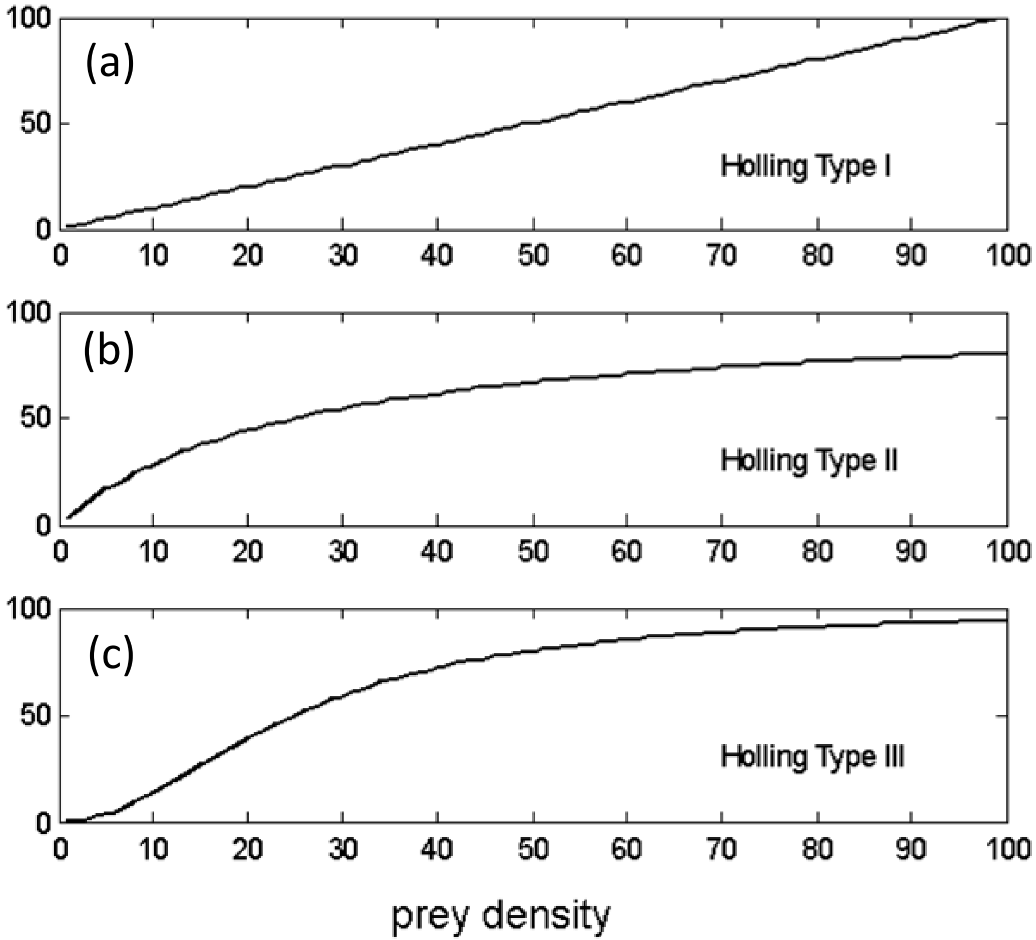
Quiz



Which *functional response* is a result of search and handling of prey by predators?
(a), (b), or (c)

Frequency of Cyclical Dynamics

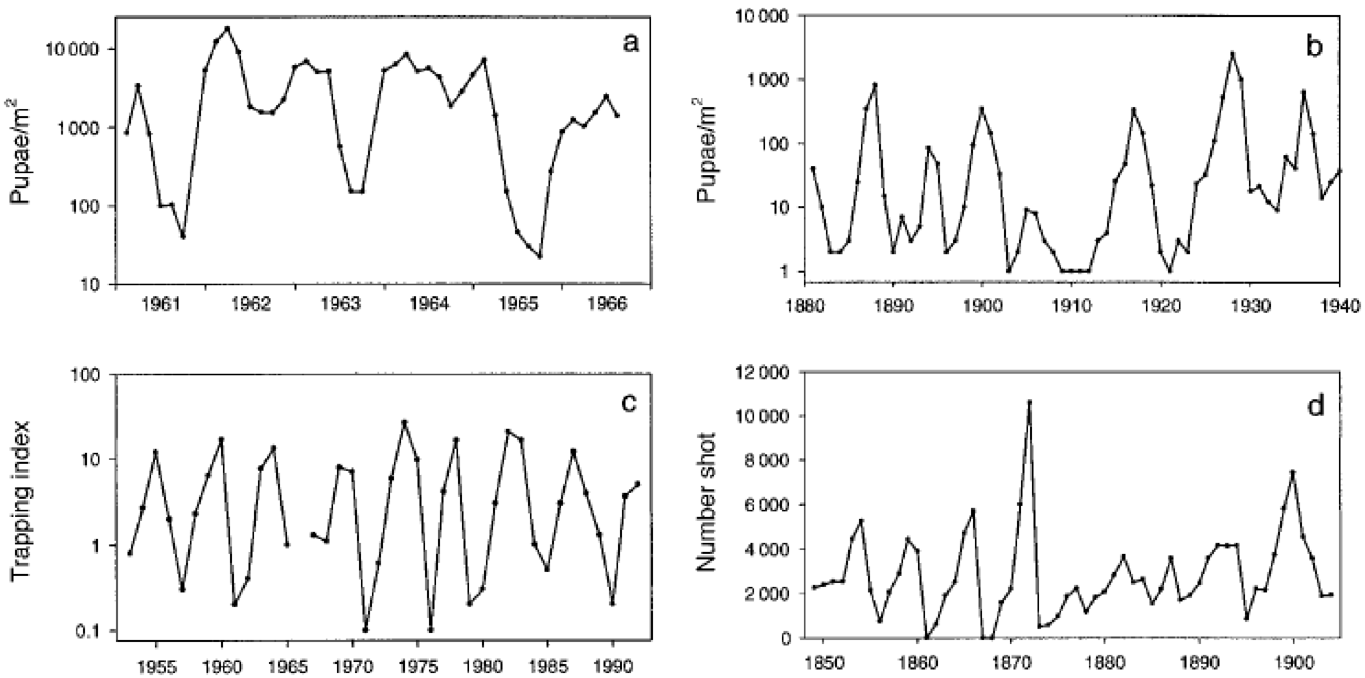
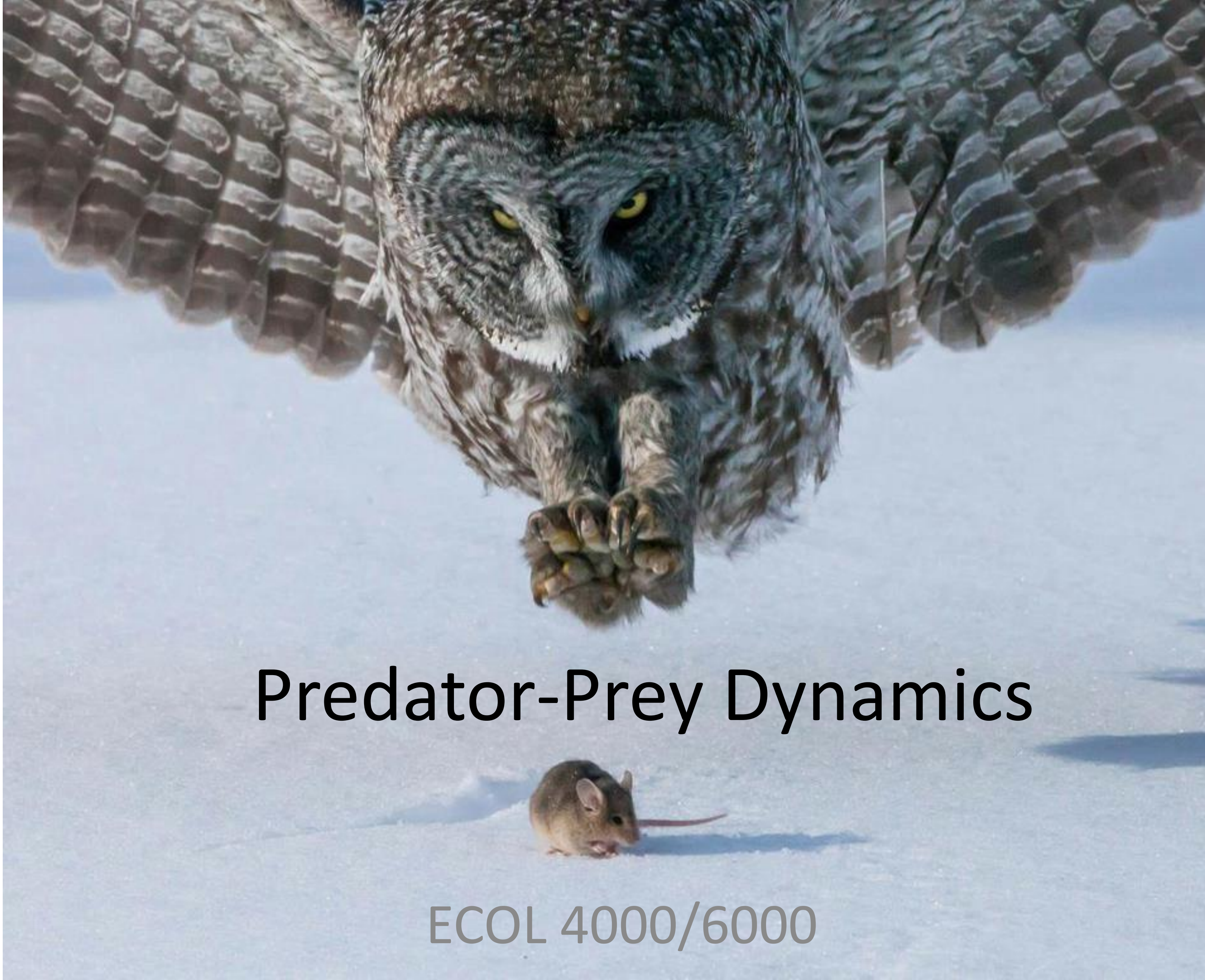


