Modeling Management Strategies for the Control of Bighorn Sheep Respiratory Disease

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The problem

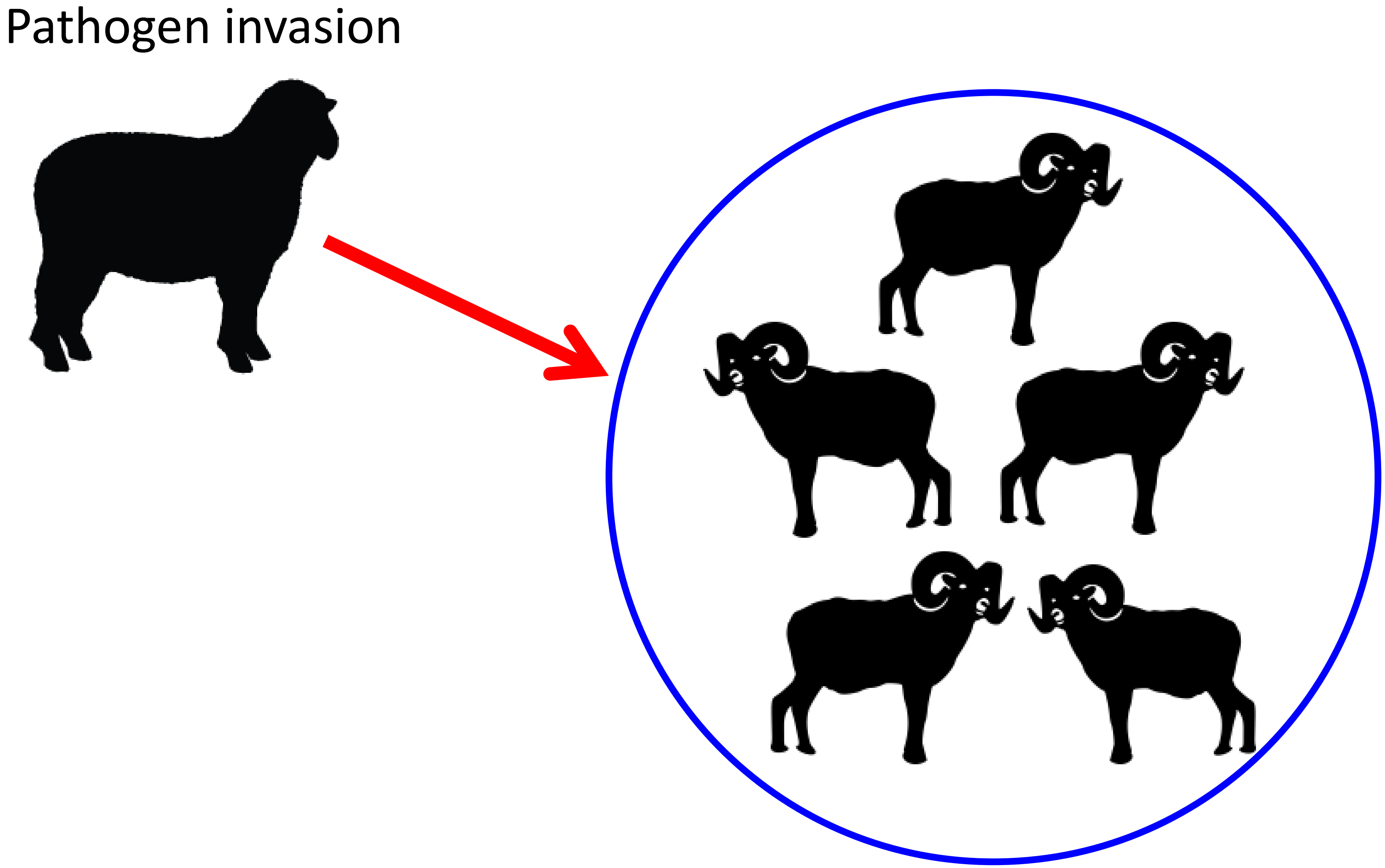
www.bighornhealth.org

Biological understanding of problem

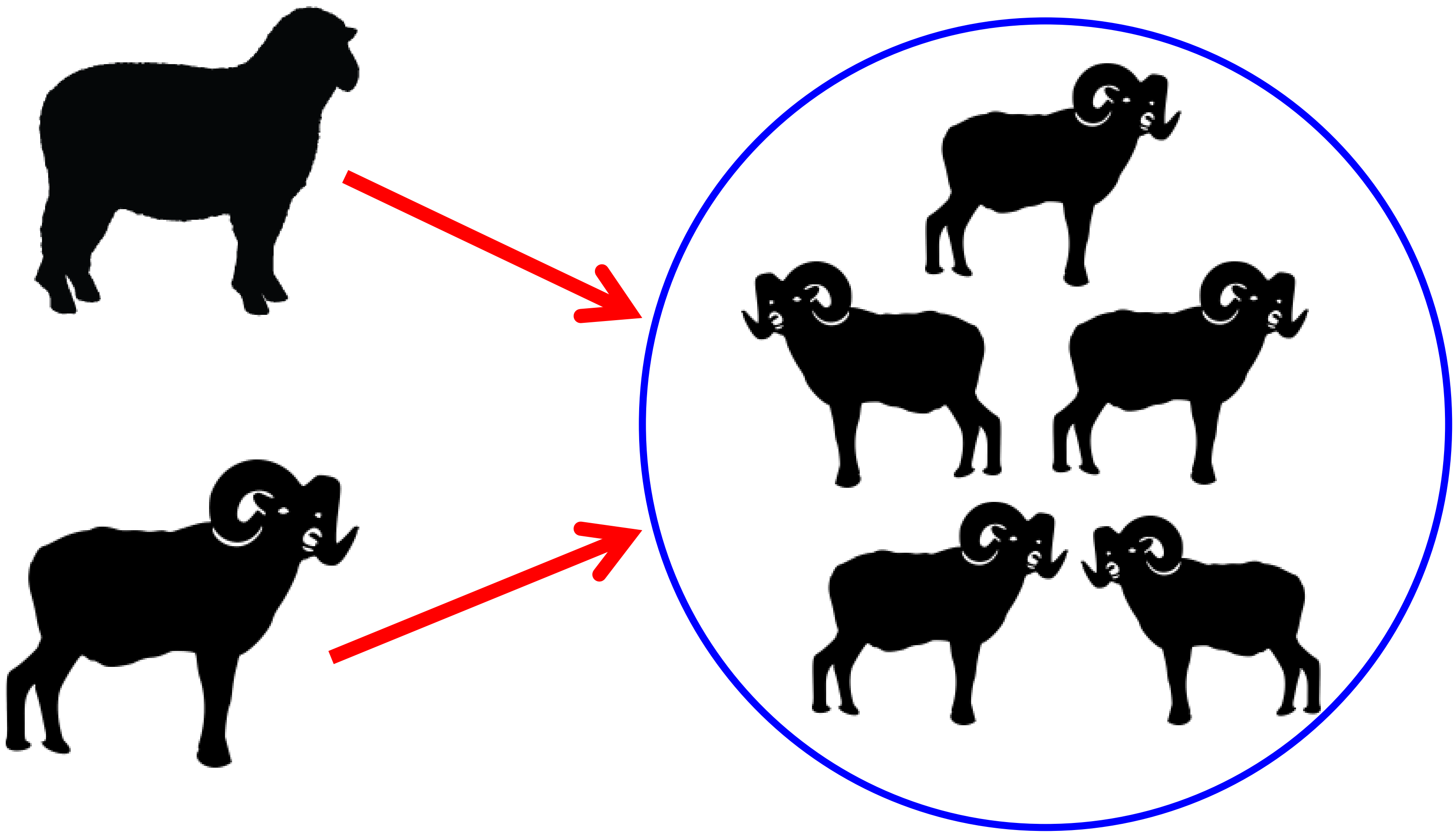
- *Mycoplasma ovipneumoniae* (Movi) is necessary to cause epidemic and chronic pneumonia
  - Domestic sheep & goats
  - Invades BHS, triggers all-age die-off, some adults become chronic carriers, this facilitates perennial lamb failure
- Unknown how other pathogens contribute to severity of morbidity and mortality
- Unknown how often Movi goes extinct

