An Agent-Based Model of Golden Eagle Predation on the Santa Cruz Island Fox

Annual Symposium on BEER

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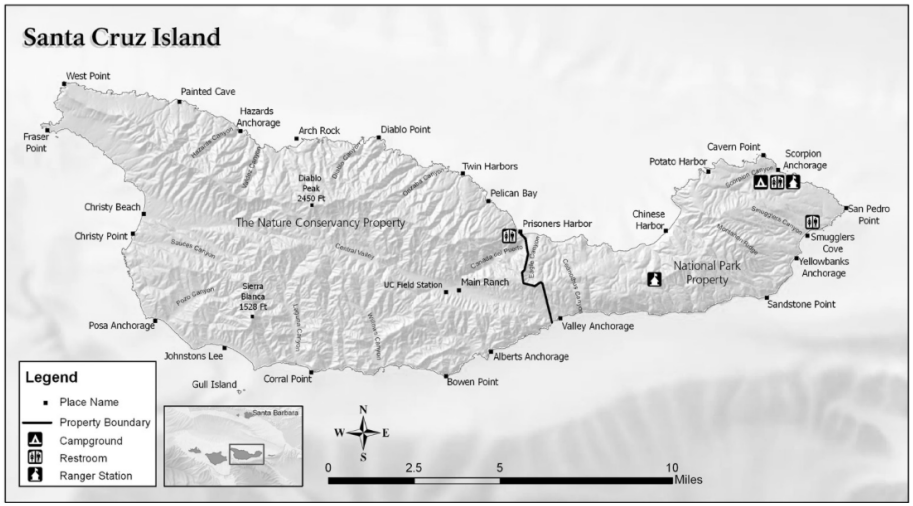
Overview

1. Background
2. Methods
3. Model
4. Results
5. Conclusions

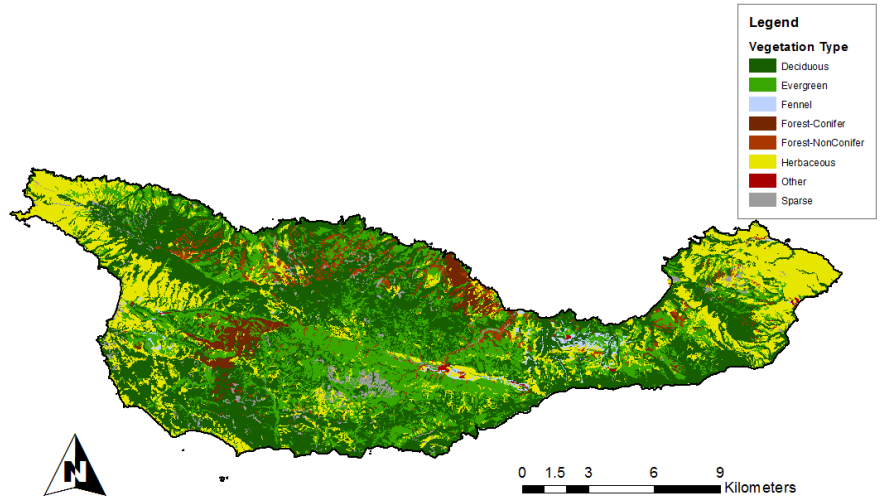
Santa Cruz Island

- California Channel Islands
- 250 km^2
- Joint ownership
  - Nature Conservancy
  - National Park Service
- Species diversity: depauperate



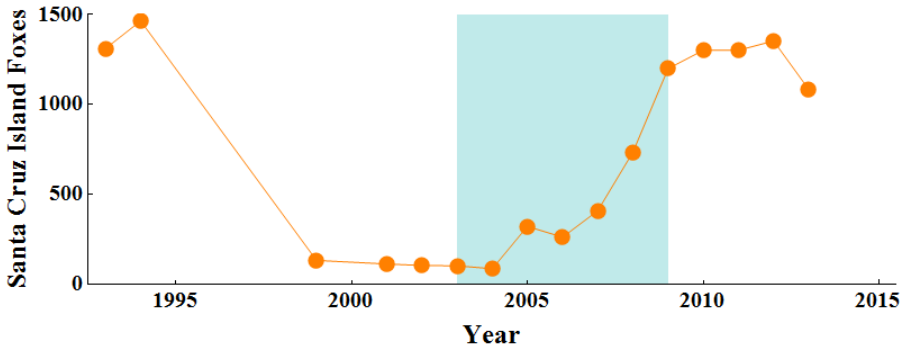
The Santa Cruz Island Fox (*Urocyon littoralis santacruzae*)

- Descendants of the mainland grey fox
- Monogamous
- Territorial – territory size dependent on vegetation
- Endangerment status



