Computational Physics Group Project: Ecosystem: predator and prey

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Introduction to eco-system modeling

Simulation and Implementation

Results and discussion

What are Predator Prey models and where are they used?

Systems involving competitive interaction of two "species" are some form of predator prey systems.

They deal with the general loss-win interactions and hence may have applications outside of ecosystems.

Population interaction of predator and prey in eco-system

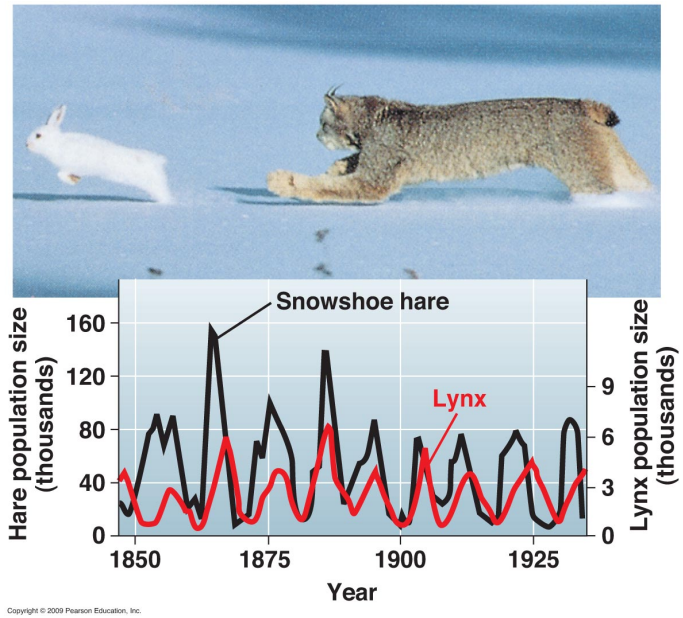

Figure :
http://www.anselm.edu/homepage/jpitocch/genbi101/ecology1intropops.html

A simplified determinisitic mode: L-V equation

The dynamics of biological systems consist of one predator and one prey can be described by Lotka-Volterra (LV) equations:

$$\begin{aligned} \frac{dx}{dt} &= \alpha x - \beta xy = x(\alpha - \beta y) \\ \frac{dy}{dt} &= -\gamma y + \delta xy = -y(\gamma - \delta x) \end{aligned}$$

When the biological system has reached eco-equilibrium, the number of predator and prey are supposed to be either situation below.

$$\begin{aligned} x &= 0, y = 0 \\ or x &= \frac{\gamma}{\delta}, y = \frac{\alpha}{\beta} \end{aligned}$$

Which is, either distinct, or reach a periodic stable situation.