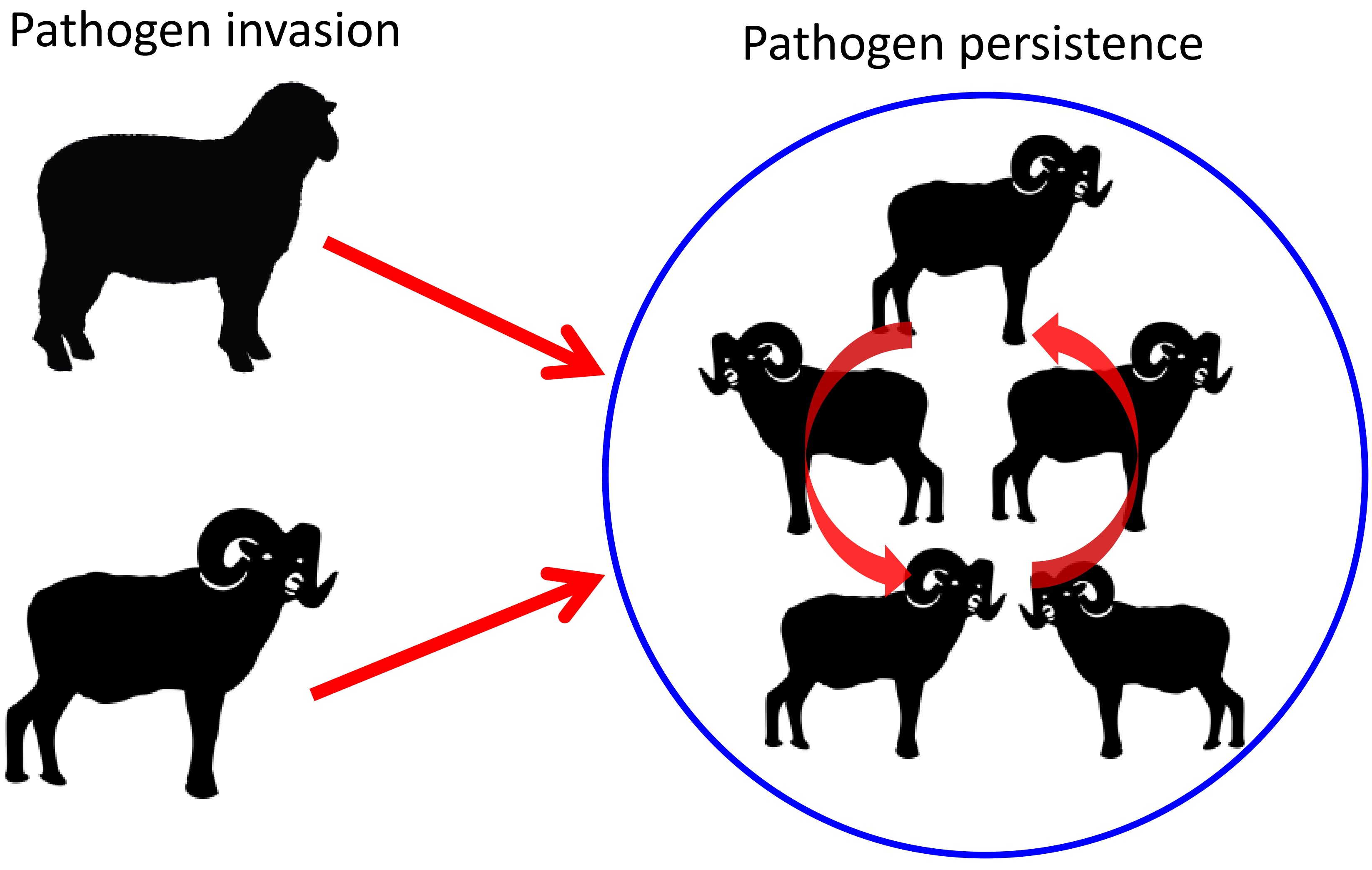
Where simulation models can help…

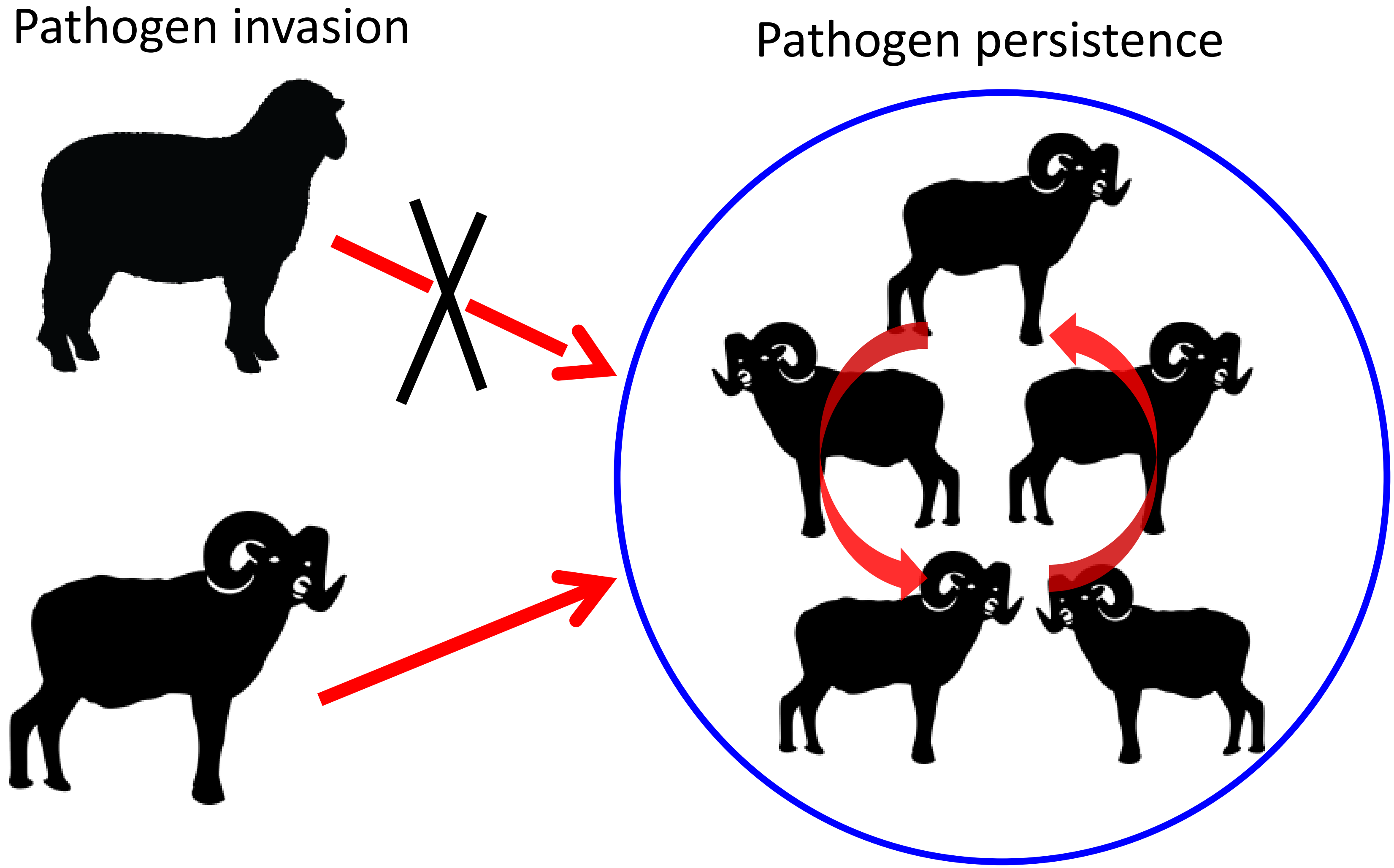
- Can we generate predictions given our current biological understanding?
  - Disease dynamics—are simulations realistic?
  - Which parameters are most influential?
  - Management tools and outcomes


Pathogen invasion

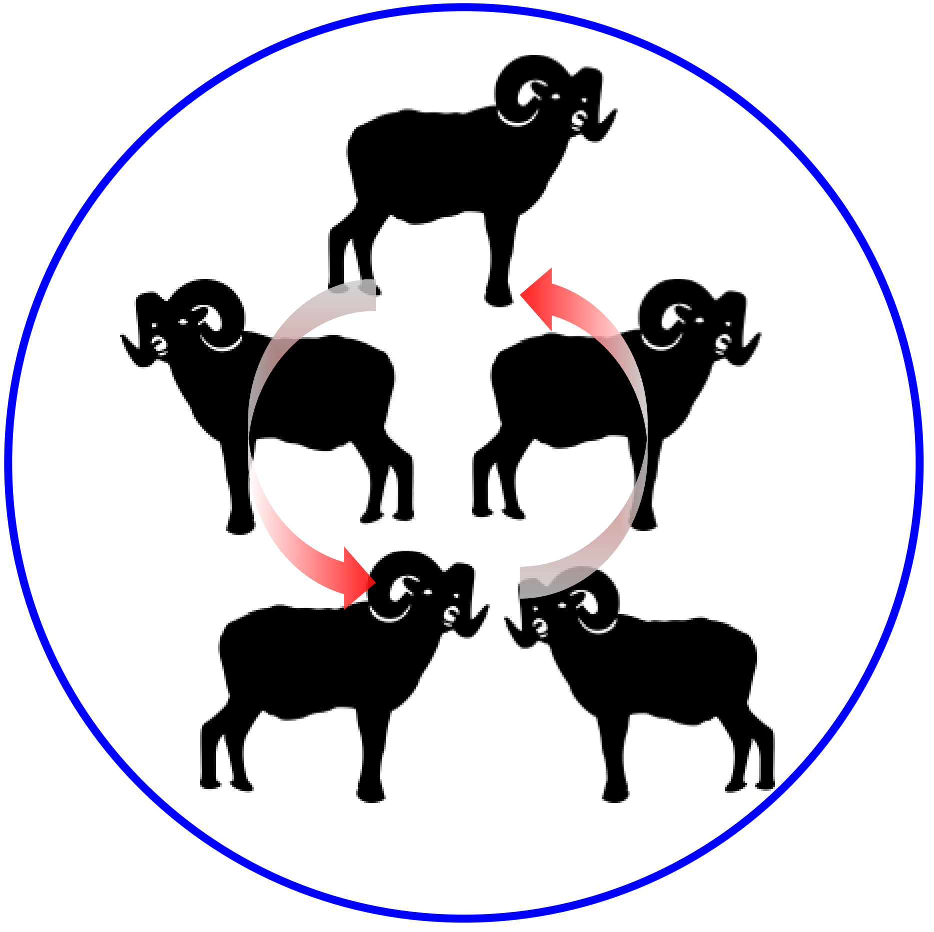
Pathogen invasion



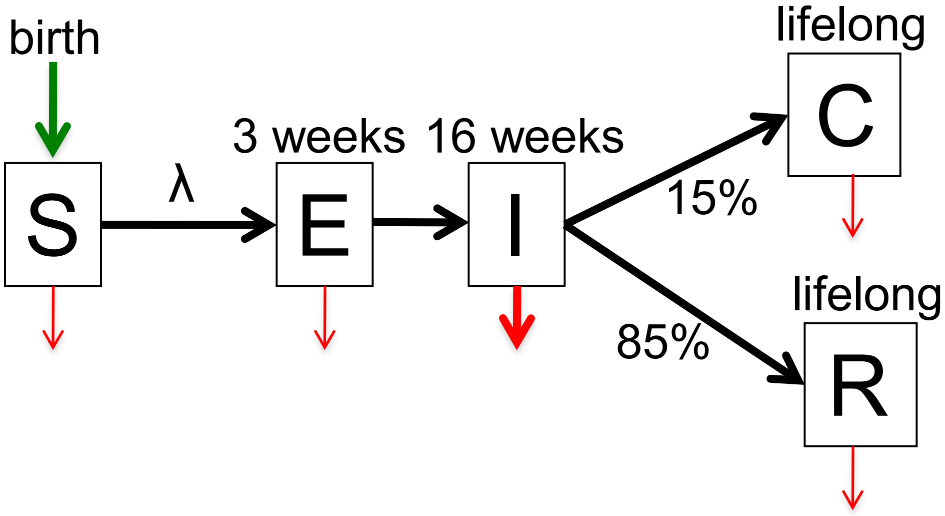

Pathogen invasion
Pathogen persistence


Pathogen invasion
Pathogen persistence

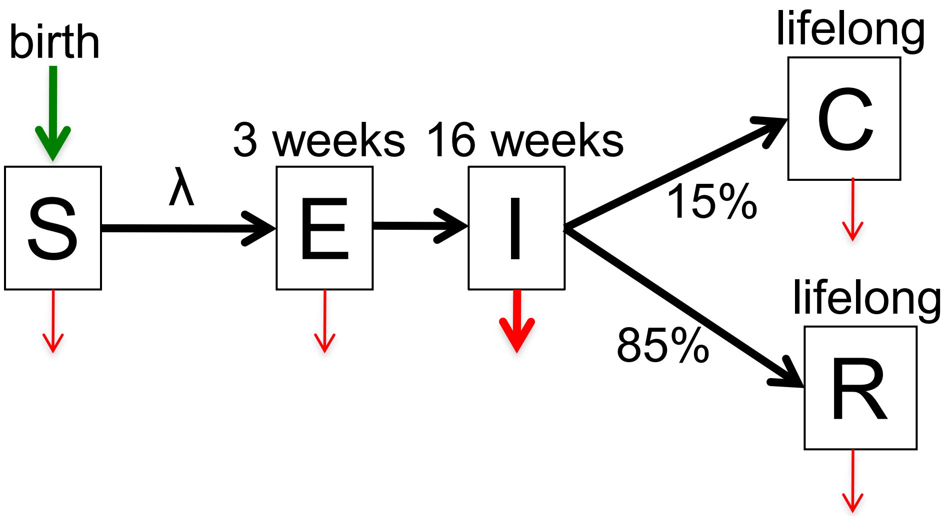
Can we reduce the persistence of Movi through management?