Reasons for Population Decline

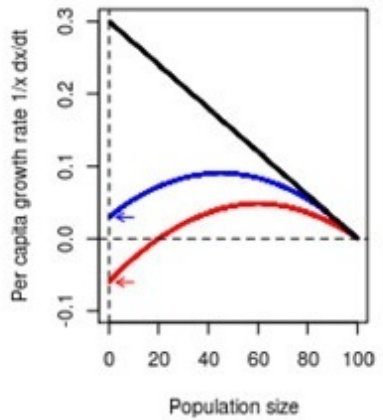
Decline & Recovery of the SC Island Fox



Golden Eagle Predation

Island Spotted Skunk Competition

Rabies & Canine Distemper Virus

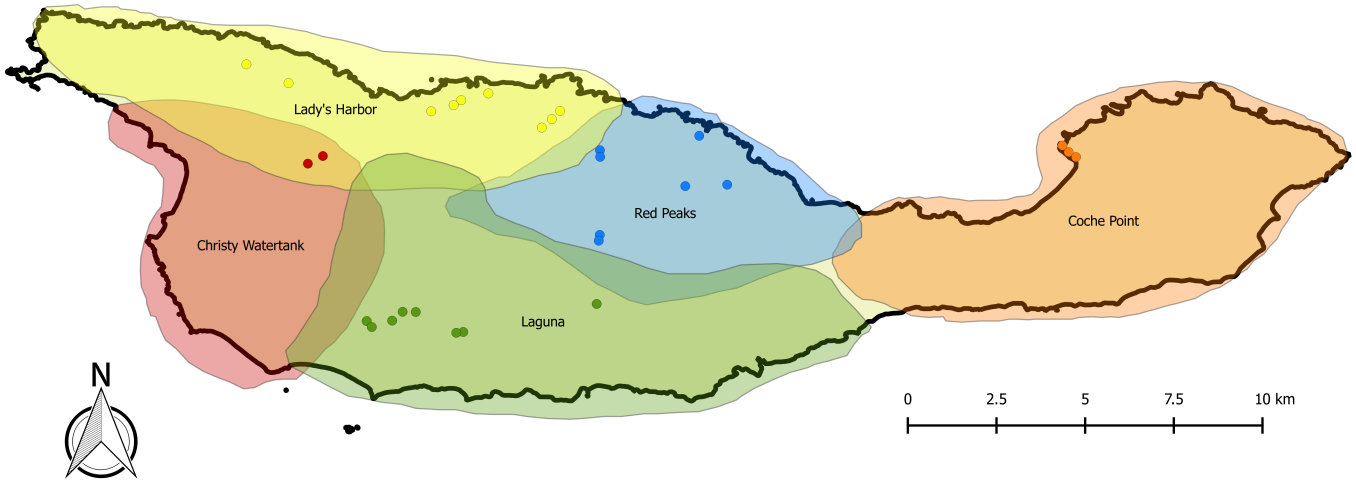


Allee Effect

The Golden Eagle (*Aquila chryseatos*)

- Introduced to Santa Cruz Island after bald eagle migration
- Dual-territorial
- Dietary Biology
- Conservation status