FIG. 1. Examples of cyclic population dynamics. (a) Coffee leaf-miners (*Leucoptera* spp.) at Lyamungu, Tanzania (Bigger 1973). (b) Pine looper (*Bupalus piniarius*) in Germany (Schwerdtfeger 1941). (c) Voles (*Microtus* and *Clethrionomys*) at Kilpisjärvi, northern Finland (Laine and Henttonen 1983, Hanski et al. 1993). (d) Red Grouse (*Lagopus lagopus scotius*) in Scotland (Middleton 1934).

From Kendall et al. (1999) Ecology 80: 1789-1805.

30% of long term time series exhibit periodic oscillations



Predator-Prey Dynamics

ECOL 4000/6000

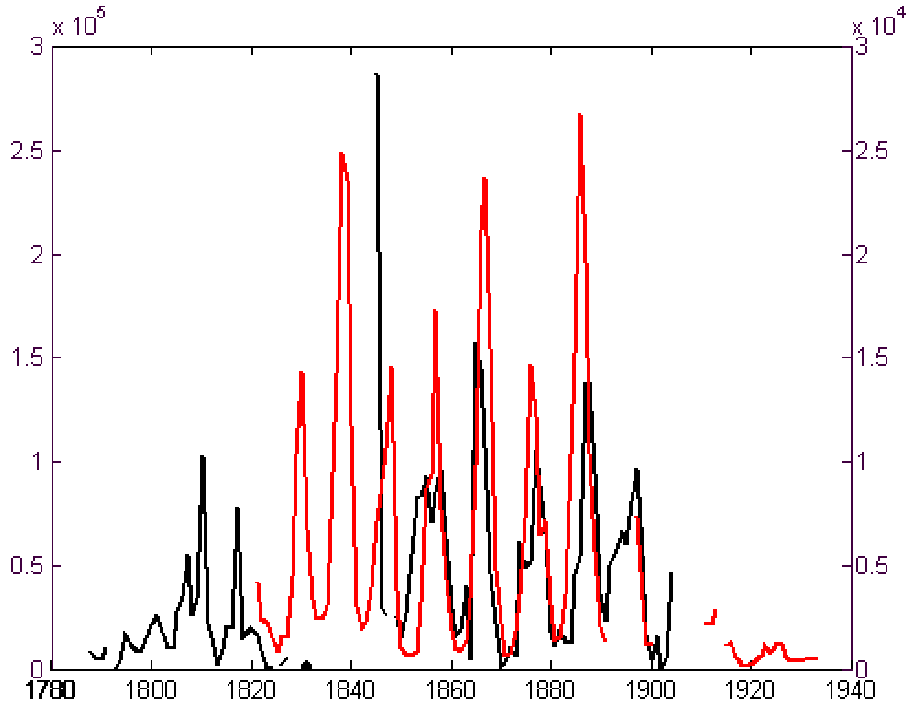
Learning outcomes

- Recall two sources of predator-prey dynamics
- Identify basic components of predator-prey models (births, deaths, predation, other terms)
- Explain, write down, sketch functional responses 1,2,3 (recall sources for each of 2 and 3)
- Identify and explain key stabilizing and destabilizing mechanisms
- Translate predator-prey dynamics to phase plane (and vice-versa)
- Calculate straightforward coexistence equilibria
- Sketch null clines (ZNGIs) for key models
- Populate Jacobian matrix for certain predator-prey models (as in the reading)
- Articulate the principle of the ‘paradox of enrichment’

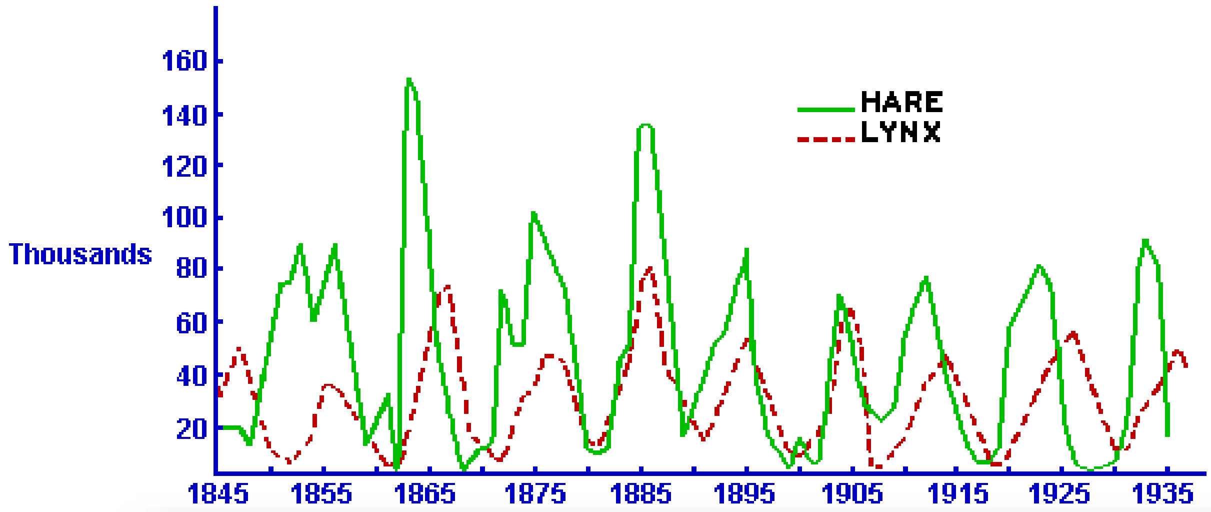
Predator-Prey Dynamics

- A ubiquitous inter-specific interaction in nature
- A building block for understanding food webs
- An explanation for cyclical population dynamics

Hare-Lynx pelts from the Hudson's Bay Co.



Hare-Lynx Dynamics in Canada



Lotka-Volterra Model
(Predator-Prey)

- Vito Volterra (1860-1940)
  - Italian Mathematician
  - Studied these equations in 1926
- Alfred J. Lotka (1880-1949)
  - Statistician and actuarial demographer
  - Studied these equations in 1925

Lotka-Volterra Model

(Predator-Prey)

What do the parts of this model represent?

$$\frac{dN}{dt} = rN - cNP$$

$$\frac{dP}{dt} = bNP - mP$$

Lotka-Volterra Model

(Predator-Prey)

Population growth through reproduction and non-predator mortality

$$\frac{dN}{dt} = rN - cNP$$

Rate of change of the prey population

Mortality due to predation is the product of:

1. per capita predation rate (c)
2. number of predator (P)
3. number of prey (N)

Lotka-Volterra Model

(Predator-Prey)

Population growth through "conversion" of prey

$$\frac{dP}{dt} = bNP - mP$$

Mortality

Rate of change of the predator population

No simple solution: Alternative strategies needed to study this model

- Graphical Analysis
- Local stability analysis

Step 1: Find equilibria

Activity:

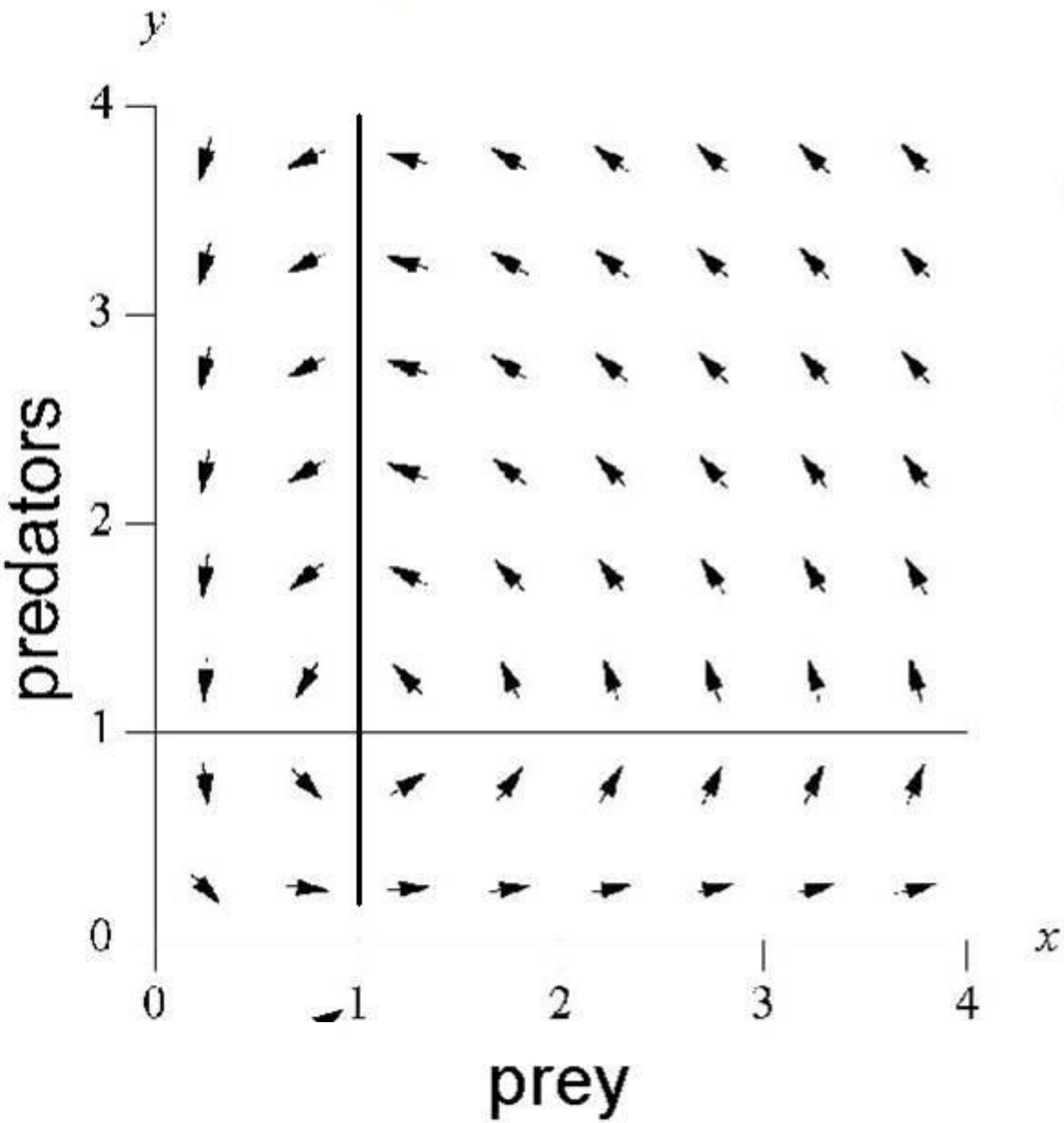
1) Take 3 minutes to solve for the for the equilibrium in the second equation. What are the conditions under which the left hand side of the equation equals zero
2) Compare your result with a neighbor