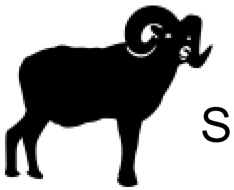


Disease model

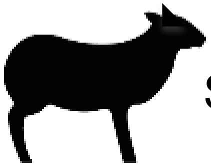


Disease model





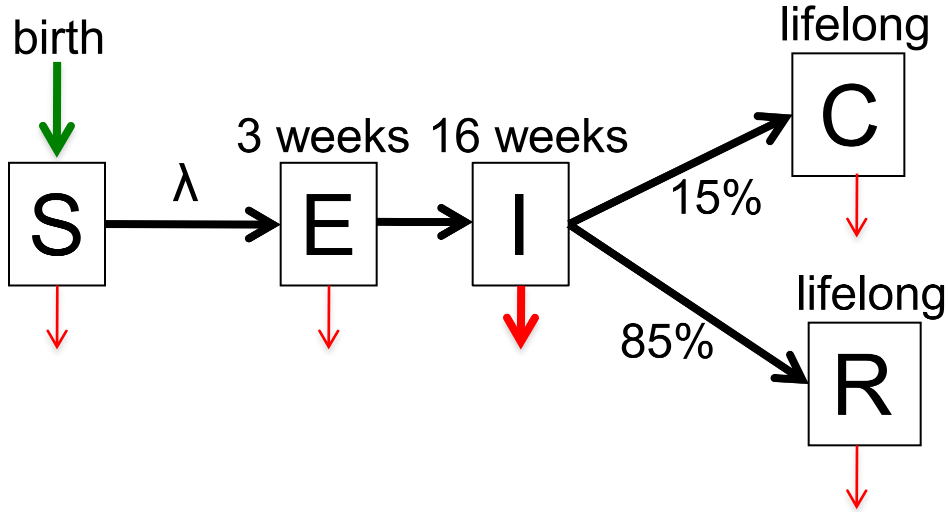
Sur = 0.77 - 0.8; **0.5**

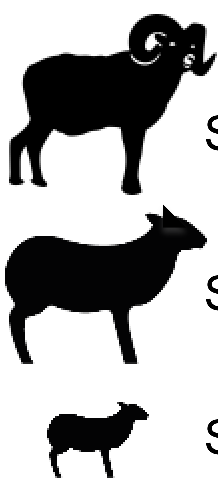


Sur = 0.87 – 0.9; **0.5**

Sur = 0.5; **0.1**

Disease model





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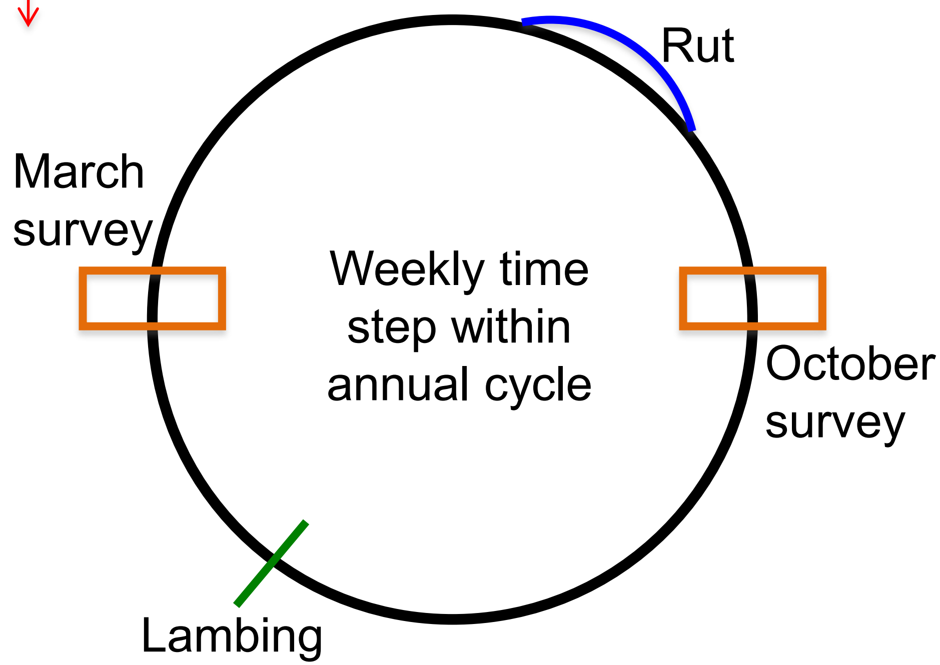
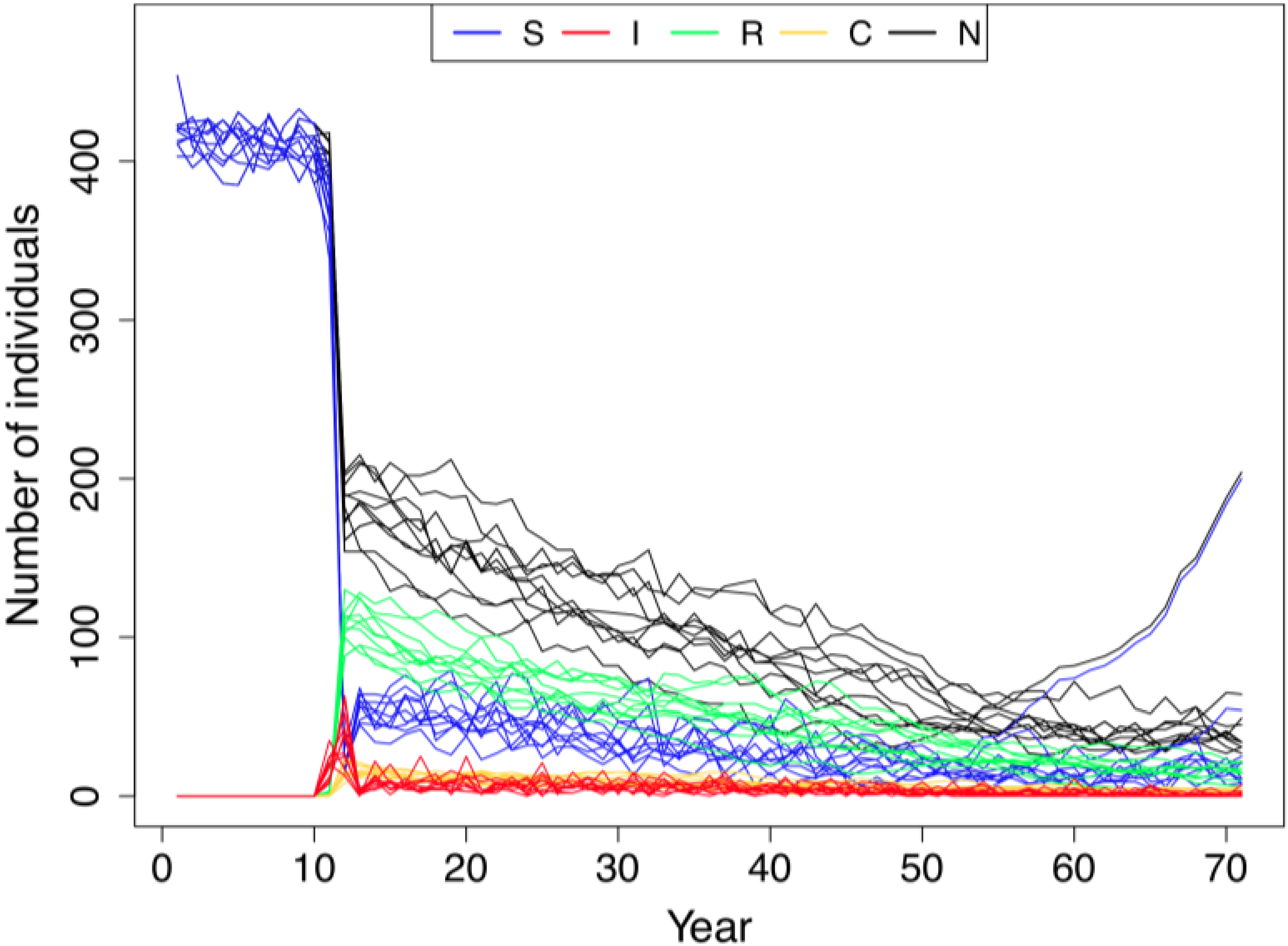