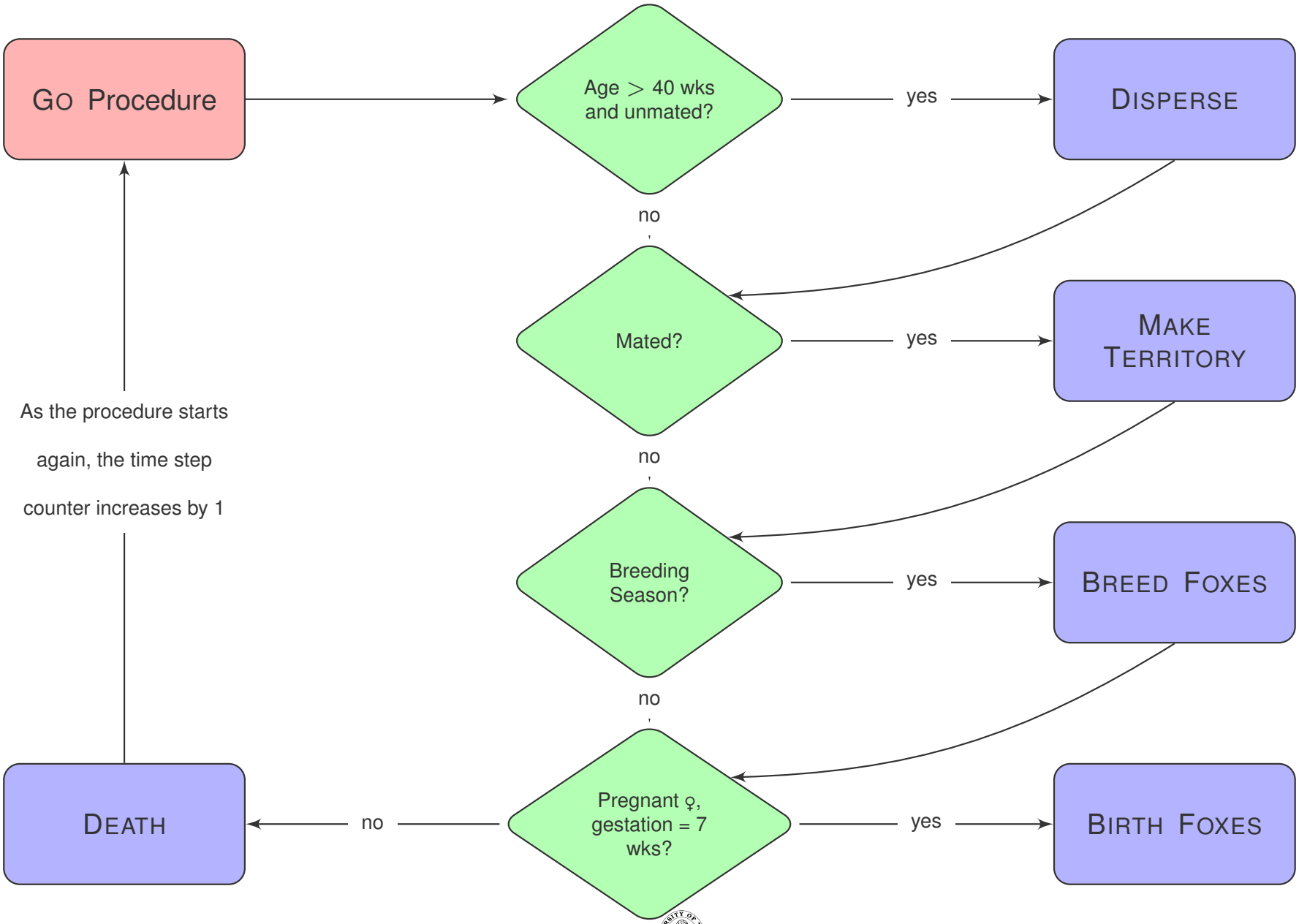
Methods



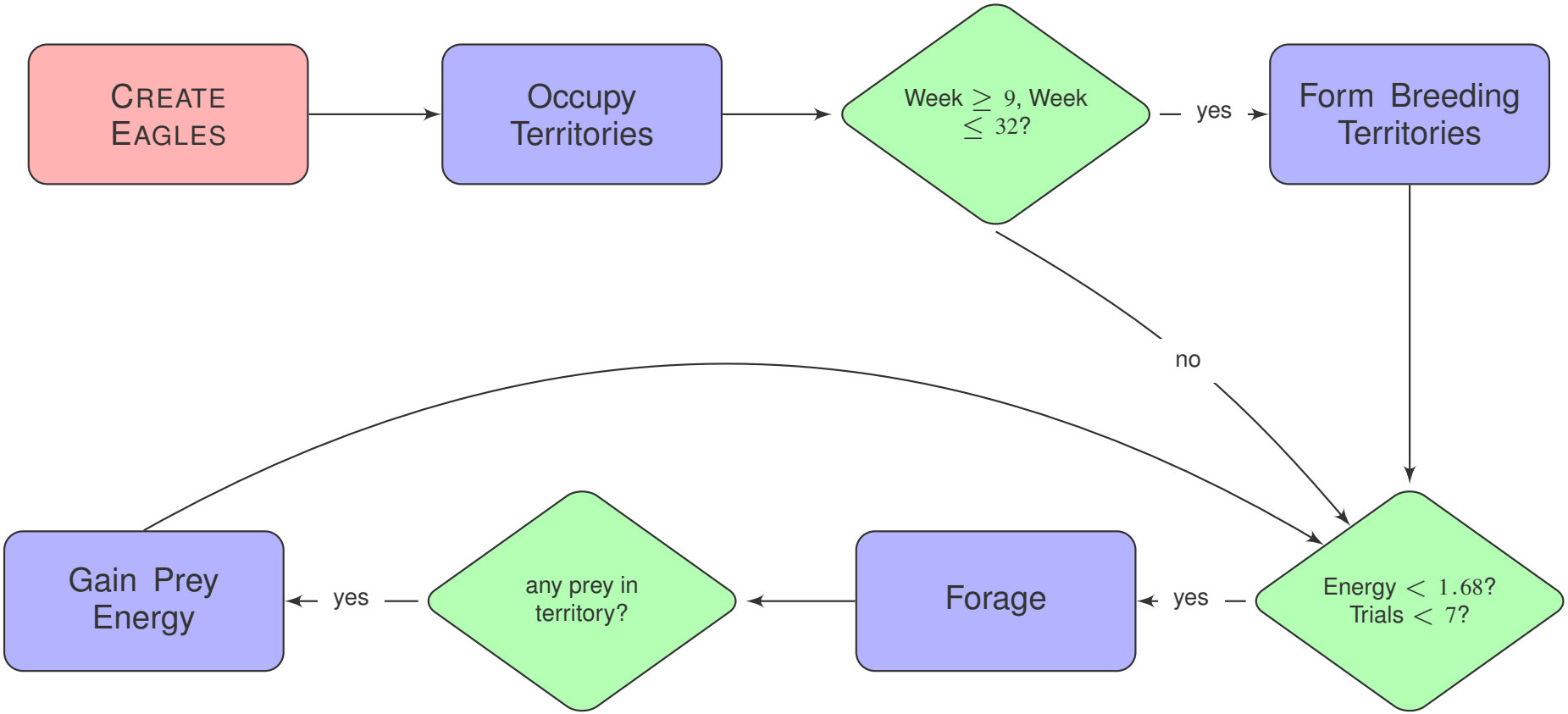
- **Objective**: Appropriately simulate the population dynamics of the Santa Cruz Island fox under predation of the golden eagle.
- **Tools**: Netlogo and QGIS.

- **Agent-Based Models**: A class of mathematical and computational models in which individuals (or agents) are unique and autonomous entities that can interact with other individuals and also with their environment.