$$\frac{dN}{dt} = rN - cNP \longrightarrow \frac{dN}{dt} = N(r - cP)$$

$$\frac{dP}{dt} = bNP - mP \qquad \frac{dP}{dt} = P(bN - m)$$

$$(N^*, P^*) = (0,0), \left(\frac{m}{b}, \frac{r}{c}\right)$$

Step 2: Sketch Null Clines

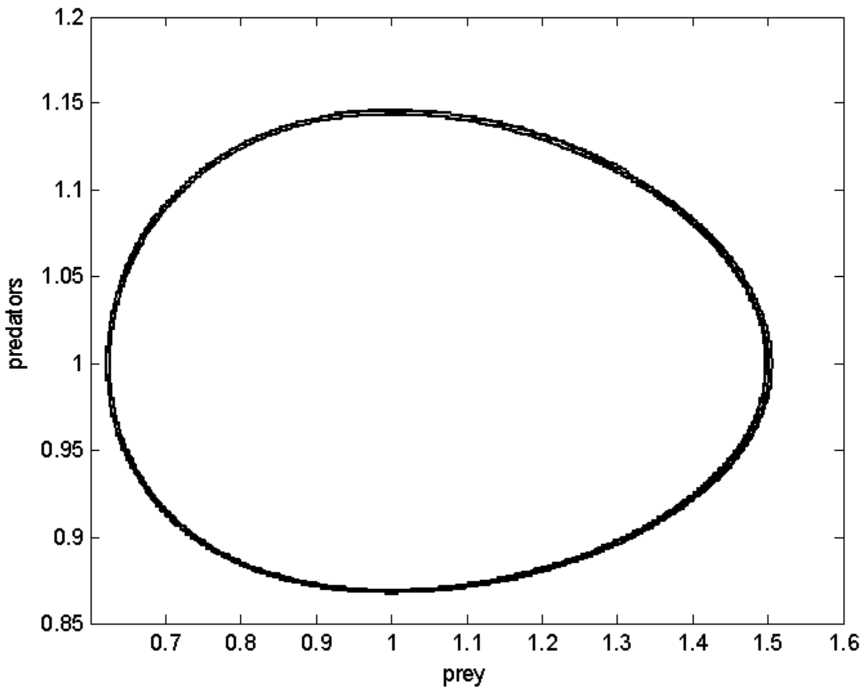


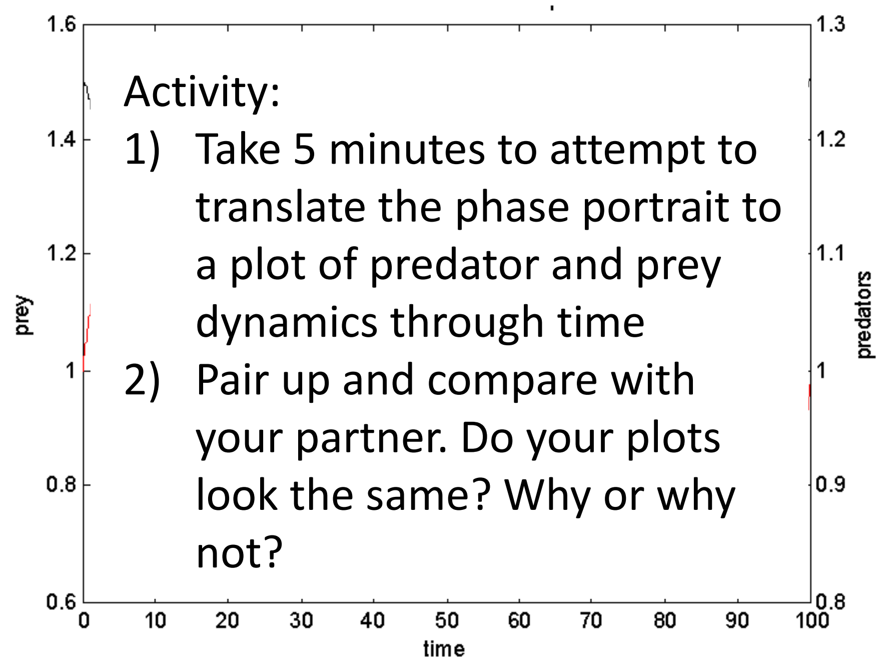
$$\frac{dN}{dt} = rN - cNP$$

$$\frac{dP}{dt} = bNP - mP$$

Phase Portrait

initial condition: prey=1.5 predators=1



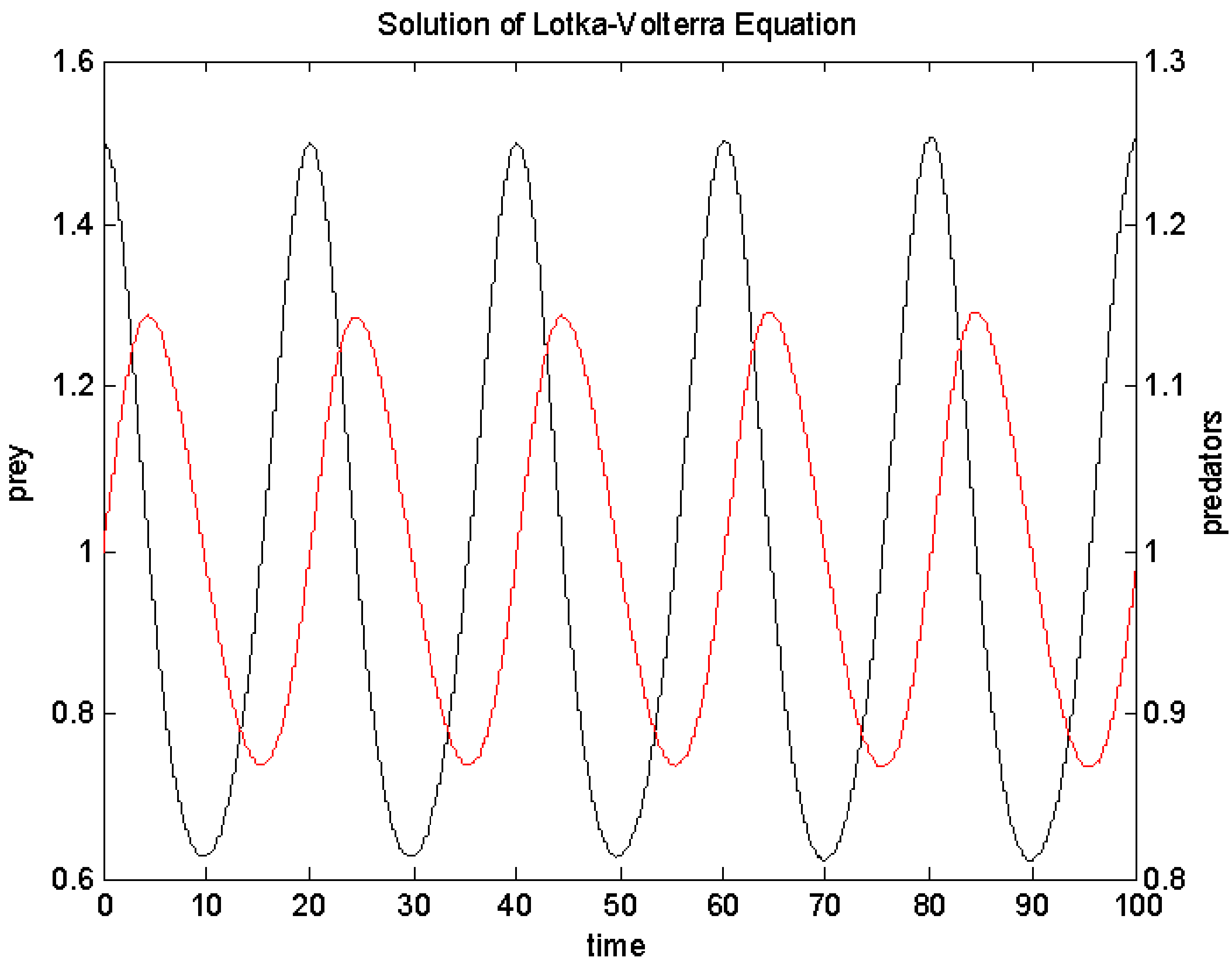


Activity:

1) Take 5 minutes to attempt to translate the phase portrait to a plot of predator and prey dynamics through time
2) Pair up and compare with your partner. Do your plots look the same? Why or why not?

Is this cycle stable?

Graphical Analysis



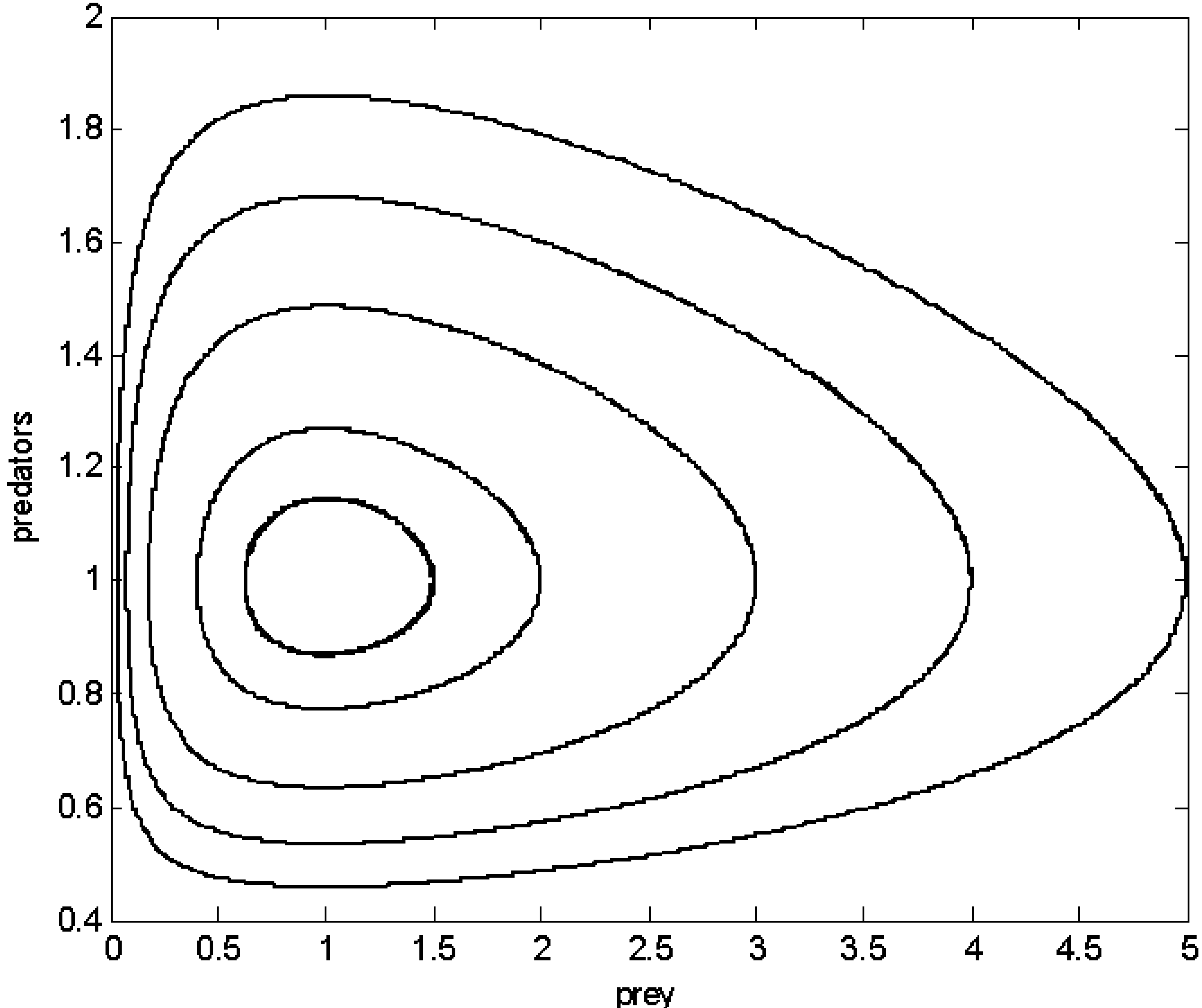
Phase Portrait

Homework: Sketch an example of a predator-prey interaction exhibiting damped oscillations as both a regular plot (x-axis=time, y-axis=both population sizes) and a phase portrait. Label the initial conditions and any stable equilibria.

1) Compare your plots with your partner. Do they look the same? Why or why not?