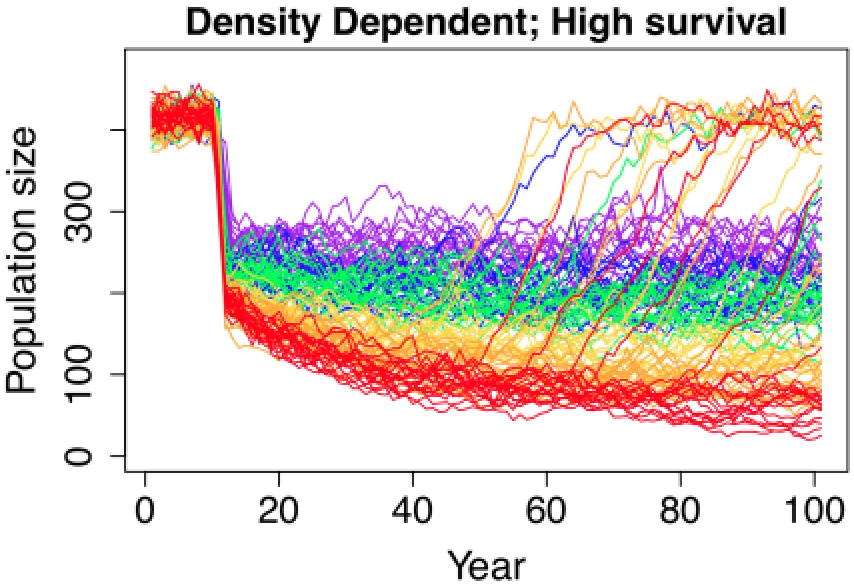
Assumptions about transmission

- Density dependent transmission
  - Contact rate increases with density
- Frequency dependent transmission
  - Contact rate is independent of density

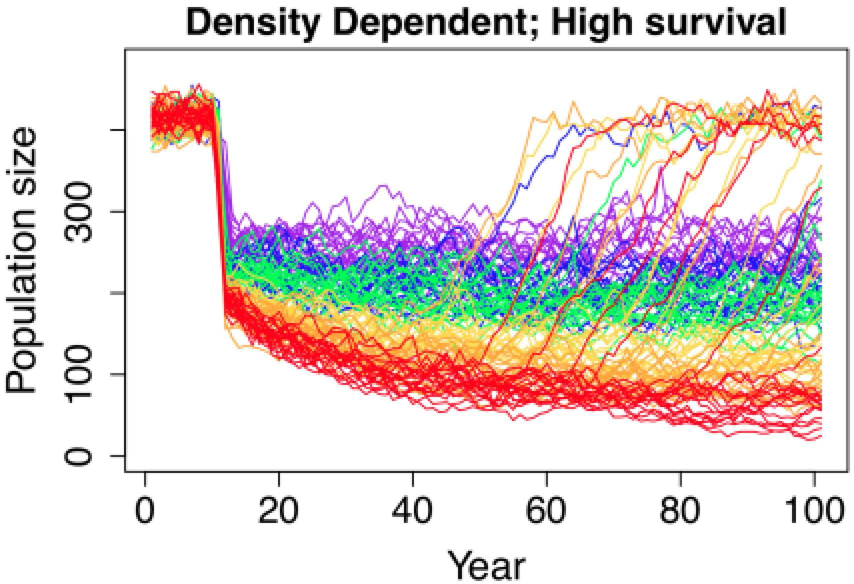
Basic dynamics

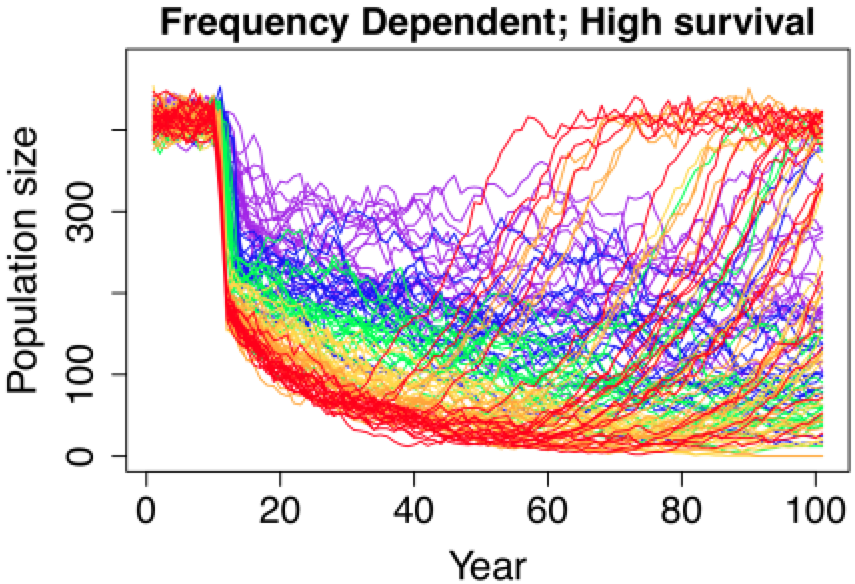


Basic dynamics

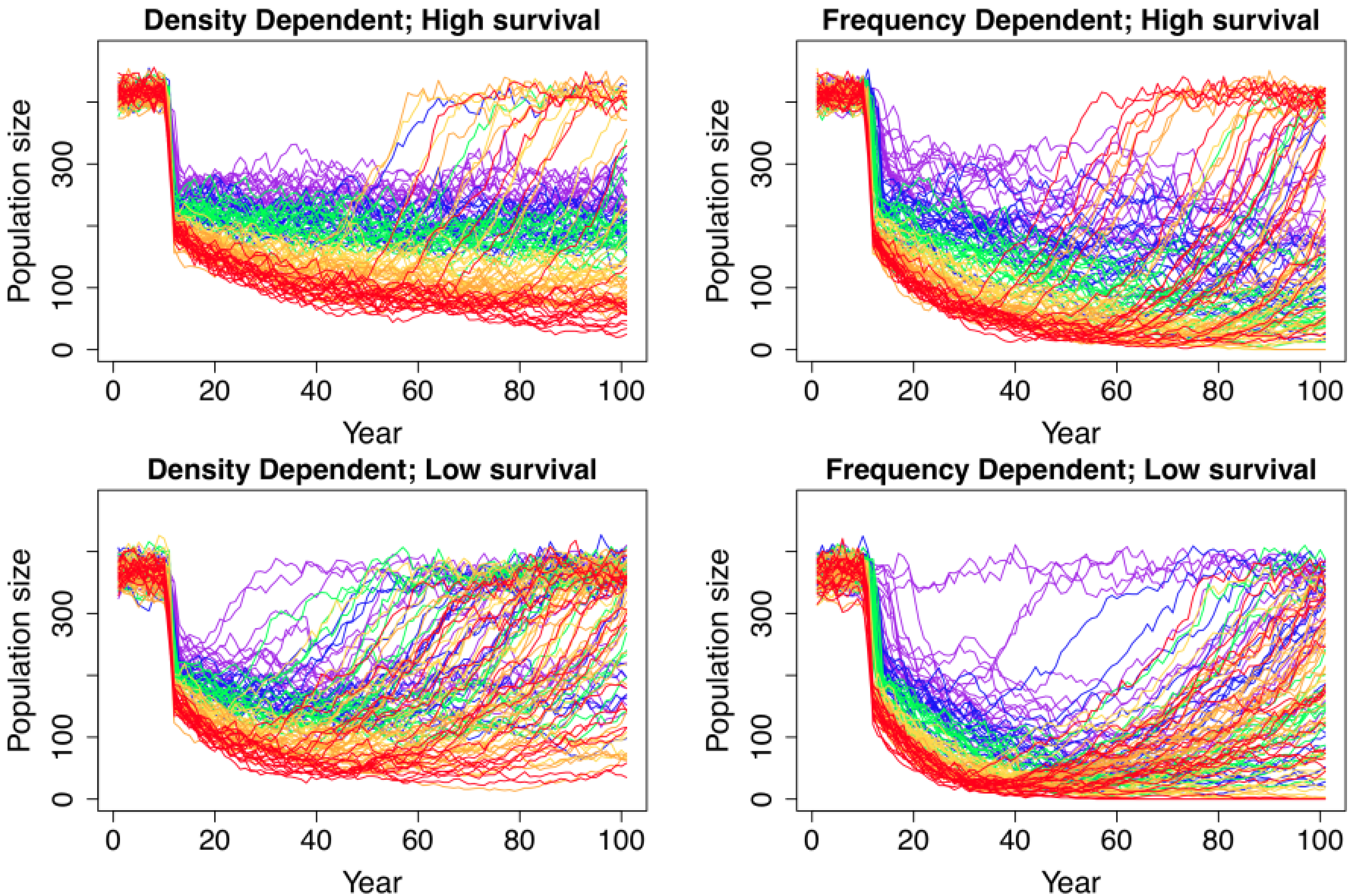


Basic dynamics





Basic dynamics



Management Tools

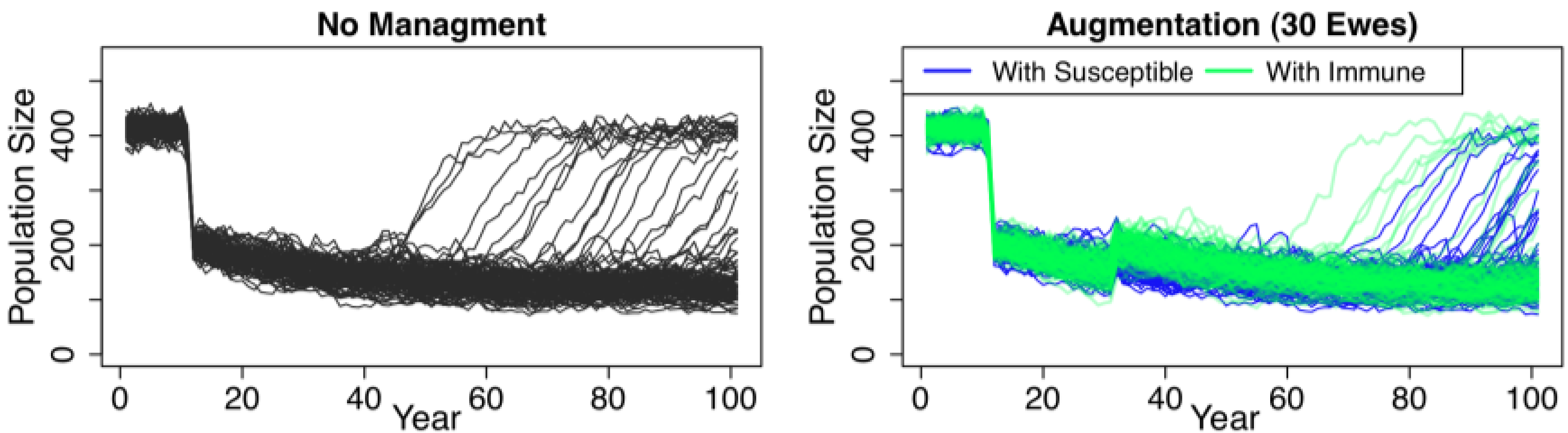
- Augmentation
- Test and cull
- Density reduction (non-selective cull)
- Depopulation and reintroduction