The Fox Model

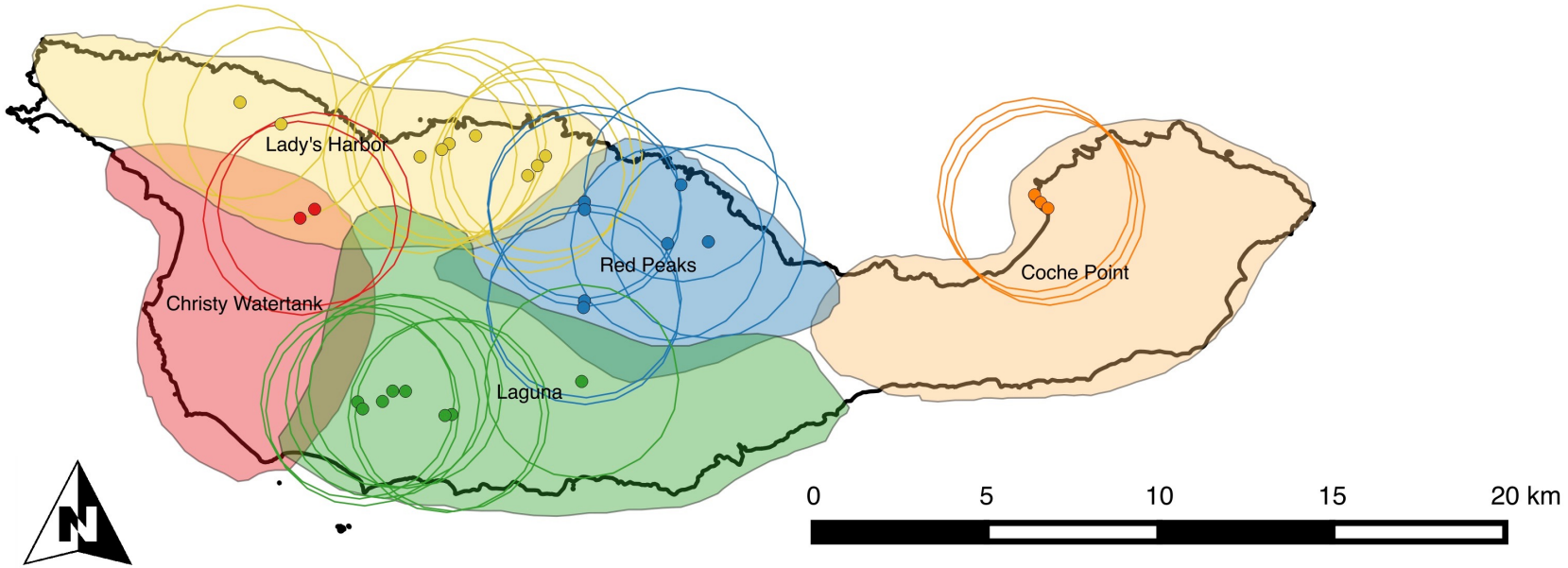


The Eagle Model



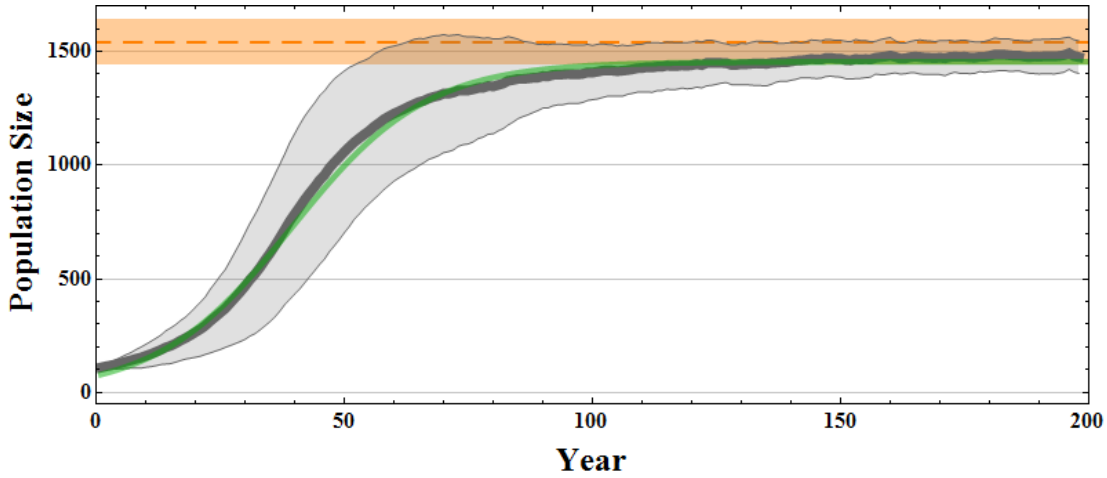
Eagle Territoriality

This is a map of the eagle hunting and breeding territories within our ABM. At the beginning of each breeding season, one of the nests is chosen and the breeding territory is created around this nest.



Fox Population Growth

The following graphs present the population size over many model simulations without golden eagle predation.



Model for Logistic Growth Data

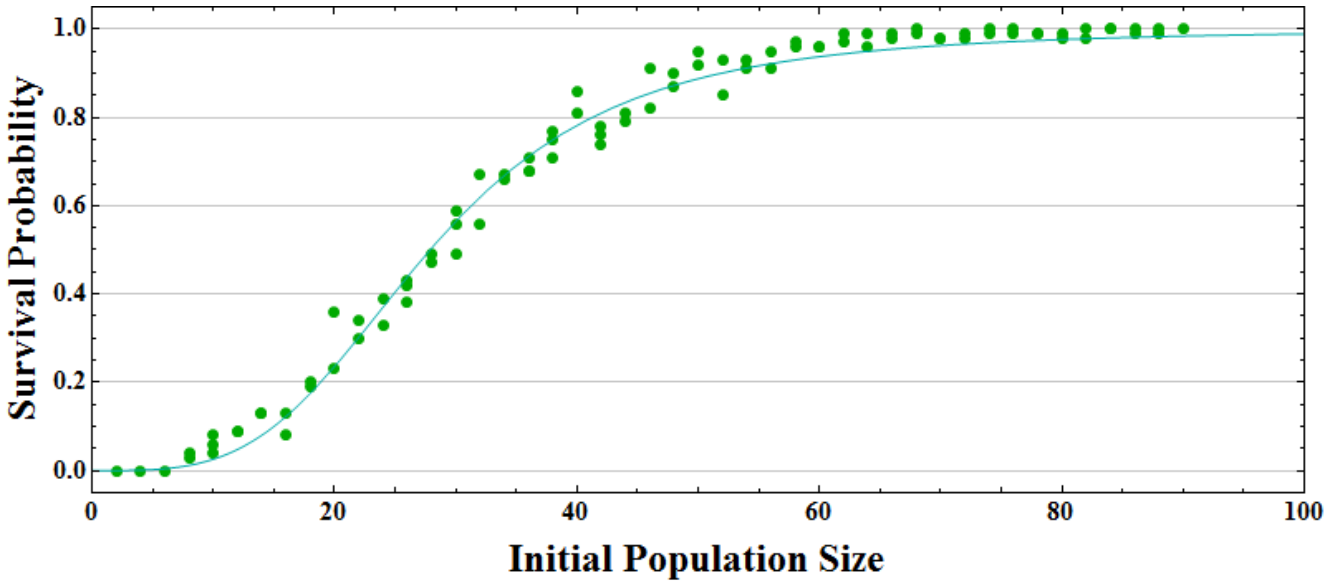
$$N(t) = \frac{KN_0e^{rt}}{K + N_0(e^{rt} - 1)}$$