The L-V model is neutrally stable

initial condition: prey=[1.5, 2,3,4,5], predators=1



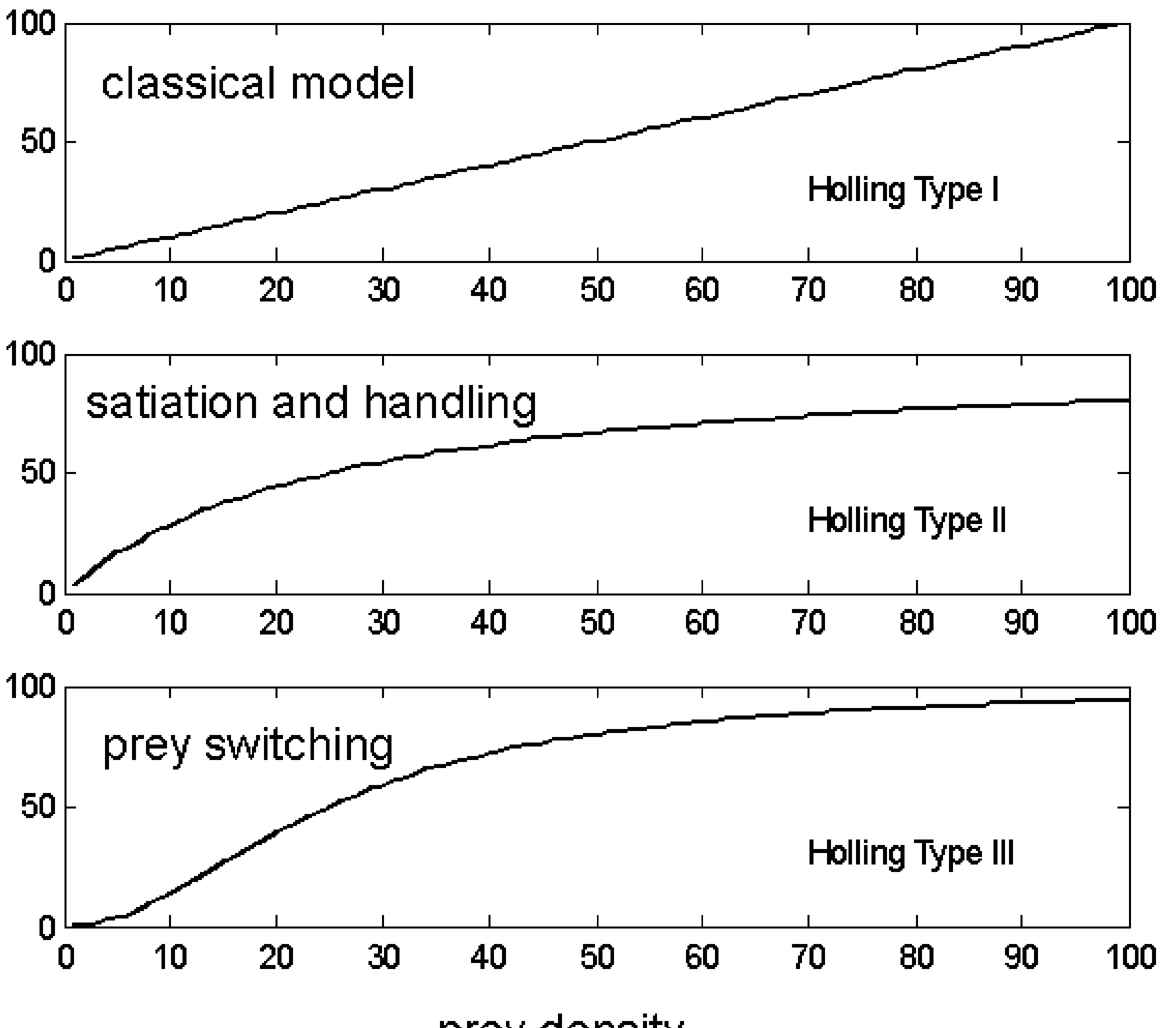
Stabilizing Mechanisms

$$\frac{dN}{dt} = f(N) - g(N)P$$

$$\frac{dP}{dt} = h(g(N))P - m(P)$$

f(x) – prey regulation
g(x) – "functional response"
h(x) – "numerical response"
m(x) – predator mortality

Functional response

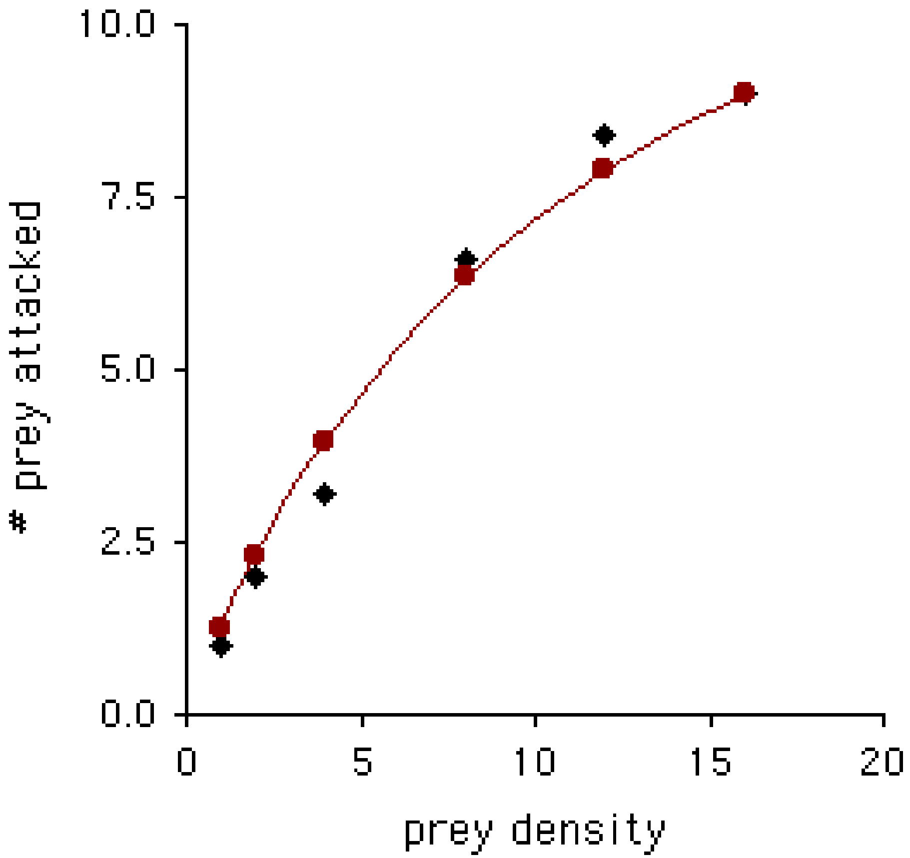


$$g(N) = \alpha N$$

$$g(N) = \frac{\alpha N}{a T_h N + 1}$$

$$g(N) = \frac{\alpha N^2}{a T_h N^2 + 1}$$

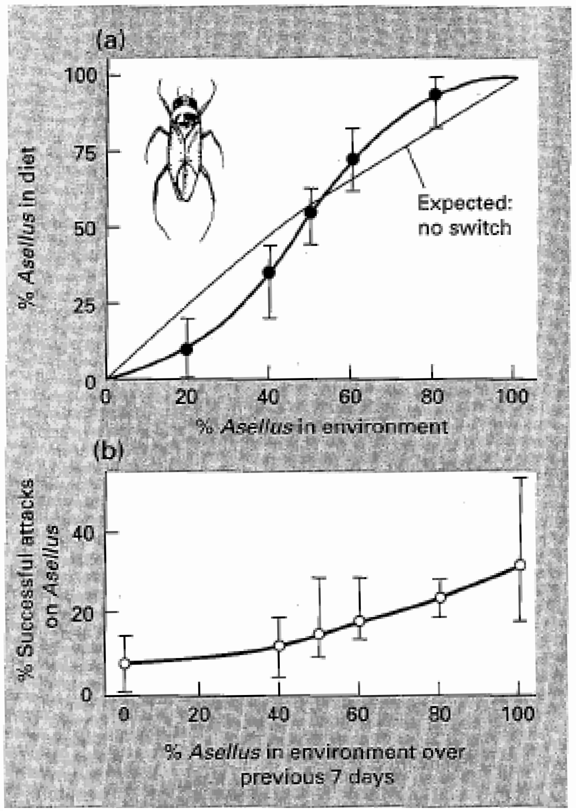
Type II Functional Response



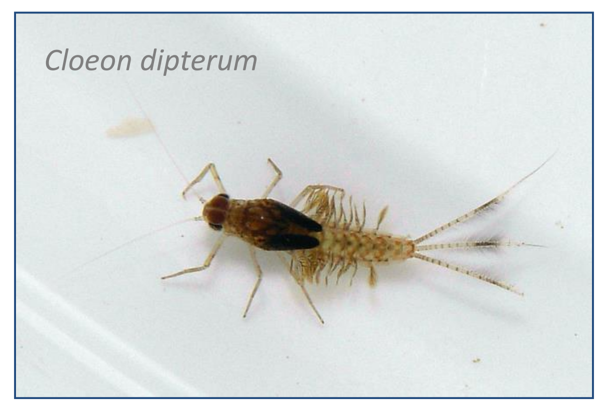
Predator: Stinkbug
(*Podisus maculiventris*)

Prey: Mexican Bean Beetle
(*Epilachna varivestis*)