*Focused on transmission, not resiliency

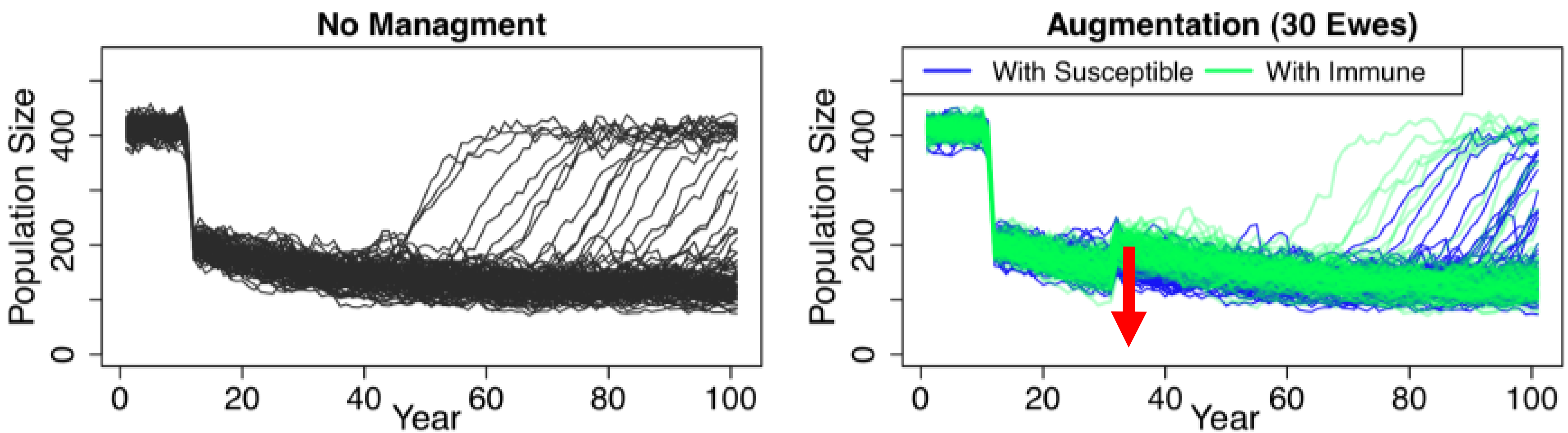
Augmentation

- Scenario 1: Add 30 ewes that are immune to the recipient herd's strain of Movi
- Scenario 2: Add 30 susceptible ewes to the recipient herd

Augmentation



Augmentation



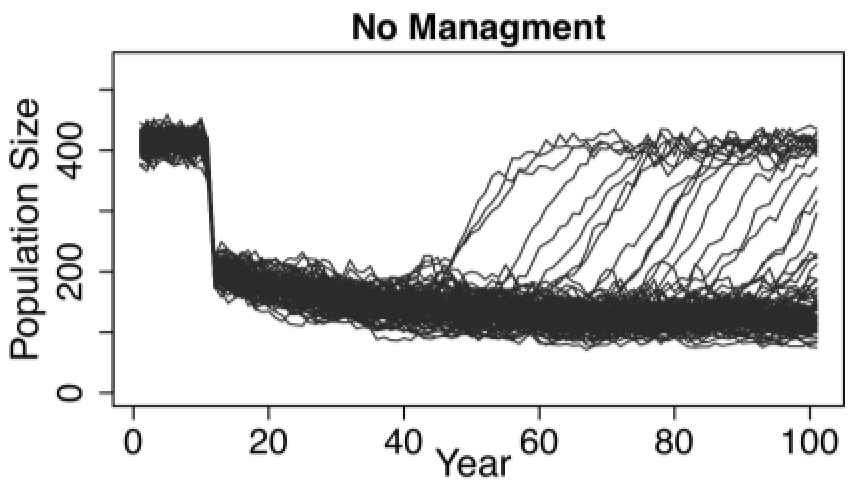
- Does not improve recovery
- What if strain typing doesn’t identify epitope variation?

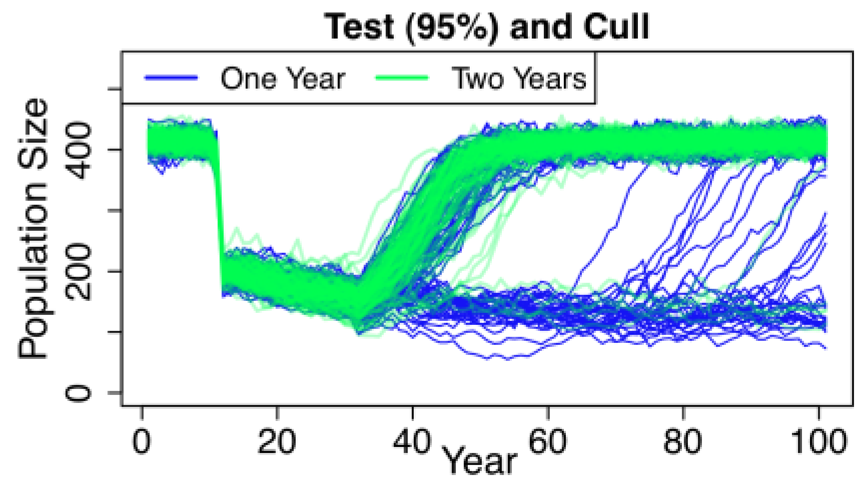
Test and Cull

- Scenario 1: Capture and test 95% of the herd and remove any individual testing positive (infectious or carriers) for Movi

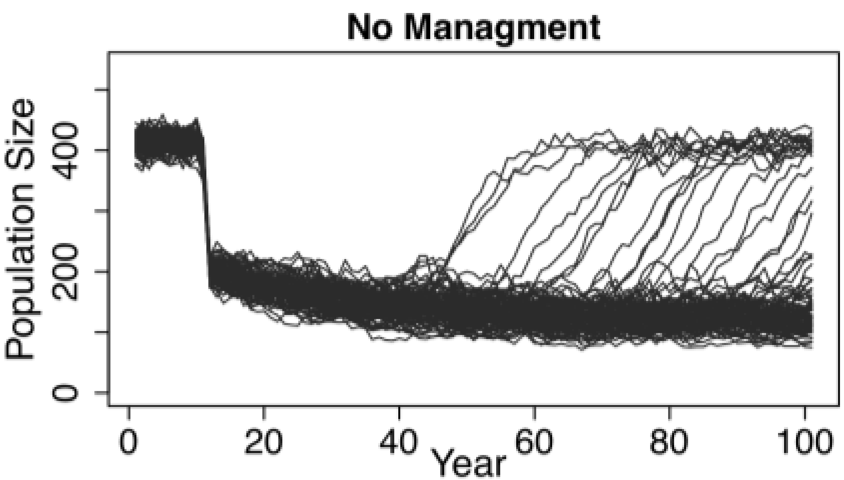
- Scenario 2: Repeat above for a total of two consecutive years