$$r = 0.0744, k = 1457, P_0 = 80$$

This is a logistic growth curve.

The model's parameter values were found using the `FindFit` function in Mathematica.

Survival Probability without Predation



Model for Survival Probability Data

$$P(x) = \frac{\alpha x^n}{1+\alpha x^n}$$

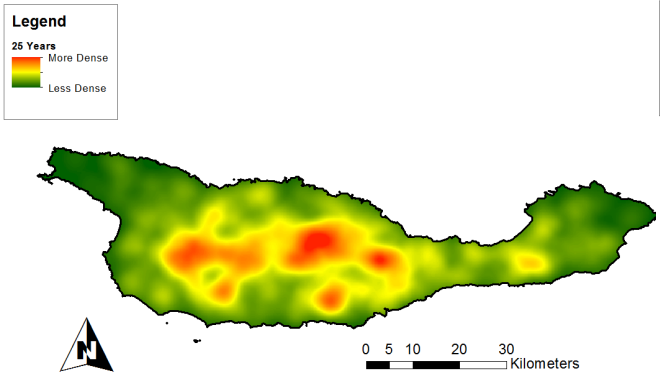
$n = 3.545, \quad \alpha = 7.53 \times 10^{-6}, \quad x =$ initial population size

This is a Holling Type III functional response curve.

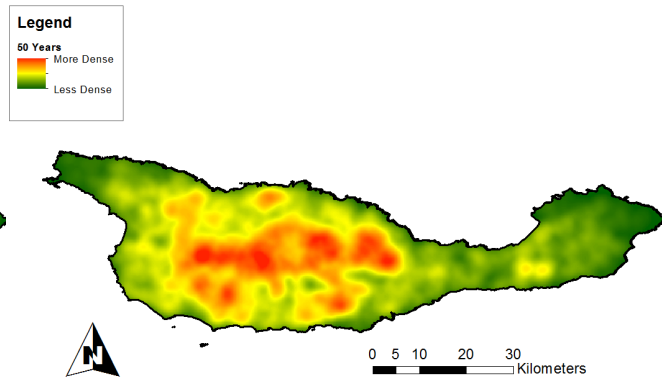
The model's parameter values were found using the `FindFit` function in Mathematica.