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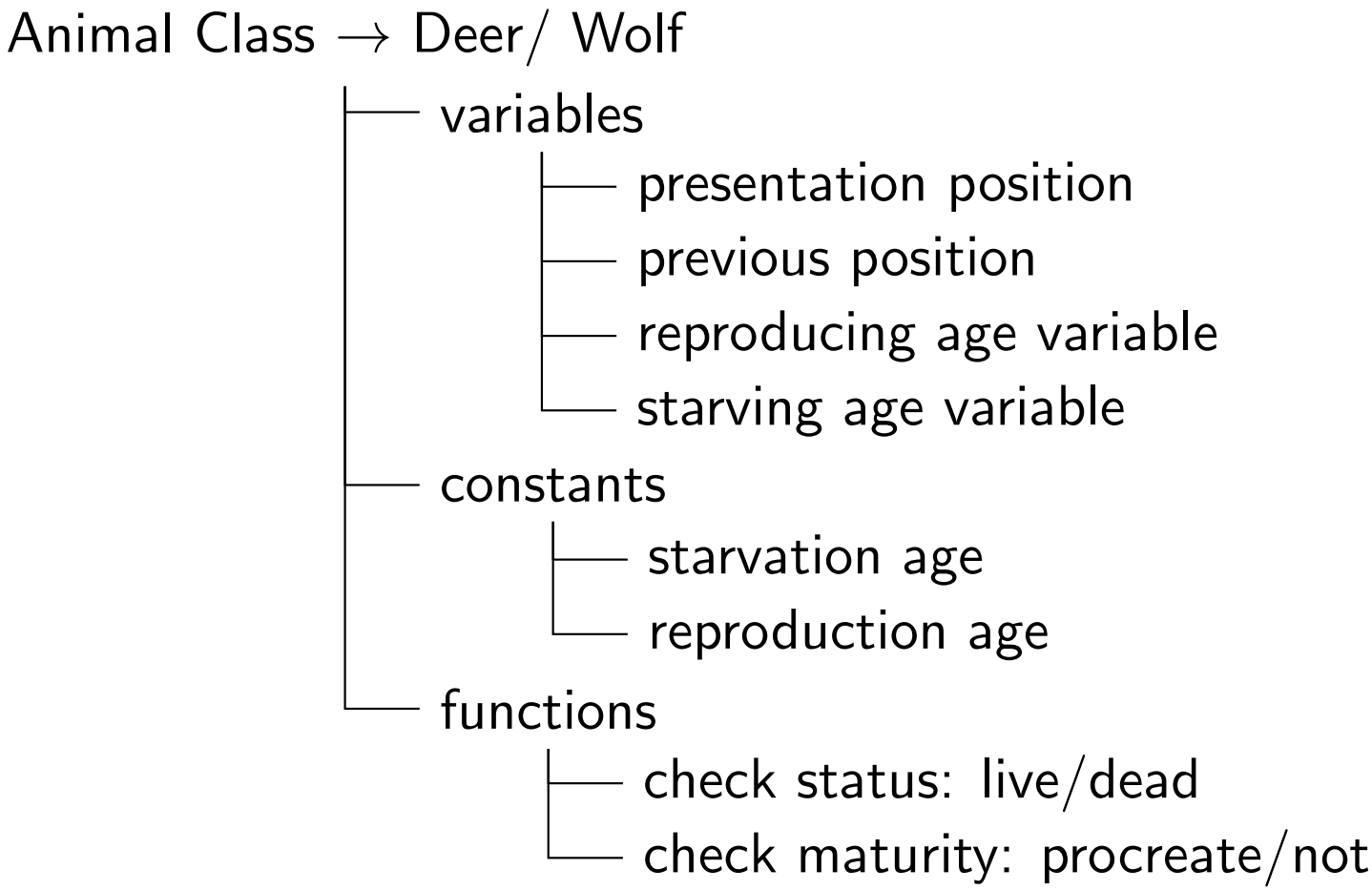
- Predator and prey will die out if maximum age is reached or starved for enough long time
- However, simulation is a random process and change the deterministic nature of LV equation (more realistic).

Structural setup



Structural setup of the code

- Eco-system
  - variables
    - a list of deer
    - a list of wolves
    - occupation matrix (0, 1, 2) $\rightarrow$ (vacant, deer, woof)
    - system time
  - constants
    - Initialisation parameters: world size, starvation ages
  - functions
    - initialisation
    - time evolution

Initialisation

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- Reproduction age of predators must be larger than their starvation age. (Or else wolf can sustain themselves ...)
- Starvation age of the deer is extremely large. (Always enough plants!)
- A realistic population always have some age structures, so we use a uniform initial age distribution for the animals.

Evolution of Wolves

We set up a $N \times N$ grid and simulate the eco-system with L-V equation.

- Step 1: check wolf and deer population, increase its age, and see whether a single animal has starved to death.