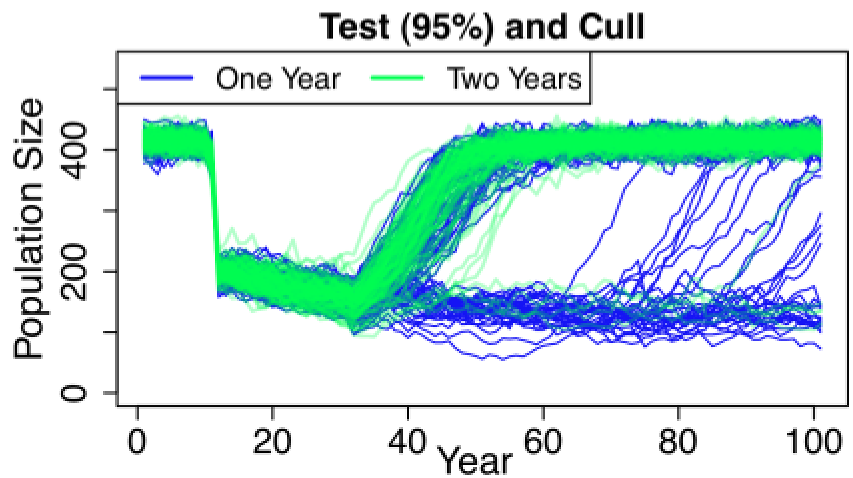
Test and Cull





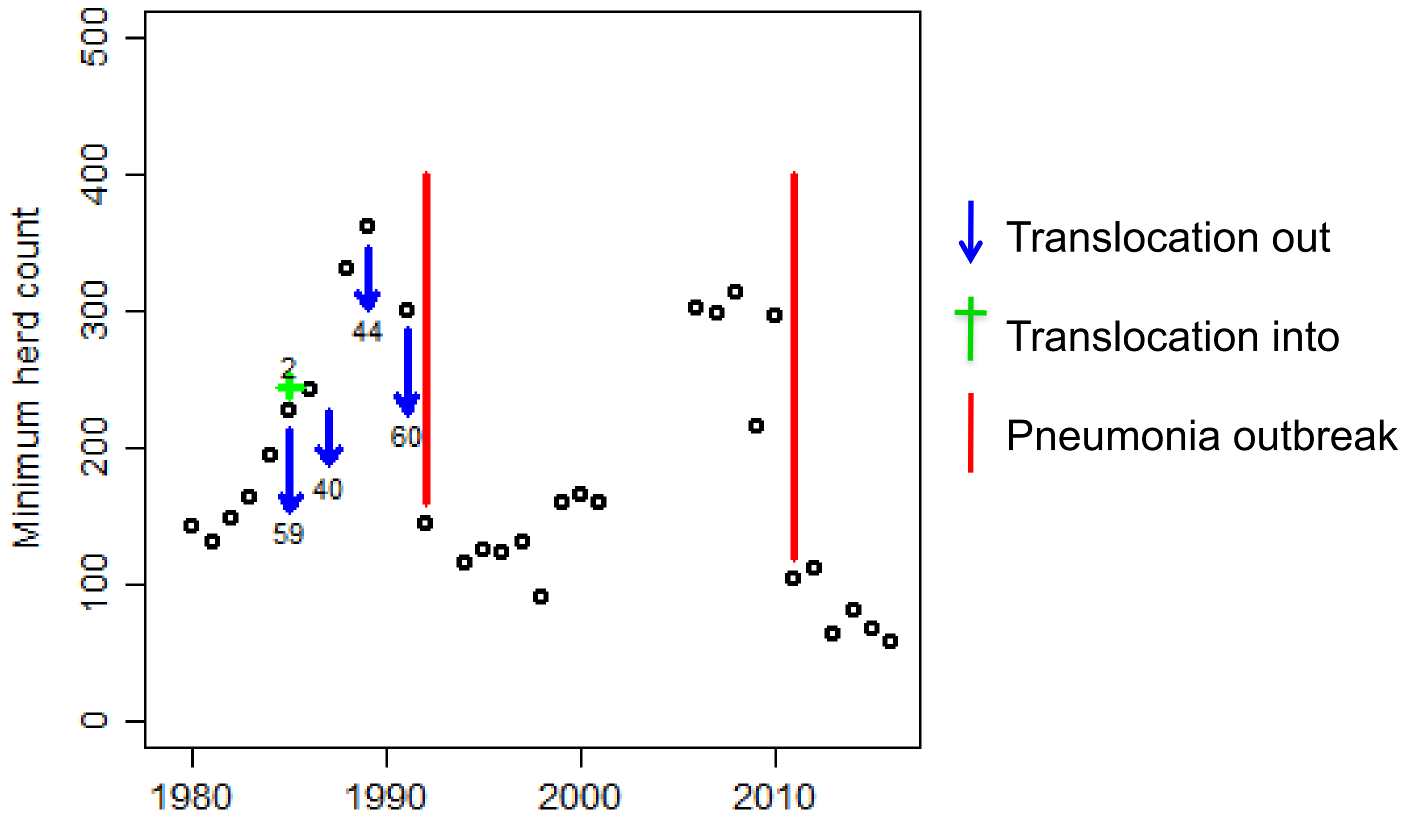
Test and Cull





- Assumes you can't detect "exposed" individuals
- Success is improved by repeating test and cull for 2 years

Density Reduction



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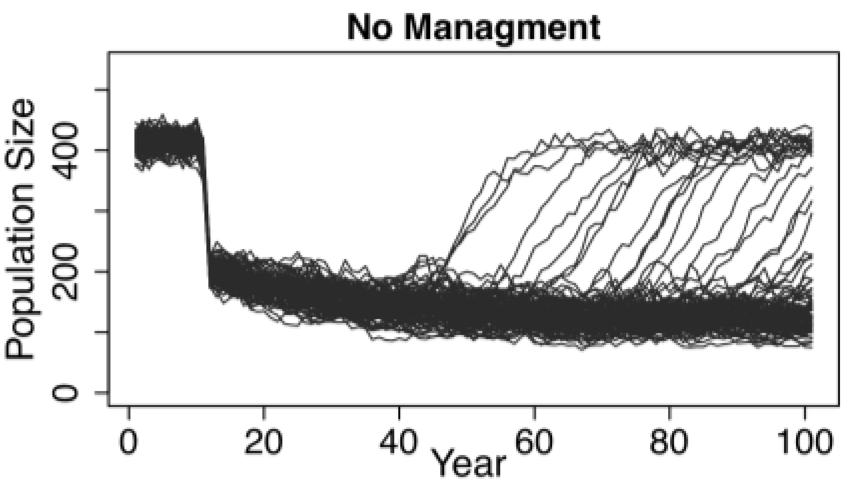
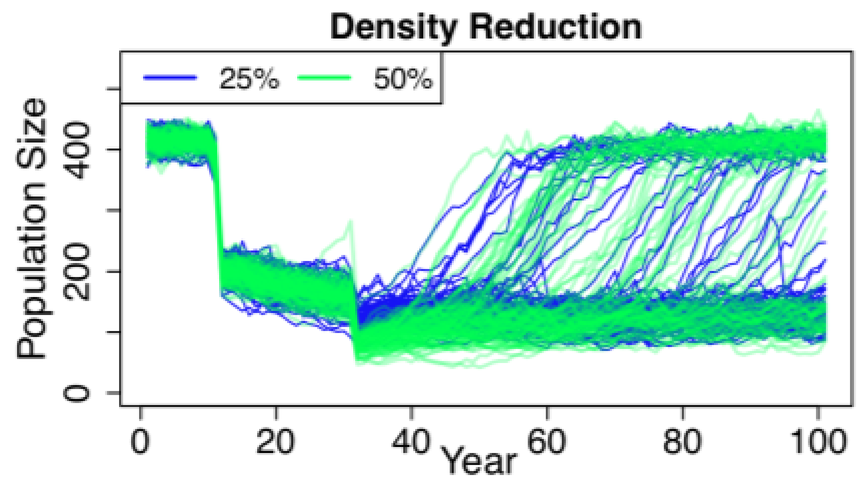
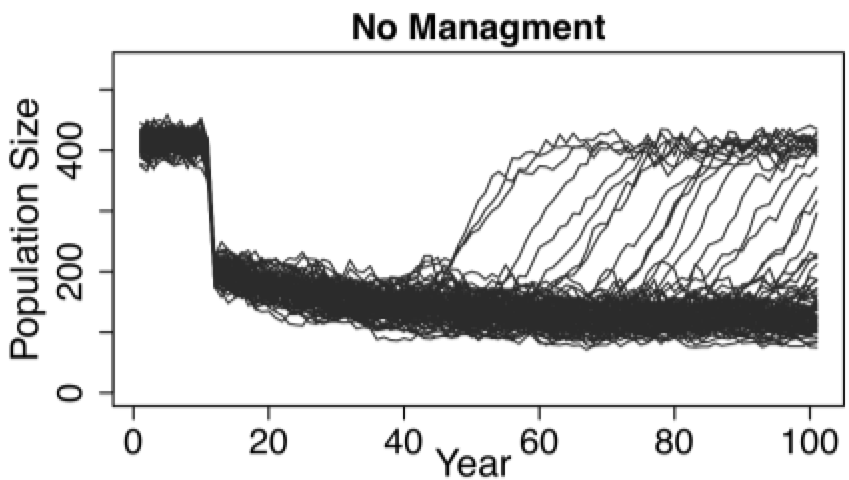
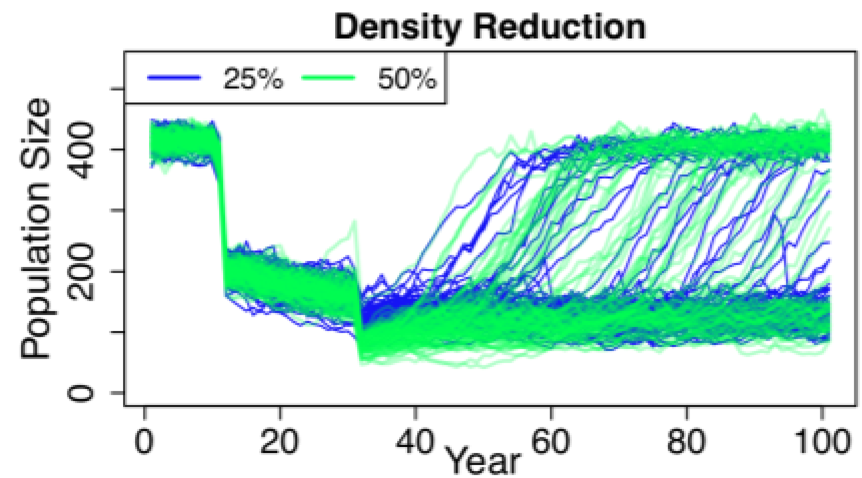




Density Reduction





- Stochastic removal of exposed, infected, and carrier individuals
- If transmission is density dependent, may slow rate of new infections