Type III Functional Response



$$g(N) = \frac{\alpha N^2}{D^2 + N^2}$$



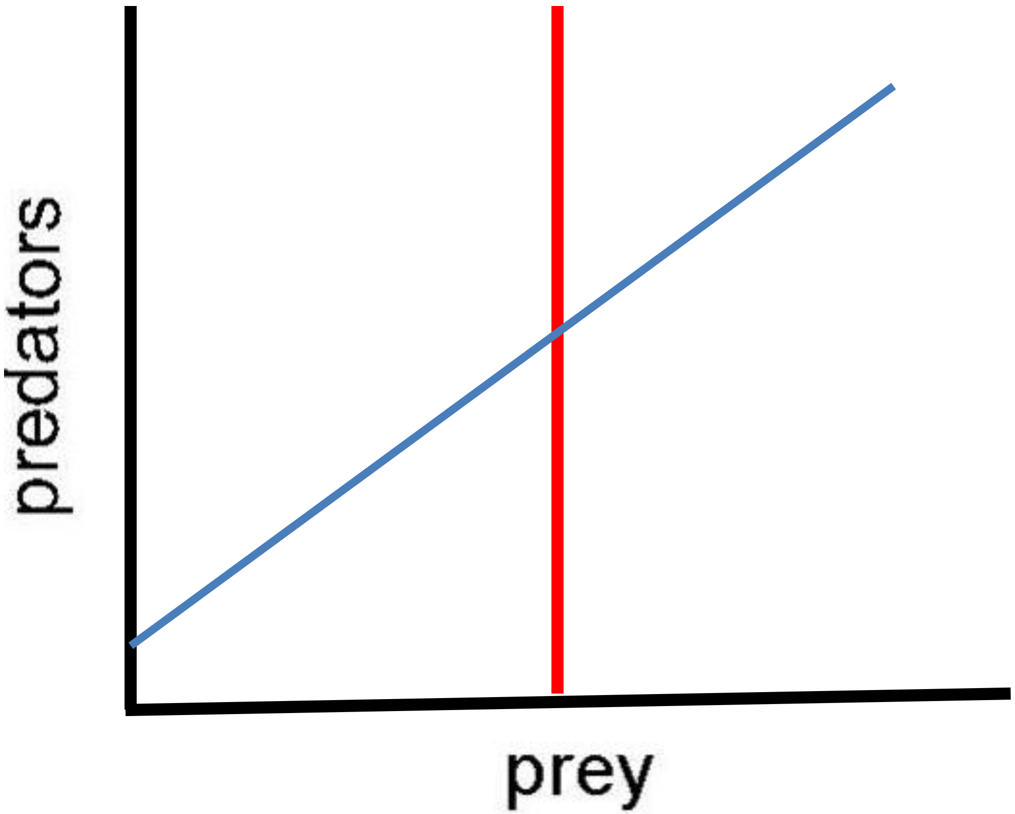
Prey Equation

(Type II functional response)

$$\frac{dN}{dt} = rN - \frac{\alpha NP}{aT_h N + 1}$$

$$P_{eq} = rT_h N + \frac{r}{\alpha}$$

Type II Functional Response



$$rT_hN + \frac{r}{\alpha}$$

Effect of Type II functional response is *destabilizing*

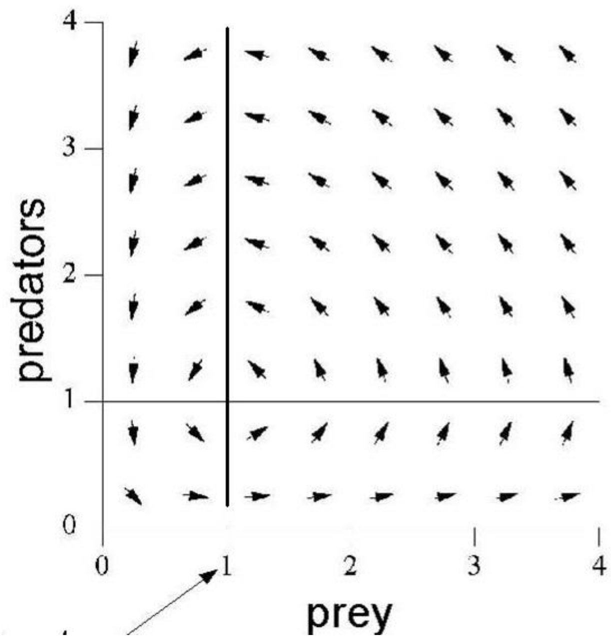
Stabilizing Mechanisms

- Basic L-V model is neutrally stable
- Type II (predator satiation) is destabilizing

Stabilizing Mechanisms

1) Take 5 minutes on your own to sketch the null-clines for predators and prey with your assigned mechanism
2) Get into groups and compare your figures. If they differ, why is that? Does one representation seem more reasonable?
3) Nominate 1-2 people to present your null-clines to the class and explain how the mechanism changes the typical null-clines

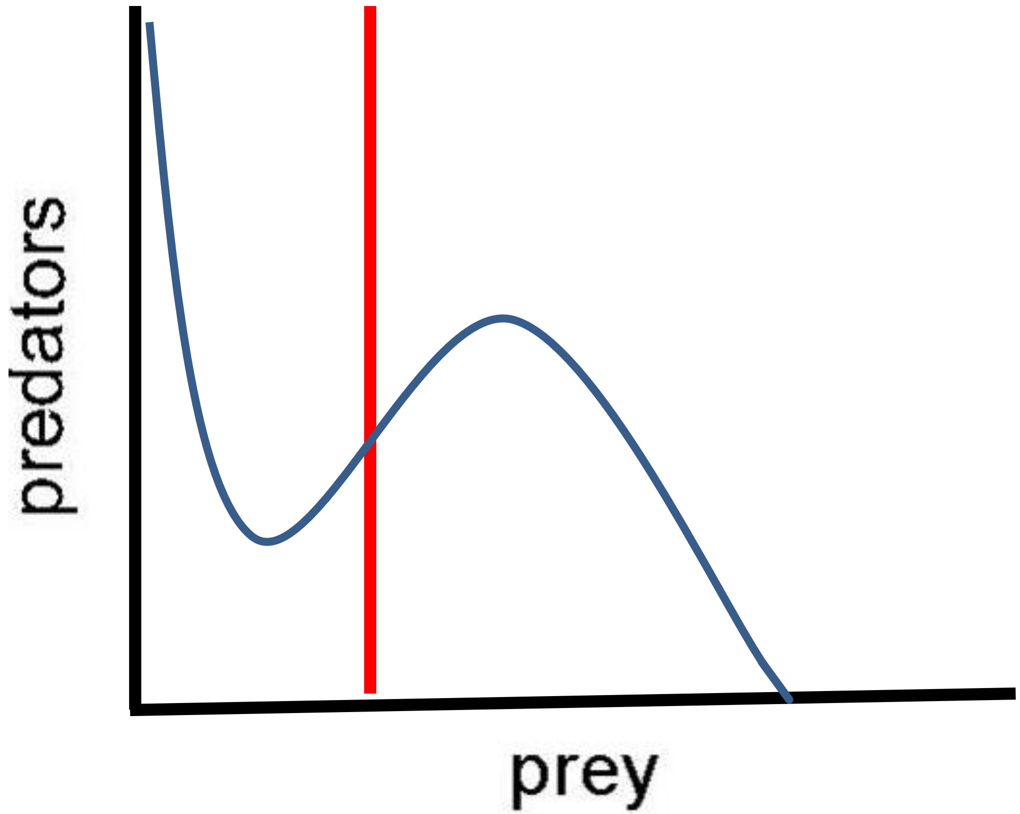
- Prey regulation (logistic)
- Predator regulation (logistic)
- Prey refuge
- Predator immigration



Stabilizing Mechanisms

- Basic L-V model is neutrally stable
- Type II (predator satiation) is destabilizing
- Prey regulation (logistic) is stabilizing
- Type III is parameter dependent and initial condition dependent
- Predator regulation (logistic) is stabilizing
- Prey refuge is stabilizing
- Predator immigration is stabilizing

- Type III is parameter dependent and initial condition dependent



Stabilizing Mechanisms

Homework: Write down a model with

1) both predator and prey density-dependent growth,
2) a type 2 functional response and
3) predator immigration.

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K_N}\right) - \frac{\alpha NP}{aT_hN + 1}$$

$$\frac{dP}{dt} = \frac{c\alpha NP}{aT_hN + 1}\left(1 - \frac{P}{K_P}\right) + i$$

Explaining Persistent Cycles

- We started with a biological observation – evidently persistent cycles in hare and lynx
- We developed a model (L-V) to explain these cycles, but it was neutrally stable and therefore biologically unrealistic
- We enriched the theory with the concept of "stabilizing mechanisms"
- But, have we explained persistent cycles?