Fox Population Density

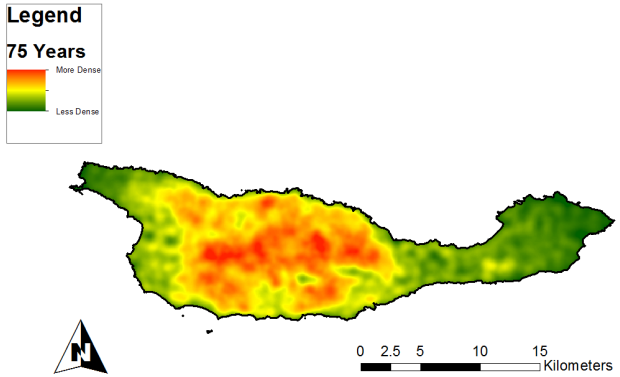
25 Years

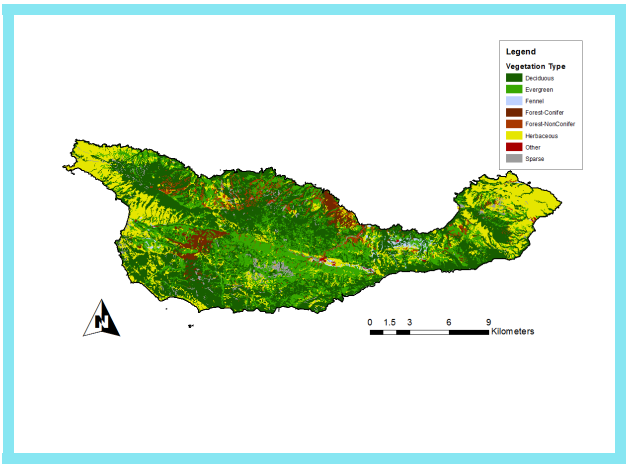


50 Years

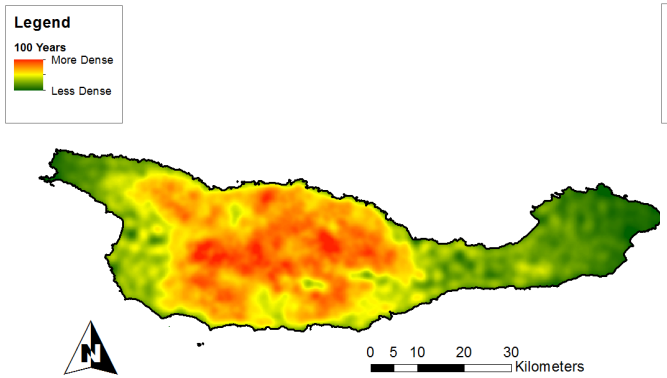


75 Years

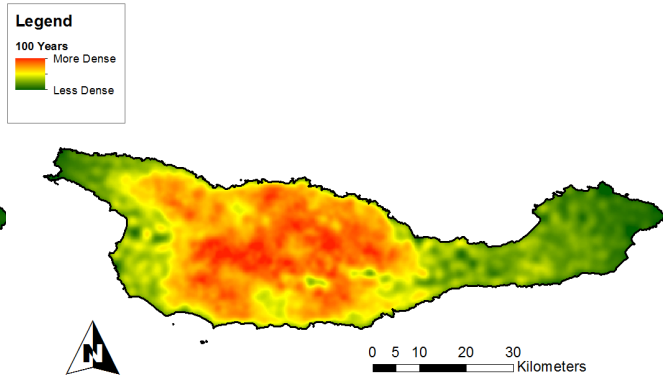




100 Years

