Predator-prey relationships

- **Definition**: interaction between species whereby one is totally or partially consumed or harmed by the other
Types of predator-prey relationships

- True predators (carnivores)
- Parasitoids
  - primarily insect orders Hymenoptera and Diptera
- Parasites
- Herbivores
- Cannibals
Fig. 11.1 (p. 189): Diagram of possible indirect effects (dotted arrows) between two predator species $P_1$ and $P_2$ that eat herbivores $H_1$ and $H_2$. 

(a) 

(b)
Fig 11.2 (p. 191): Population changes in a hypothetical predator-prey system → coupled oscillations.
Why predation is important

• Restricts distribution and/or abundance of prey populations

• Can influence the organization of communities

• Acts as a major force in natural selection
  – camouflage and warning colorations
  – alarm behaviors
Lotka-Volterra predator-prey model

• Population growth curve for **prey** species

\[
\frac{\delta N}{\delta t} = r_N N - \epsilon P N
\]

where

- **P**: predator population size
- **N**: prey population size
- \(\epsilon\): interaction coefficient for predator efficiency
- “-”: negative effect of predator abundance on prey abundance
Lotka-Volterra predator-prey model

• Population growth curve for **prey** species
  – \([(K-N)/K]\) omitted because prey populations assumed to be in growth phase well below \(K\) (term assumed to equal 1); i.e., no intraspecific limitations on prey population growth
  
  – assumes prey numbers are limited only by the predator
Lotka-Volterra predator-prey model

- Population growth curve for predator species

$$\frac{\delta P}{\delta t} = - r_p P + \theta PN$$

where
- $P$: predator population size
- $N$: prey population size
- $\theta$: interaction coefficient for predator efficiency
- “+”: benefit to predator of any abundance of prey
- “-”: predator population decreases exponentially in absence of prey
Lotka-Volterra predator-prey model

- **Isoclines**: combinations of prey and predator population numbers at which neither population is increasing or decreasing

- Plots
  - $N$ (x-axis) versus $P$ (y-axis): preferred!
  - time point (x-axis) versus $N$ and $P$ (y-axis, separately)
Fig 11.2 (p. 191): Population changes in a hypothetical predator-prey system → coupled oscillations.
Predator-prey data plotted as time (x) versus population size (y) [from Fig. 11.2 (p. 191)].
Predator-prey data plotted as prey population size N (x) versus predator population size P (y) [from Fig. 11.2].
Predator-prey data plotted as prey population size N (x) versus predator population size P (y) [from Fig. 11.2].

Minimum number of prey required to support increase in predator population

Predator isocline
Predator-prey data plotted as prey population size $N$ (x) versus predator population size $P$ (y) [from Fig. 13.2].

- **Prey isocline**
- **Predator isocline**

**Maximum number of predators allowing for increase in prey population**
Predator-prey data plotted as prey population size $N$ (x) versus predator population size $P$ (y) [from Fig. 13.2].
Classical predator-prey cycles predicted from the Lotka-Volterra model using different reproductive rates.
Modifications to model by Rosenzweig and MacArthur

• Added intraspecific limitations on the prey population sizes

• Considered prey-dependent effects on the predator population sizes
Fig. 11.3 (p. 192): Prey isocline of Rosenzweig and MacArthur predator-prey interaction
Fig. 11.4 (p. 211): Predator isocline of Rosenzweig and MacArthur predator-prey interaction.
Fig. 11.5 (p. 193): Superimposed predator and prey isoclines in the Rosenzweig-MacArthur predator-prey model.
Modifications to model by Rosenzweig and MacArthur

- Assuming vertical predator isocline, stability of predator-prey interaction is dependent on the slope of the tangent to the prey isocline
  - slope = 0 → neutral stability
  - negative slope → stable oscillations
  - positive slope → unstable oscillations
Neutral stability