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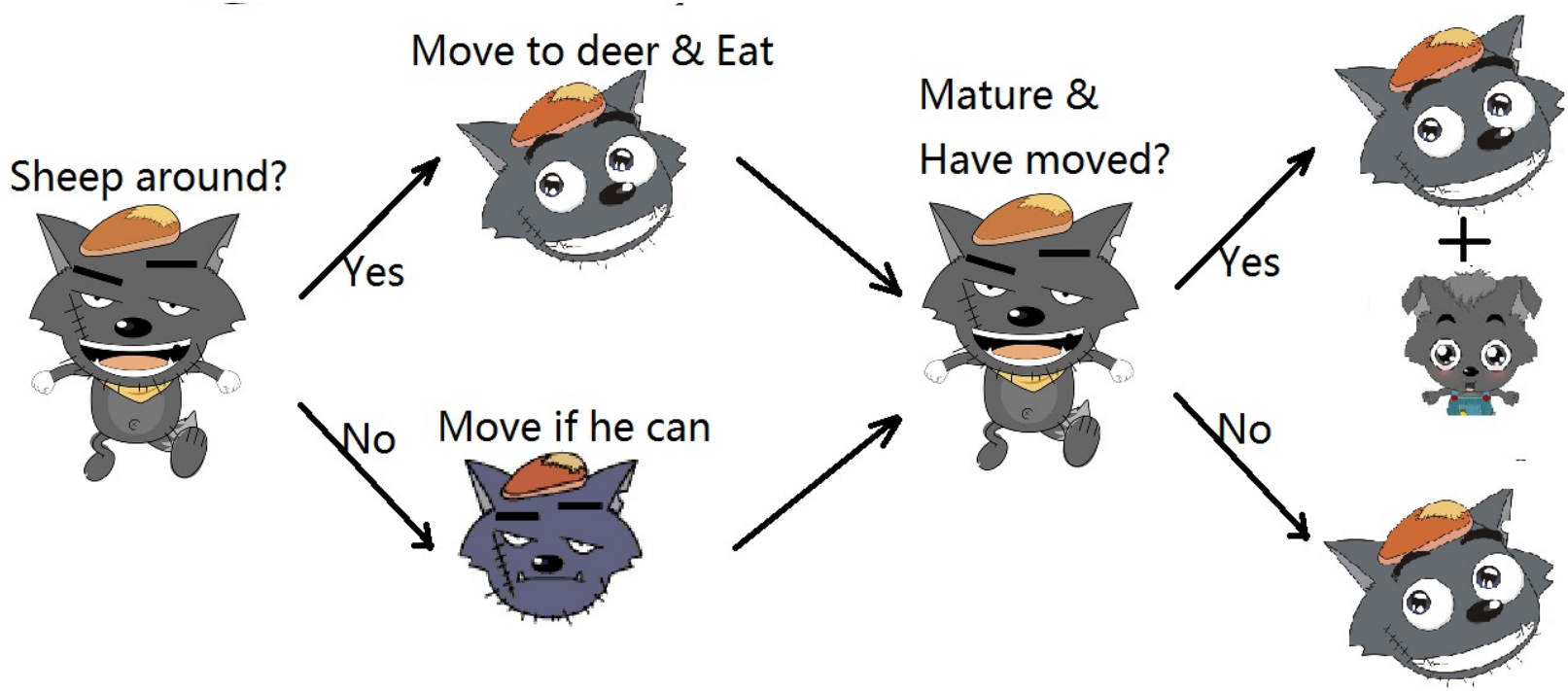
- Step 2: evolution of wolves:



Evolution of deer

Evolution of deers:

- Step 1: Delete all unfortunate deers.