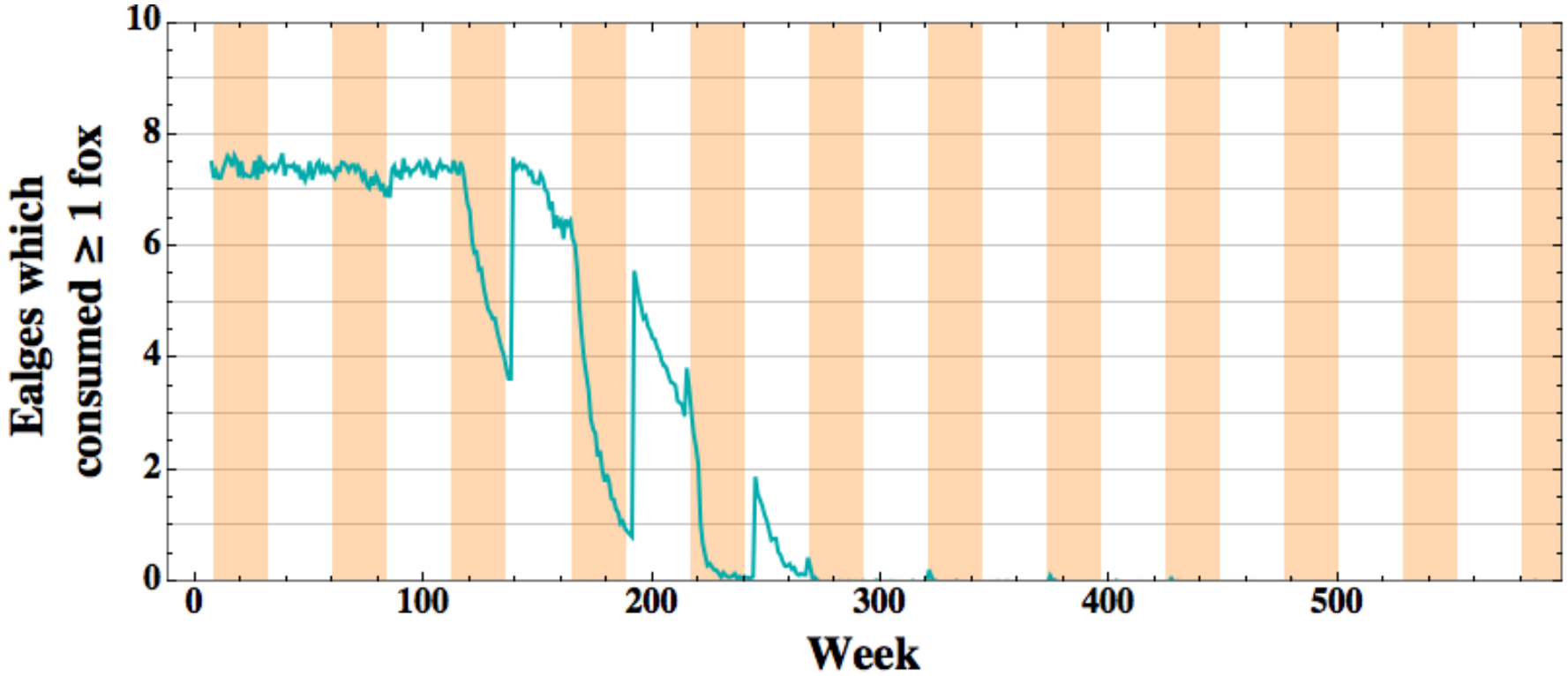


130 Years



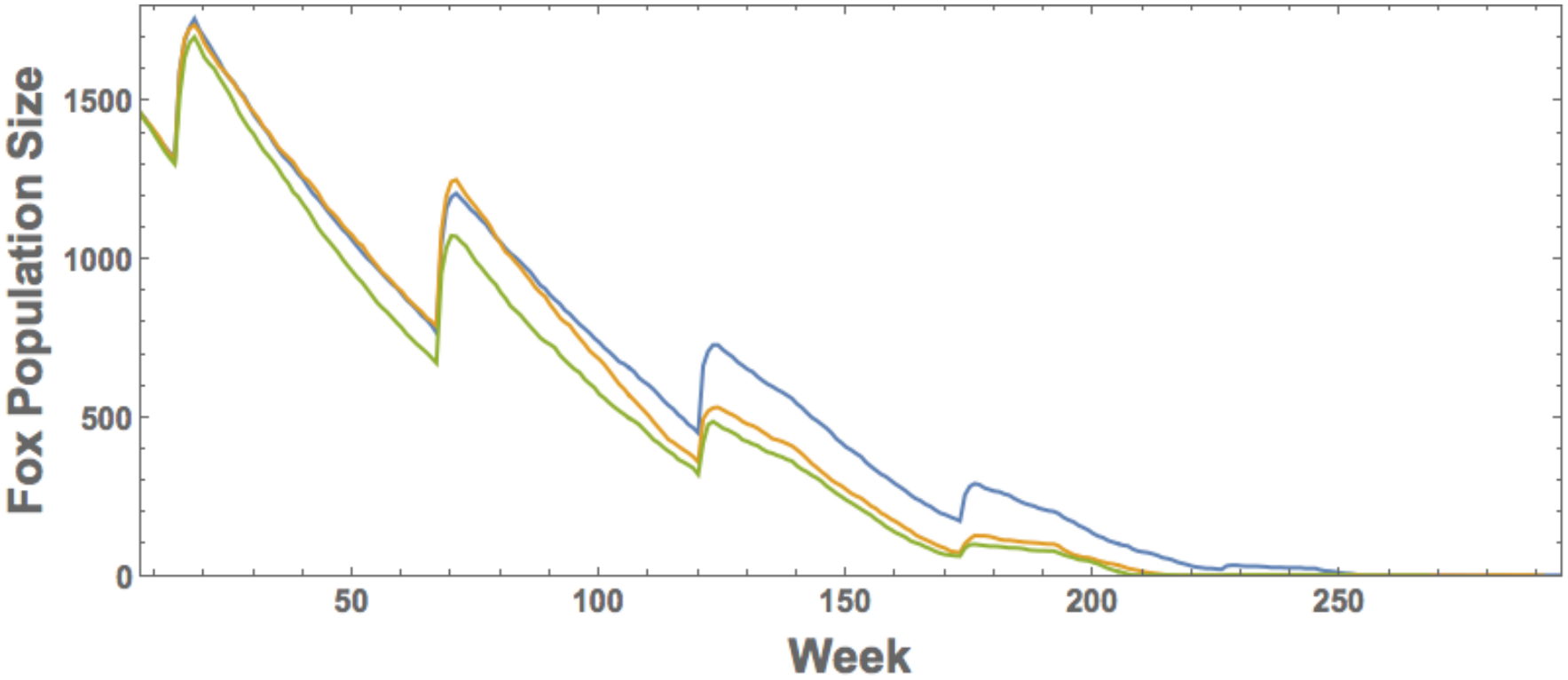
Eagle Consumption of Island Foxes

This graph presents the average number of eagles that consumed at least one fox per week over 200 simulations.