Explaining Persistent Cycles

Combining stabilizing and destabilizing processes

The Rosenzweig-MacArthur Model

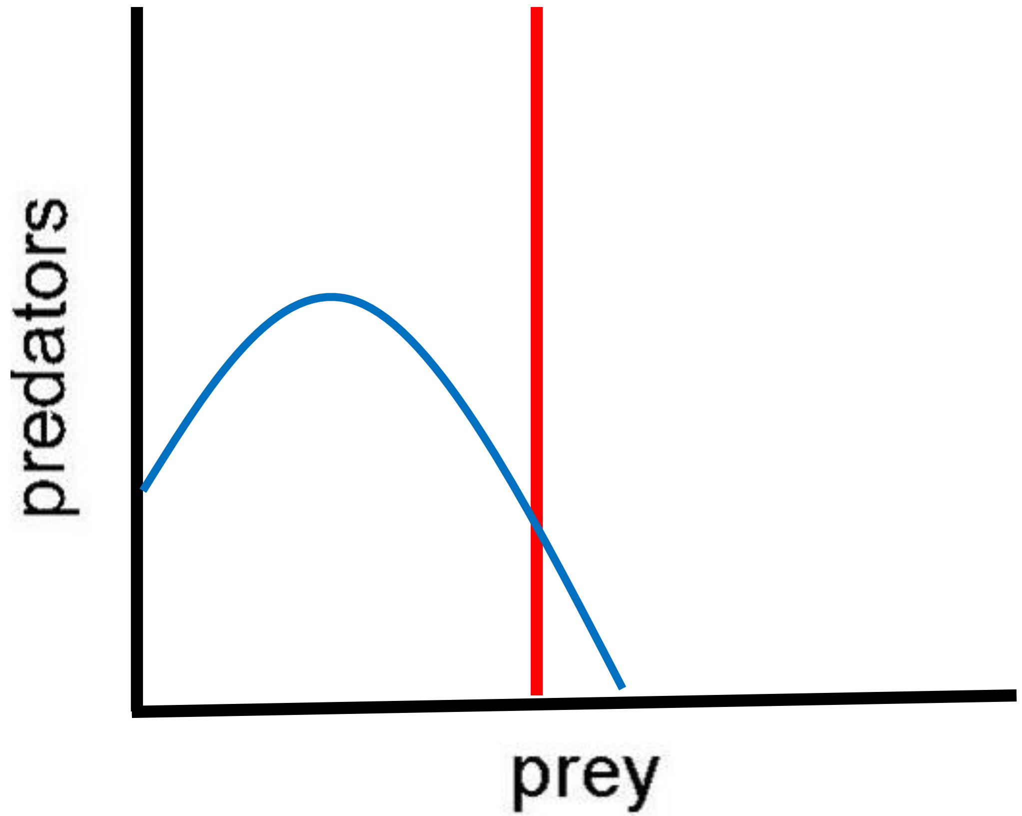
$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) - \frac{\alpha N P}{1 + \alpha T_h N}$$

$$\frac{dP}{dt} = b\frac{\alpha N P}{1 + \alpha T_h N} - mP$$

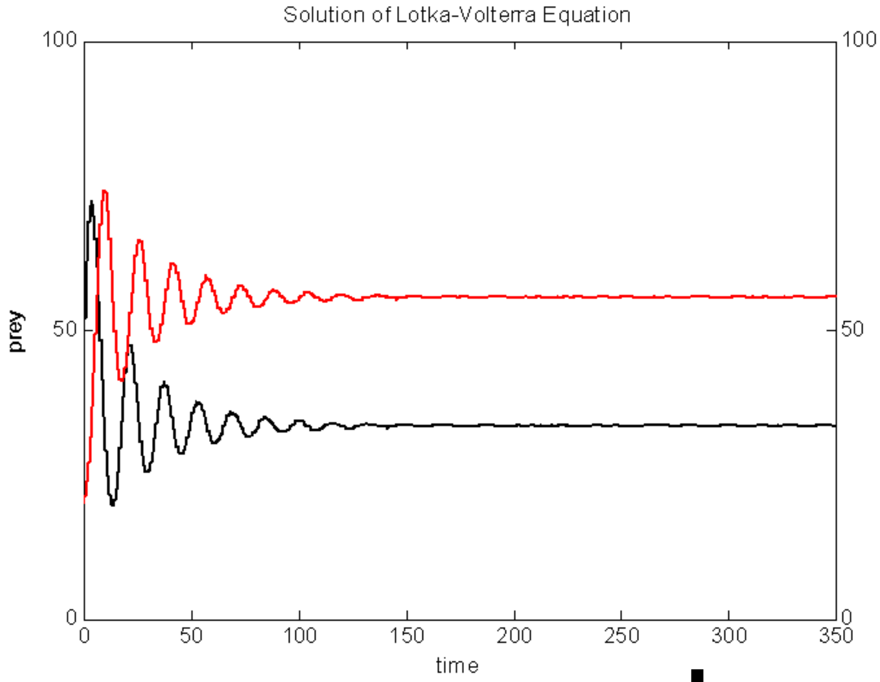
Explaining Persistent Cycles

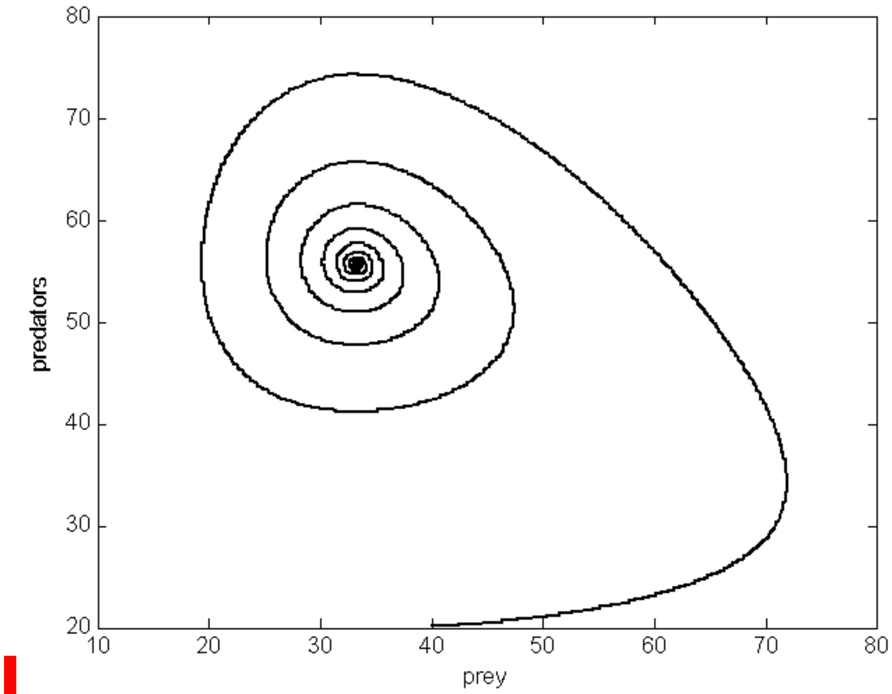
Combining stabilizing and destabilizing processes