Evolution of deer

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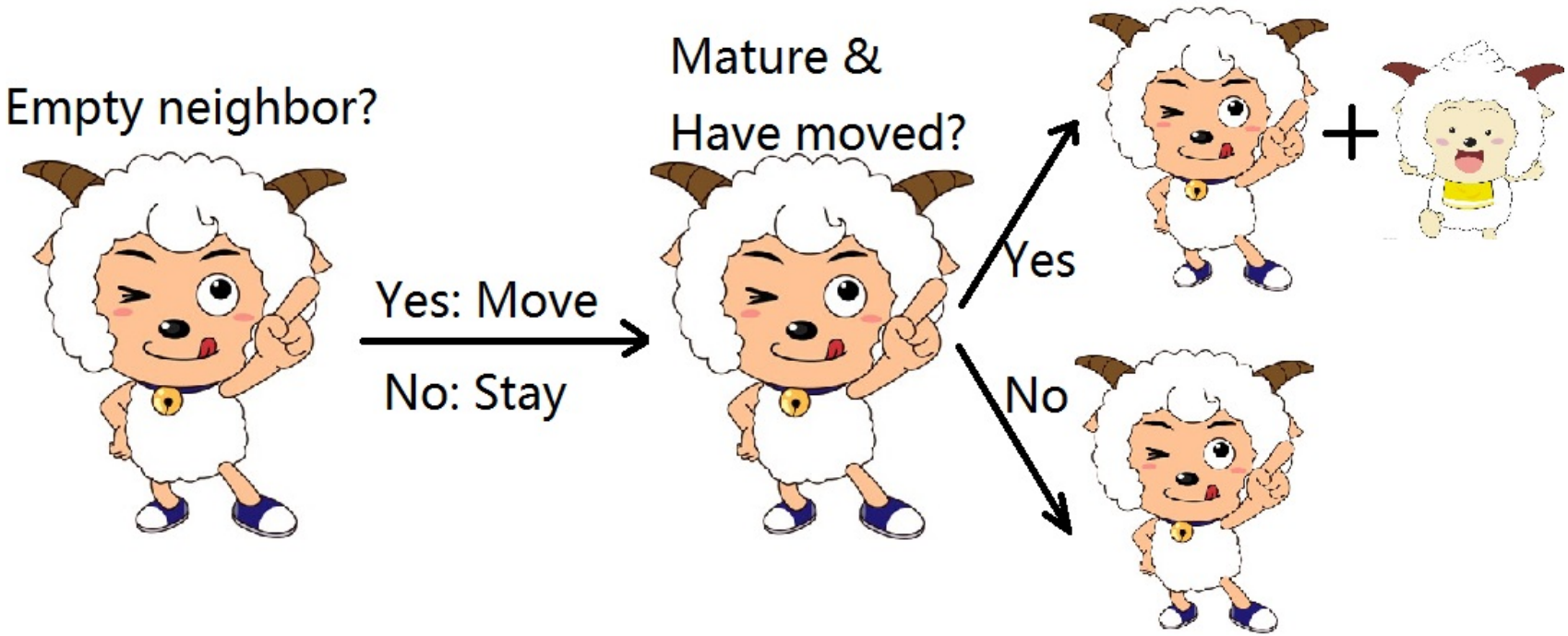
- Setp 2: Evolution of live deers.



