D. R., Chelsvig, J. E., Anchor, C. L., and Warner, R. E. (2002). Survival and movements of white-tailed deer in suburban chicago, illinois. The Journal of Wildlife Management, pages 500–510.
- Wheldon, M. C., Raftery, A. E., Clark, S. J., and Gerland, P. (2013). Reconstructing past populations with uncertainty from fragmentary data. Journal of the American Statistical Association, 108(501):96–110.
- Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., and Rubin, D. B. (2013). Bayesian data analysis. Chapman and Hall/CRC.

Acknowledgments

- Thank Michigan DNR officers who collected these data when I was not born
- Thanks my lab mates for all the discussions
- Special thank to Department of Chemistry, UW-Madison for offering me TAship to fund my study in UW-Madison

Questions?

Open source statement:

All source code (in R and C++) can be find on Github repo

YunyiShen/ReCAP, source code of this report can be found in repo

YunyiShen/UW-Course-Projects under GPL 3.0

Optimal/Worst Age Structure of Annual Growth

Consider a Leslie matrix A and a population X, the growth rate can be written as:

$$\lambda = \frac{1^T AX}{1^T X} = (1^T A)\frac{X}{1^T X}$$

This equals to the **weighted average** of $1^T A$, which is the column sum of Leslie matrix A, and we have

$$min(1^T A) \leq \lambda \leq max(1^T A)$$

will take equal when all individuals are at the age that maximize/minimize column sum of Leslie matrix, so: healthy fat doe/naive male fawn