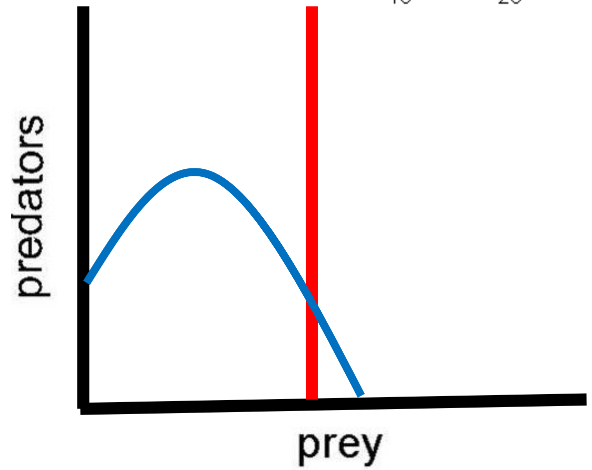
The Rosenzweig-MacArthur Model



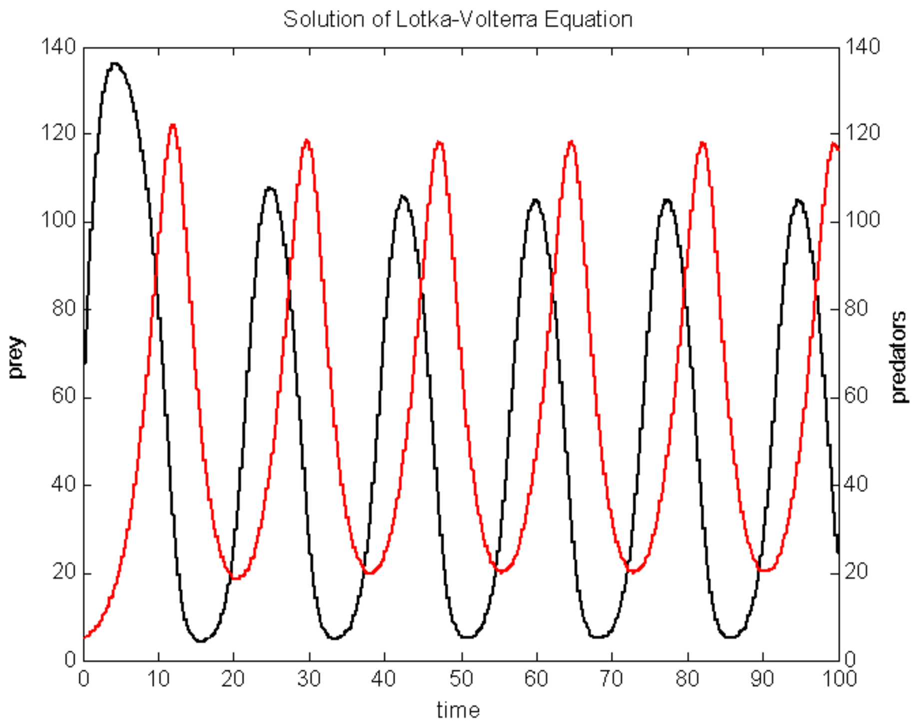
Exhibits Damped Oscillations

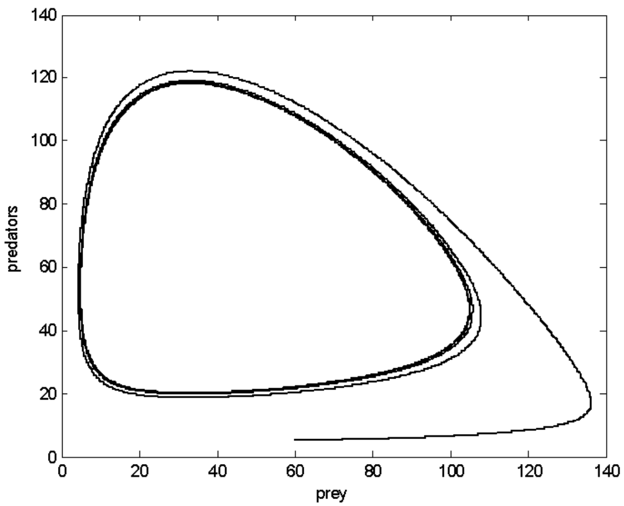


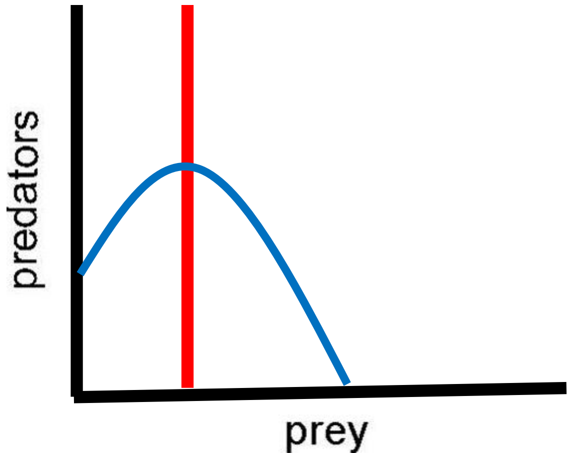


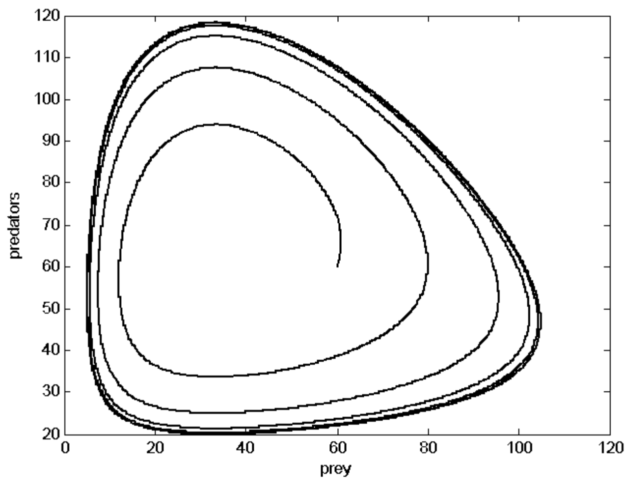


Or, Persistent Cycles

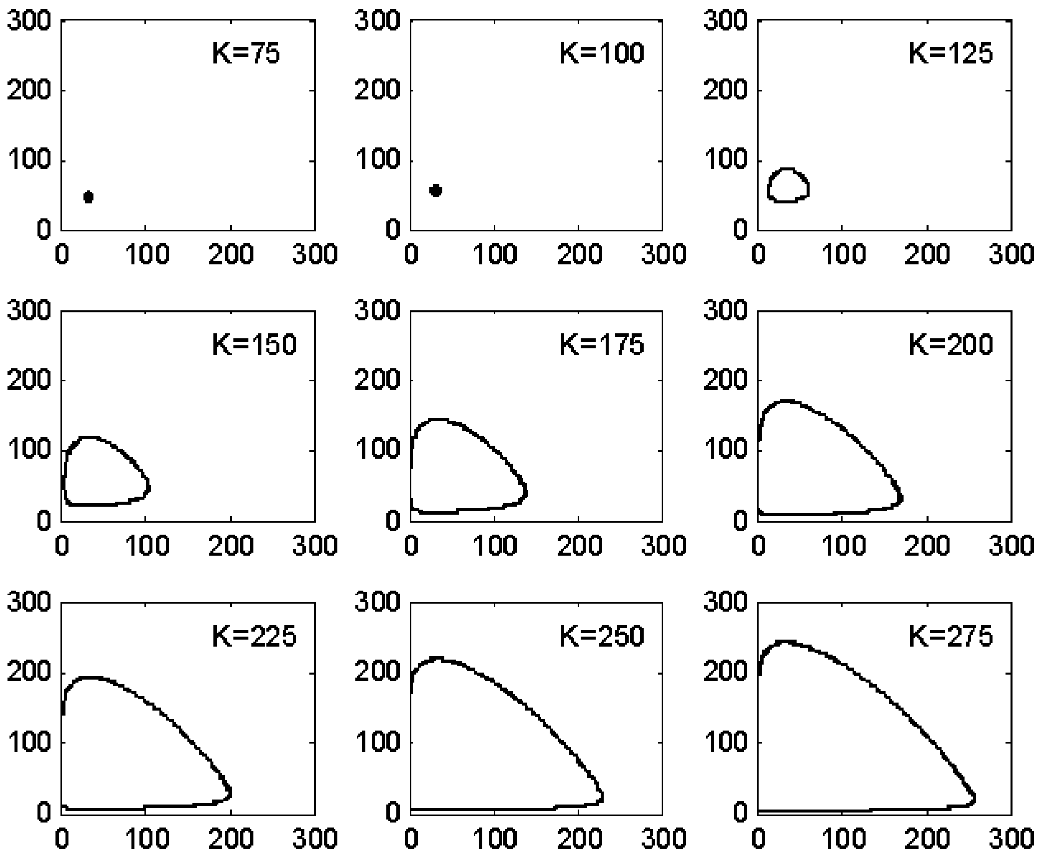


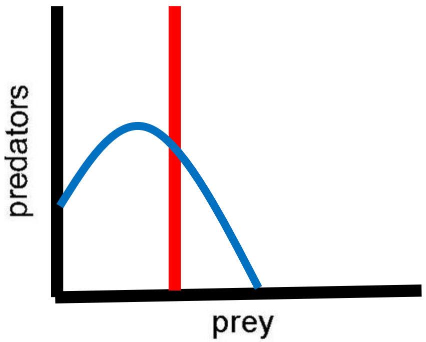


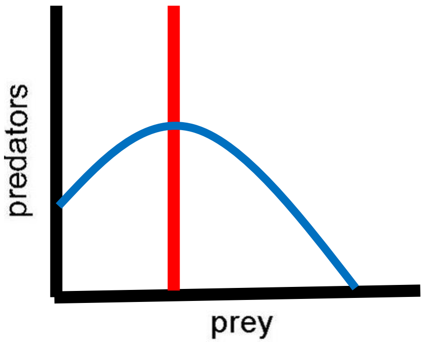


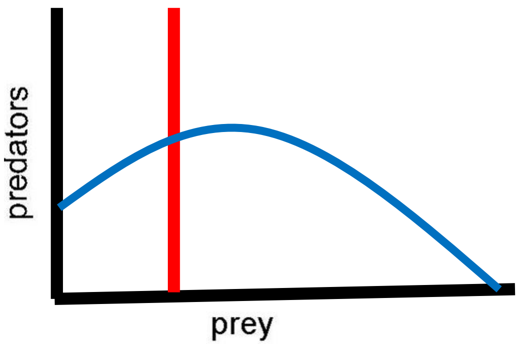


The Paradox of Enrichment









Conclusions

- Periodic population dynamics are common
- Periodicity appears most frequently among pairs of antagonistically interacting species
- Antagonistic interactions (i.e., predator-prey) are not sufficient to explain persistence, however, as revealed by the neutral stability of the Lotka-Volterra model
- Persistent periodic dynamics appear to result from the addition of both stabilizing and destabilizing mechanisms