Population interaction of predator and prey in eco-system

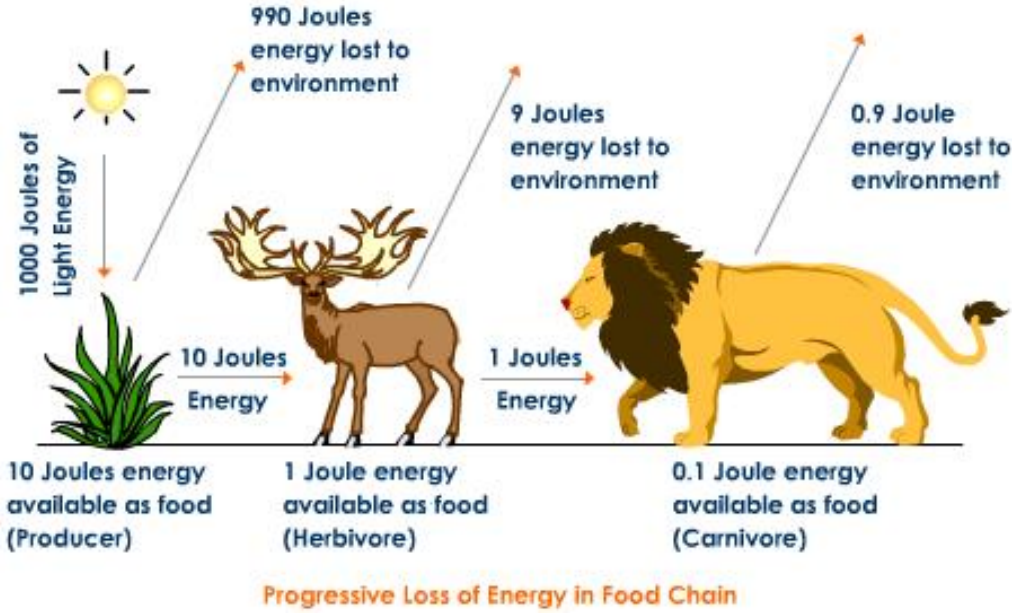


Figure : default

Generic results

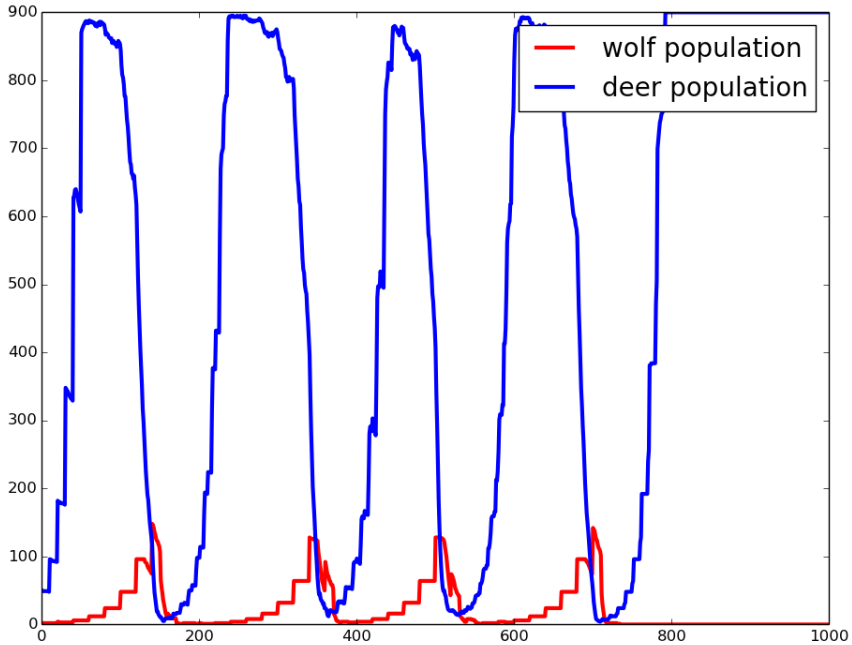


Figure : Initialised without age structure. This is an example of wolf distinction.