Slope of tangent = 0
Amplitude of oscillations does not change
Neutral stability

Slope of tangent = 0
Amplitude of oscillations does not change

P

N
Neighborhood stability

*Inefficient predator*

Slope of tangent = neg
Amplitude of oscillations decreases
Instability

Efficient predator

Slope of tangent = pos
Amplitude of oscillations increases
Instability

Efficient predator

Slope of tangent = pos
Amplitude of oscillations increases
Limit cycle

*Efficient predator, prey can hide*

Slope of tangent = pos
Amplitude of oscillations increases, then stabilizes
Coevolution in predator and prey

Efficient predator

STABILITY

Inefficient predator

\[ P \]

\[ N \]
Experimental study of the predator-prey models

• Lab studies
  – Gause (1934): protozoans
  – Huffaker (1958): strawberry mites
  – Utida (1957): weevil and parasite
Fig. 11.7a (p. 195): Predator-prey interactions between protozoans *Paramecium caudatum* and *Didinium nasutum* in oat medium without sediment (Gause 1934).
Fig. 11.7b (p. 195): Predator-prey interactions between protozoans *Paramecium caudatum* and *Didinium nasutum* in oat medium with sediment (Gause 1934).
Fig. 11.7c (p. 195): Predator-prey interactions between protozoans *P. caudatum* and *D. nasutum* in oat medium without sediment but with immigration (Gause 1934).
Fig. 11.8 (p. 195): Densities (per unit area orange) of prey mite *Eotetranychus sexmaculatus* and predator mite *Typhlodromus occidentalis* (20 food + 20 foodless oranges) (Huffaker 1958).
Fig. 11.9 (p. 196): Predator-prey interactions between prey mite *Eotetranychus sexmaculatus* and predator mite *Typhlodromus occidentalis* in a 252-orange universe (Huffaker 1958).
Host-parasitoid interactions between the azuki bean weevil (*Callosobruchus chinensis*) and the wasp *Heterospilus prosopidis* (Utida 1957)
Host-parasitoid interactions between the azuki bean weevil (*Callosobruchus chinensis*) and the wasp *Heterospilus prosopidis* over 112 generations (Utida 1957)
Experimental study of the predator-prey models

• Field studies
  – Greenwood (1986): ducks versus skunks
  – Bergerud et al. (2007): wolves versus caribou
  – Krueger et al. (1995): lake trout versus sea lampreys
Mean hatching rates for upland duck nests in N. Dakota versus predation by striped skunks (*Mephitis mephitis*) (Greenwood 1986)
Fig. 11.10 (p. 198): Impact of wolf predation on woodland caribou along north shore of Lake Superior.
Do predators limit the abundance of their prey in nature?

- Predators may be removing only the “doomed surplus”
- Most large predators in the Serengeti (e.g., lions, cheetahs, hyenas) have little effect on the abundance of large mammal prey
- Some introduce predators do limit the abundance of their prey
Fig. 11.13 (p. 200): Effect of sea lamprey introduction on lake trout fisher of the upper Great Lakes.
Components of predation

• **Functional response**
  – response of average predator to abundance of prey
  – does an individual predator eat more prey when prey are abundant?

• **Numerical response**
  – response of predator population to a change in prey density
  – does the density of predators change as prey numbers increase?
Fig. 11.14 (p. 200): Three types of functional responses for predators to changes in prey abundance.

- **Type 1**: constant consumption with no satiation
- **Type 2 and 3**: satiation at high prey densities
Fig. 11.15 (p. 201): Functional response of Canada lynx to abundance of snowshoe hares.
Fig. 11.16 (p. 201): Numerical response of Canada lynx to changes in snowshoe hare density, 1987-1995 in Kluane Lake, Yukon.
Fig. 11.17 (p. 202): Functional and developmental responses of predatory insect *Notonecta* feeding on mosquito larvae in the lab.
Fig. 11.18 (p. 202): Components of predation that combine to give the total response of predators to changes in density of prey.
Fig. 11.19 (p. 203): Canada lynx trapping results, 1821-1913, showing population oscillations.