Depopulation and Reintroduction

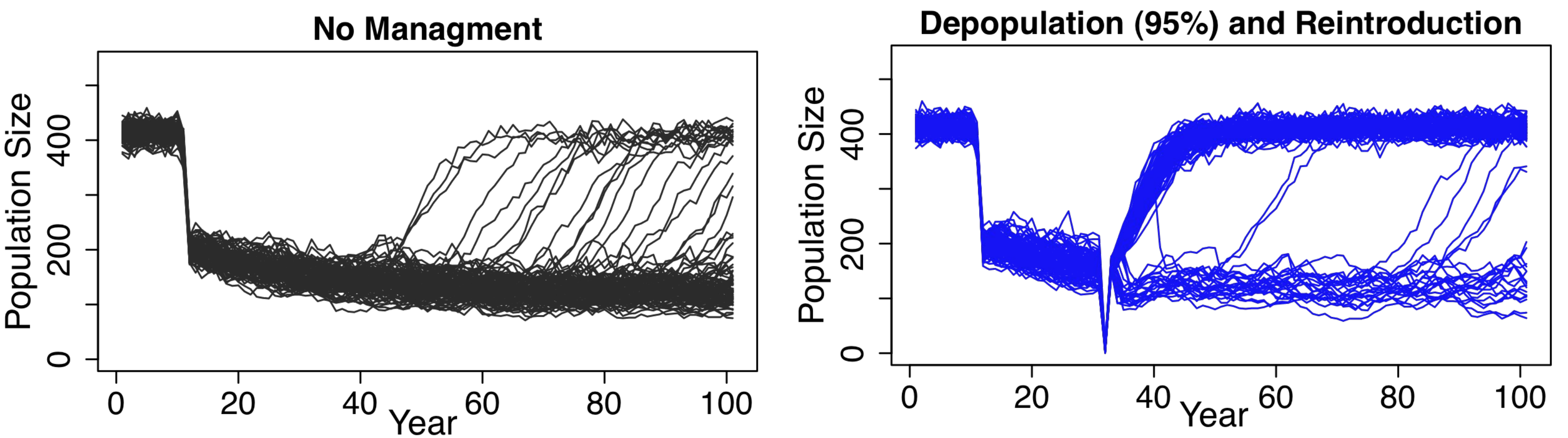
Tendoy Mountains

Bighorn sheep herd in Montana's Tendoy Mountains targeted

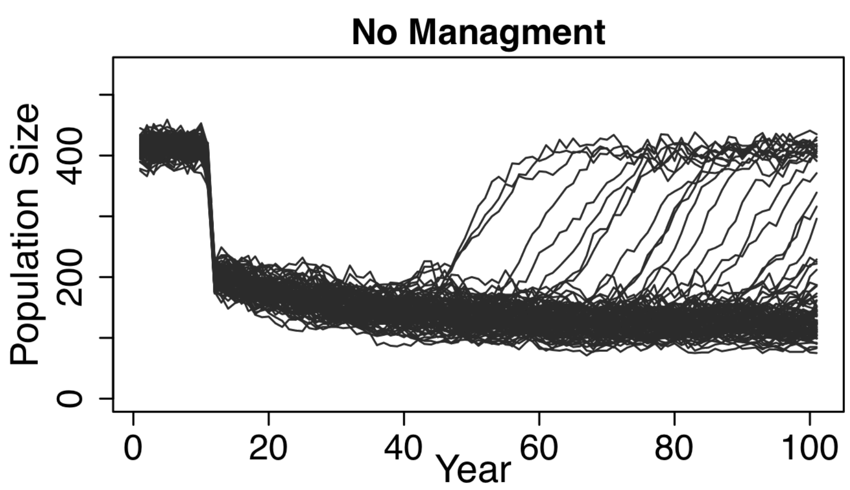
Jul 12, 2015 1

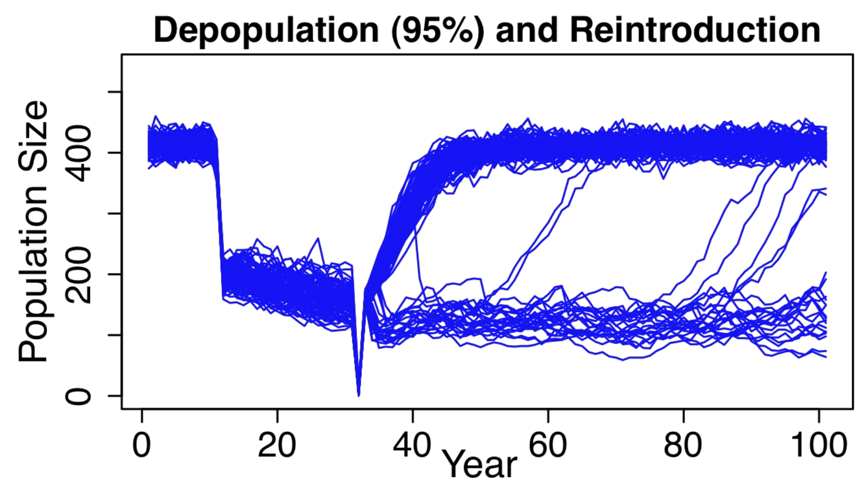
- Ideally, depopulation = 100% removal
- What if we are only able to remove 95% of the herd?

Depopulation and Reintroduction

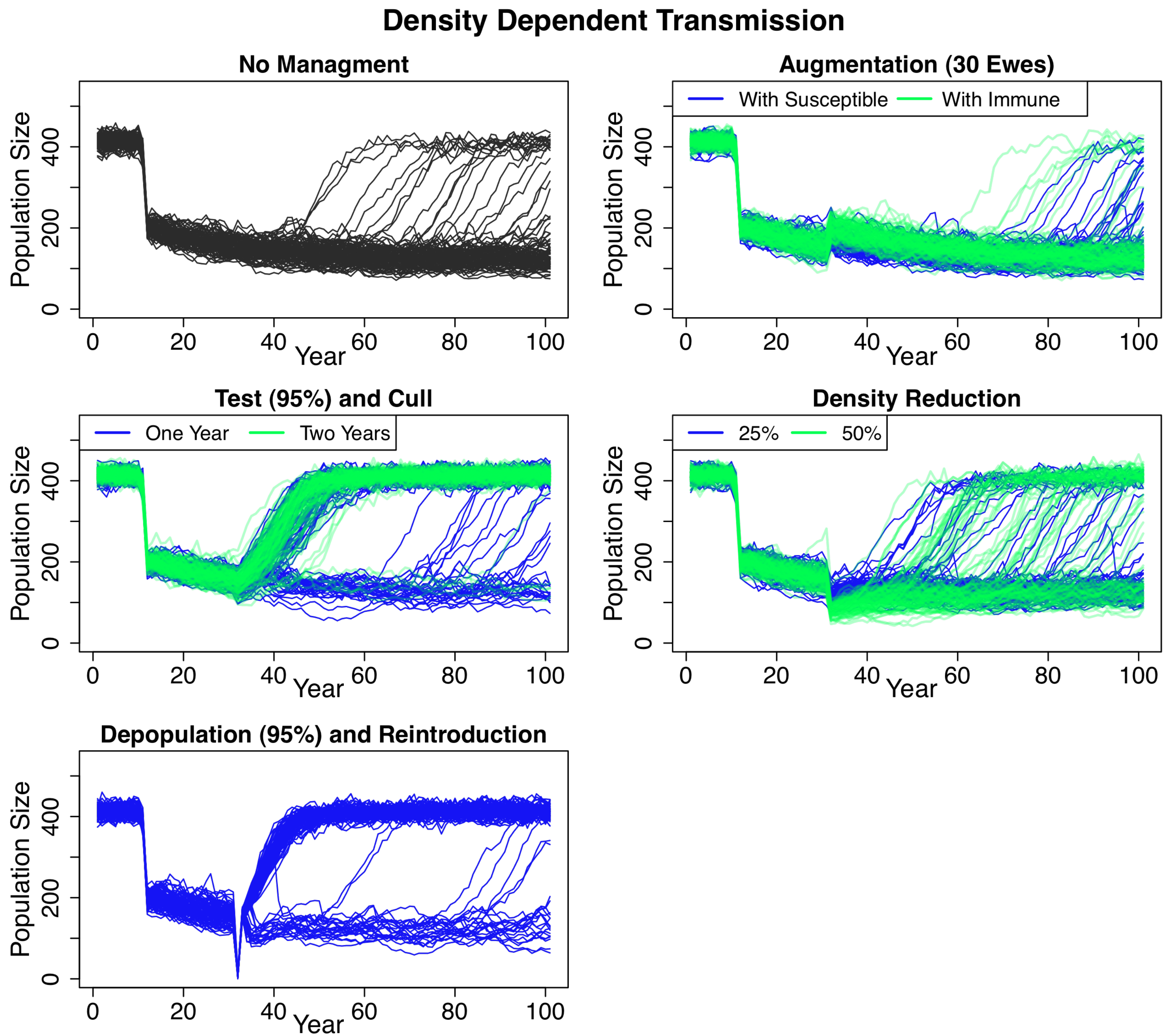


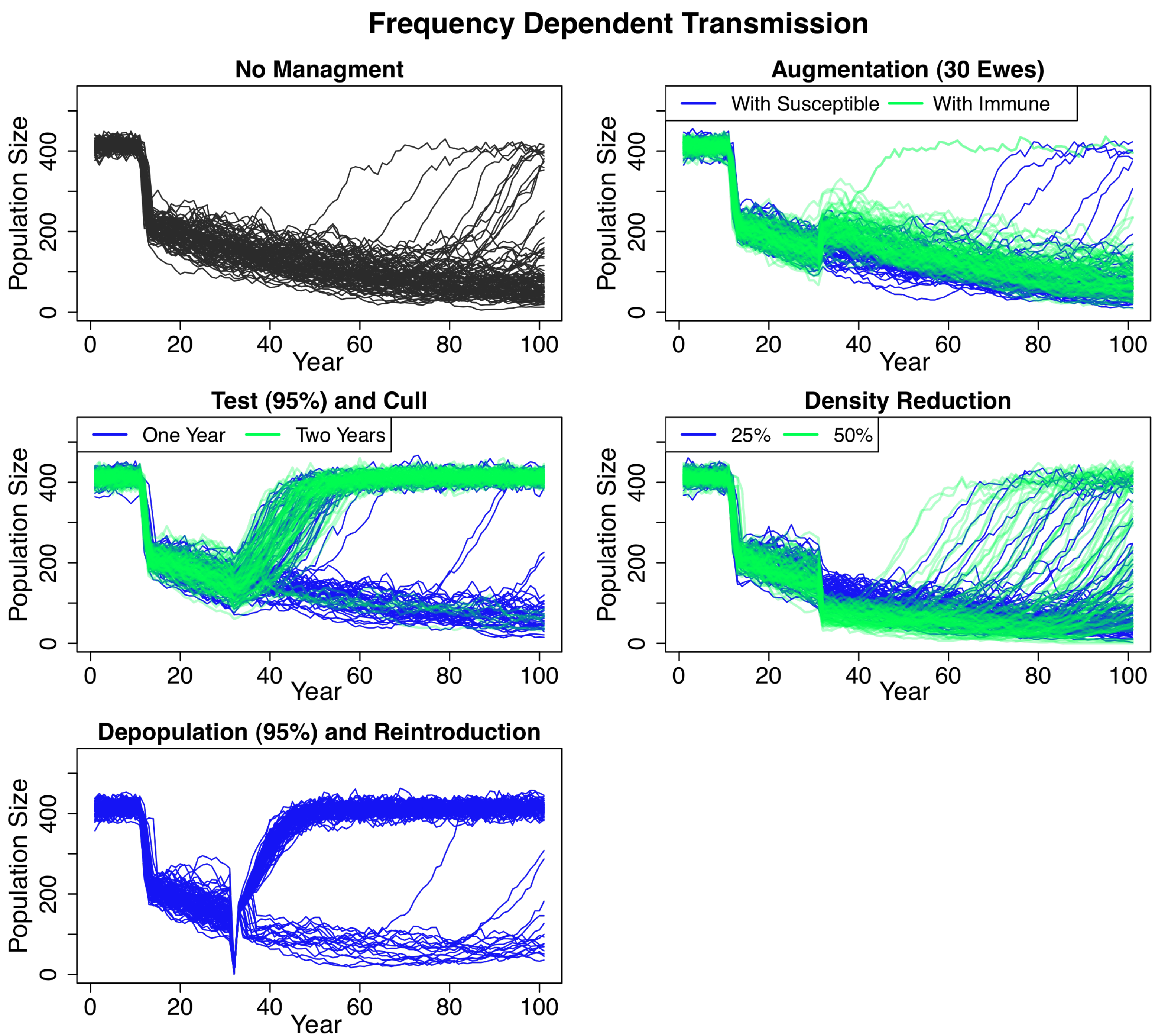
Depopulation and Reintroduction





- Ability to find sufficient numbers of “clean” sheep?
- How long does it take to completely depopulate?