Generic results

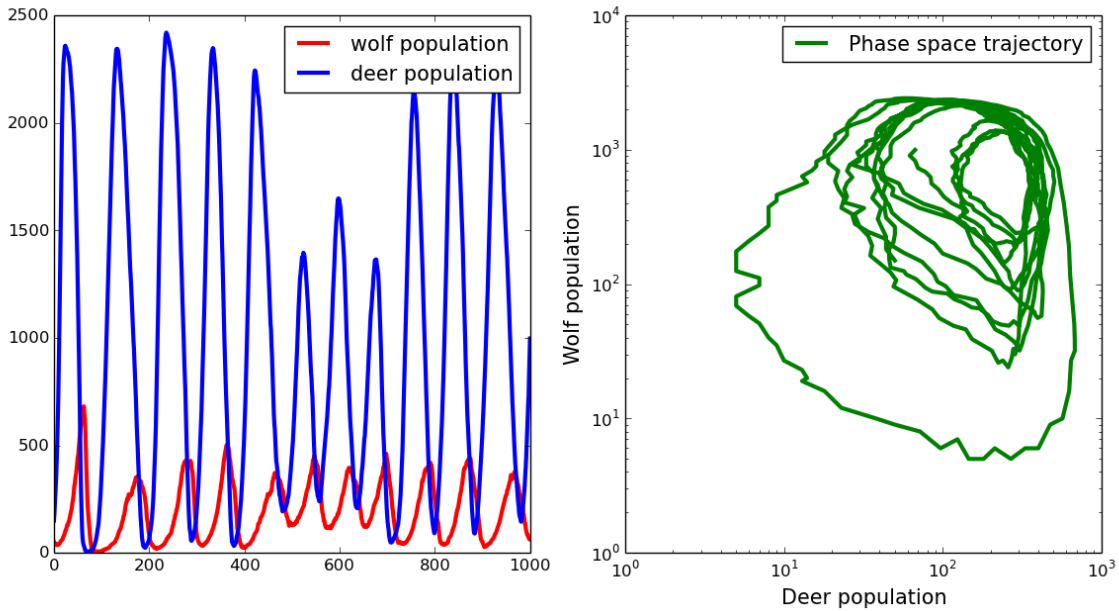


Figure : Initialised with uniform age structure. A quasi-periodic evolution is obtained.

Parameter Search

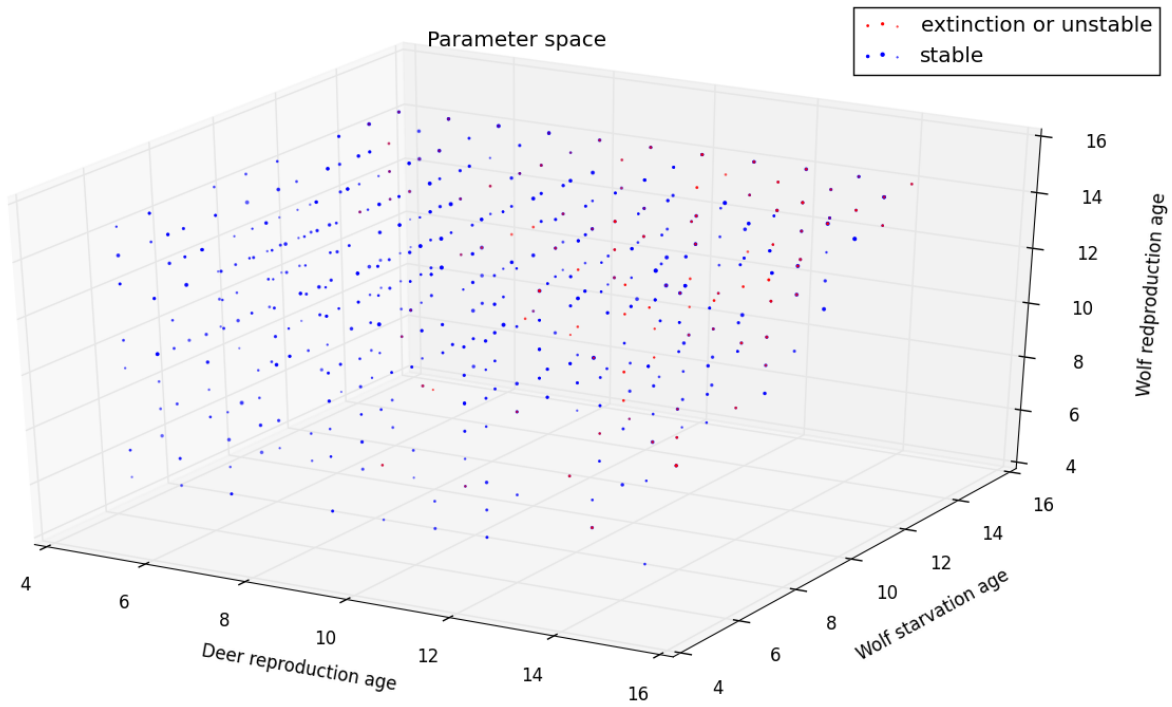
5 parameters to test (5-D parameter space)