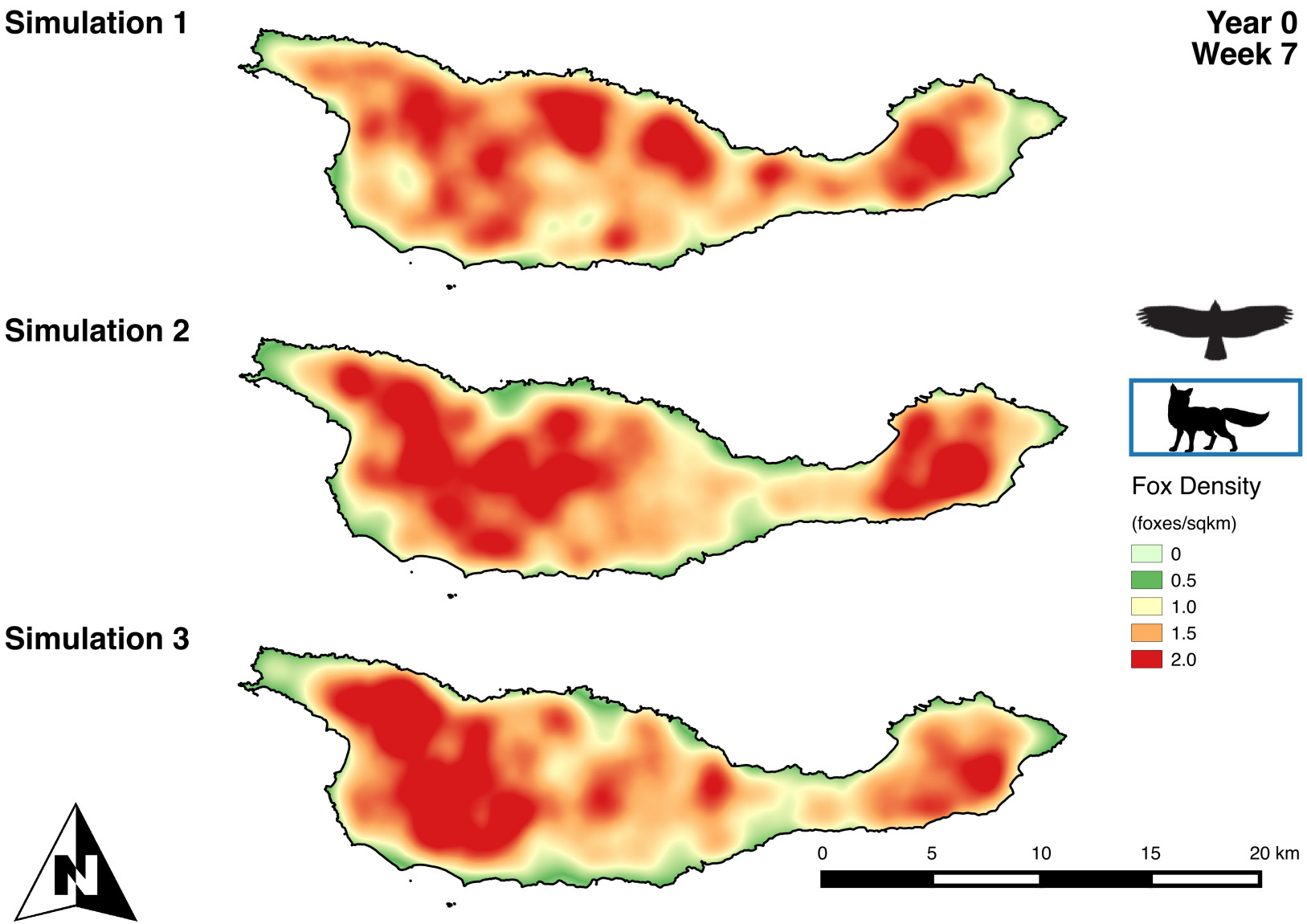


Fox Population Size

This graph presents the population size of the foxes over 3 simulations under golden eagle predation, each persisting for $\approx$ 5 years.

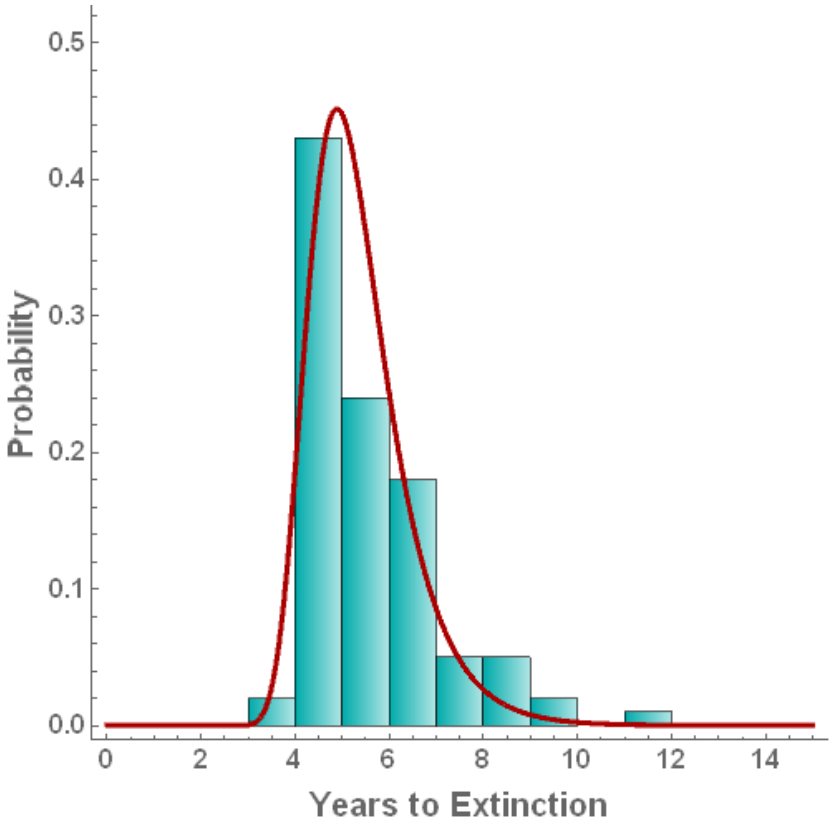


Spatial Distribution of Foxes



Time to Extinction

Under predation, the probability of the fox population going extinct at a given year is shown below.



Extreme Value Distribution

The curve here is best fit to an extreme value distribution with the equation:

$$P(x) = exp(-exp(\frac{\alpha - x}{\beta}) + (\frac{\alpha - x}{\beta}))$$

with α = 25.38 (location parameter) and $\beta = 131.5$ (scale parameter).

Conclusions

Simulations with no golden eagles:

- *Carrying Capacity:* Our model appropriately predicts K = 1457 with an intrinsic growth rate of $r = 0.0744$.
- *Survival Probability:* In the absense of predation, we can predict the probability of survival for different initial population sizes.
- *Fox Population Density:* We predict that the highest density of foxes will occur in the central grassland area of SCI, while lower density will occur in outer areas of mixed vegetation.

Simulations with golden eagles:

- *Eagle Consumption:* With high fox density, breeding season will not affect eagle hunting abilities. At low fox densities, the number of eagles that consume foxes during the breeding season decreases.
- *Spatial Distribution of Foxes:* Under predation, foxes with territories in mixed vegetation persist for longer than those with territories in grassland.
- *Time to Extinction:* The distribution of time to extinction can be approximated by an Extreme Value Distribution with $\mu = 5.41$ years and $\sigma = 1.27$ years.

Future Work

- Current Project
  - Analyze model
  - Complete manuscript
  - Submit for publication
- Future Projects
  - Ph.D.: Ecology and Evolutionary Biology
  - Masters in Statistics
  - NSF GRFP: Methods of parameterizing infectious diseases

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- Annual Symposium on BEER

Thank You!

Any Questions?

Michael Lynch (2007)

"It is well known that most biologists abhor all things mathematical."