Density Dependent Transmission
No Managment
Population Size
Year
Augmentation (30 Ewes)
With Susceptible
With Immune
Test (95%) and Cull
One Year
Two Years
Density Reduction
25%
50%
Depopulation (95%) and Reintroduction
0
200
400
0
20
40
60
80
100



Frequency Dependent Transmission
No Managment
Augmentation (30 Ewes)
With Susceptible
With Immune
Test (95%) and Cull
One Year
Two Years
Density Reduction
25%
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Depopulation (95%) and Reintroduction
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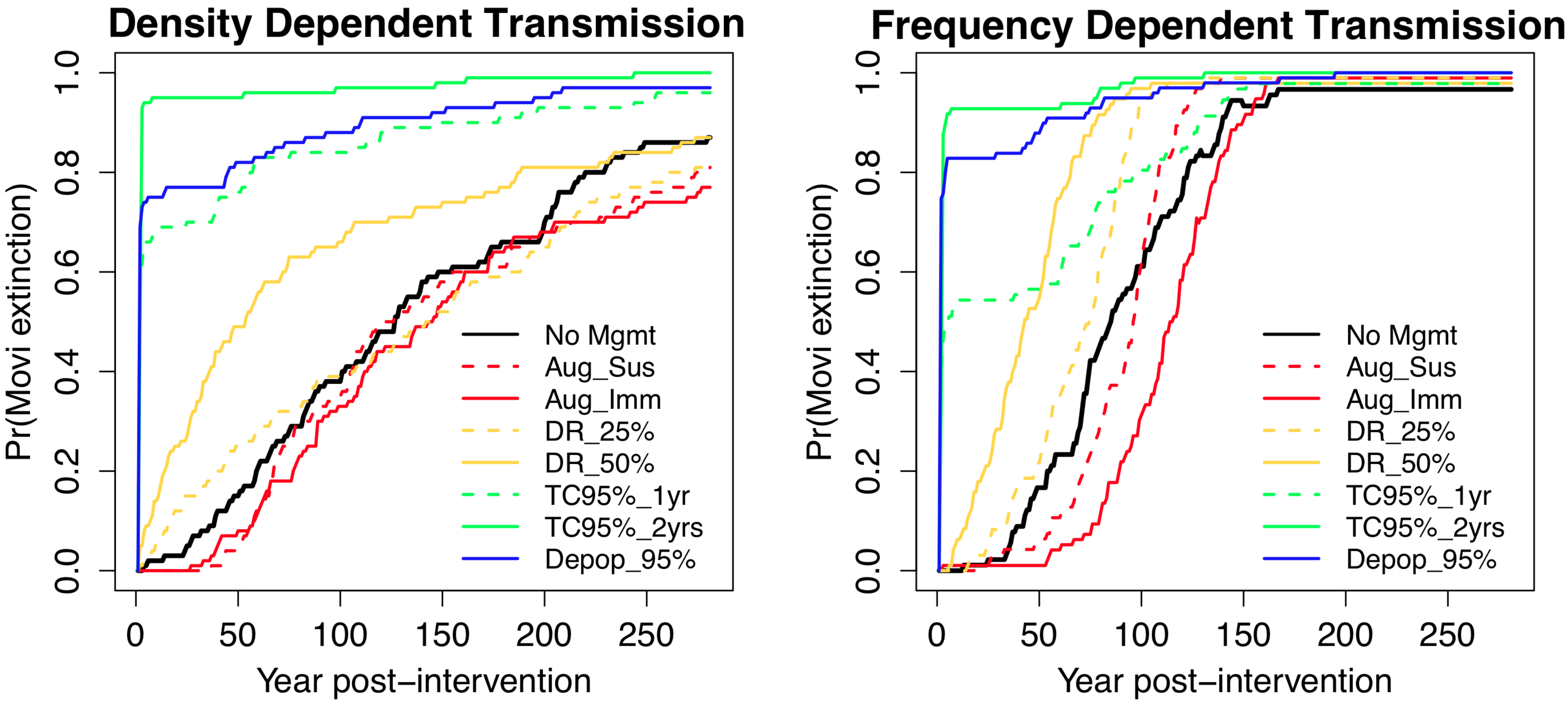
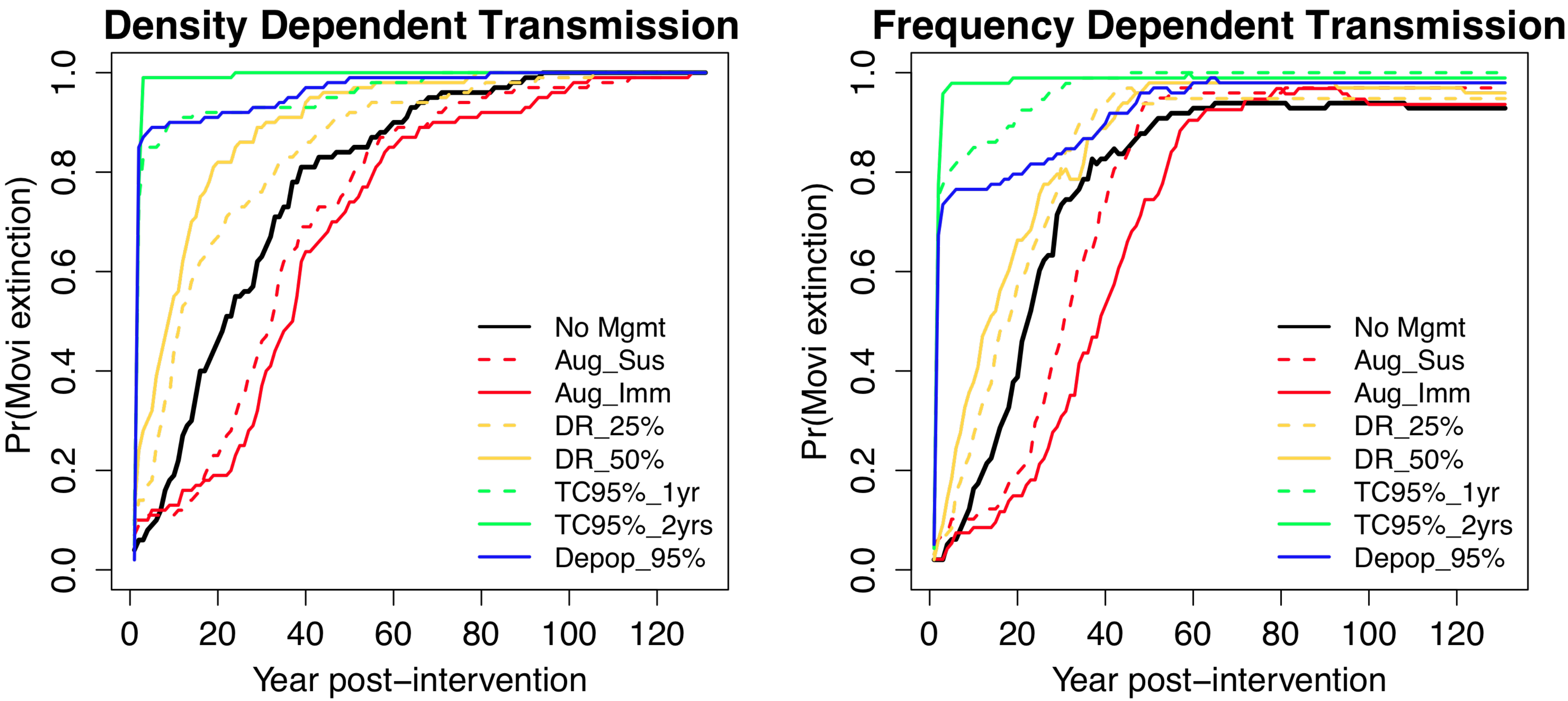
Probability of Movi extinction



*Assuming high host survival

Probability of Movi extinction



*Assuming low host survival; note shorter time scale

Conclusions

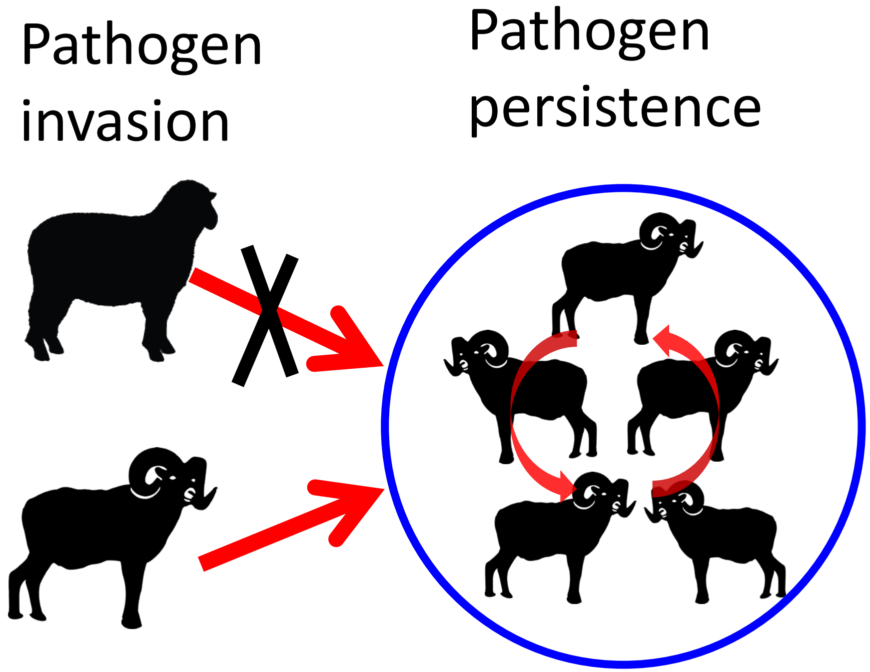
- Augmentation not predicted to help
- Density reduction offers small improvement
  - Added risk of inbreeding depression, Allee affects
- Test and cull and depopulation predicted to offer best probability of recovery
  - Must test or depopulate large portion of herd
- Shinny app

Caveats

- Model results are preliminary—still need full sensitivity analysis
- Different measures of “success” and acceptability
  - Speed/probability of population recovery
  - Management costs
  - Values
- Timescales
  - Action vs waiting?
  - Waiting is complicated if spillover risk continues

Management must address entire picture to make progress

- Prevention is still best practice




Adrian Sanchez-Gonzalez