- **Initial population of deer**
- **Initial population of wolves**
- Reproduction age of deer
- Reproduction age of wolf
- Starvation "age" of wolf

Reduce to 4 dimensions (4-D)

- **Ratio of initial populations : Size of point**
- Reproduction age of deer : x-axis
- Reproduction age of wolf : y-axis
- Starvation "age" of wolf : z-axis

Results of Full Parameter Search



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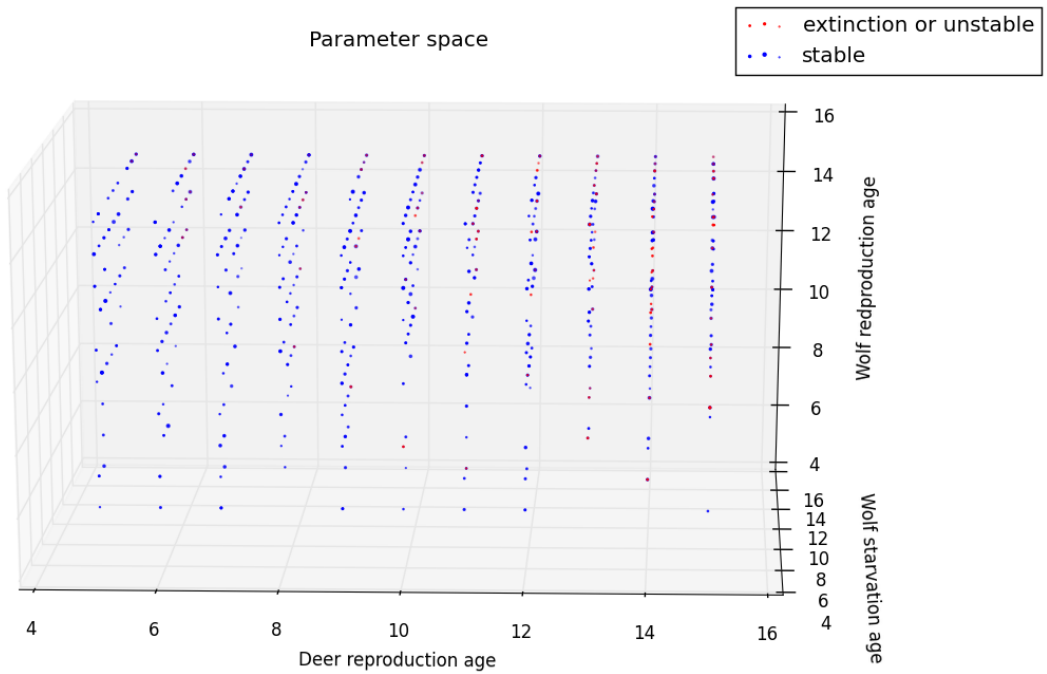

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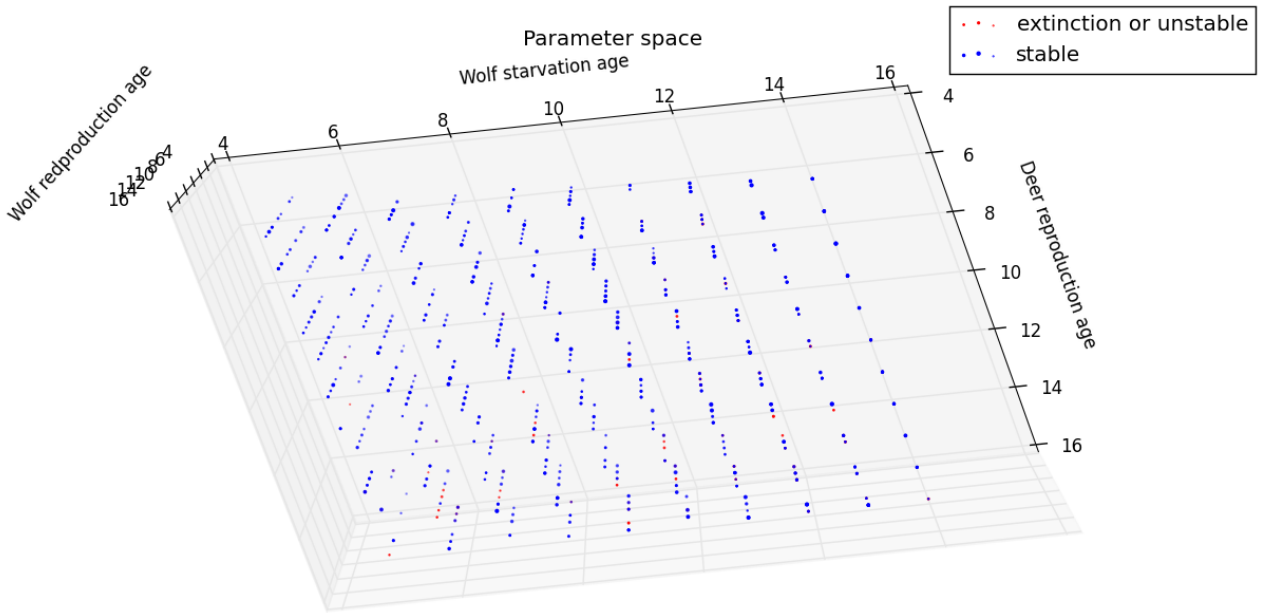
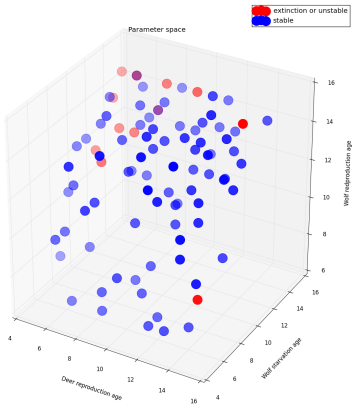
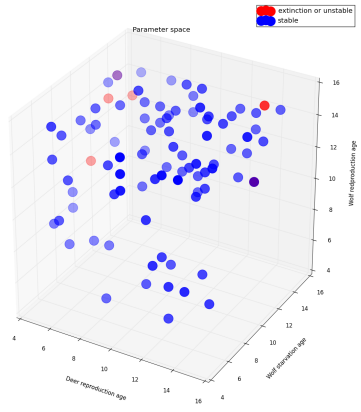
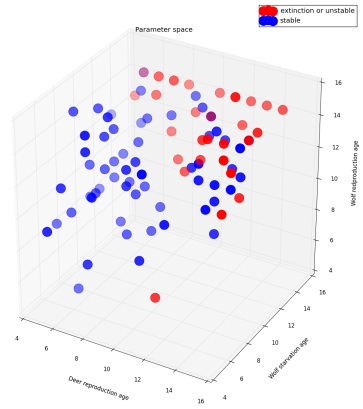


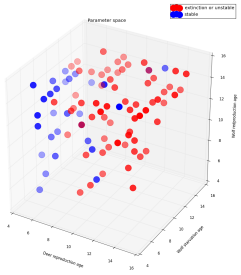
Results of Restricted Parameter Search

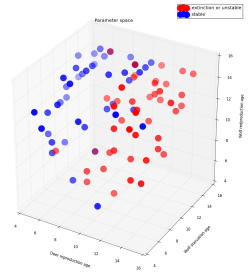
Fix initial population ratios











Ecosystem at Equilibrium

Parameters used:

- Initial number of deer: 2,500
- Initial number of wolves: 250
- Deer reproduction rate: 5
- Wolf reproduction rate: 14
- Wolf starvation rate: 11

Animation Time!