Predation I

BIOL/BOT 160 – Ecology

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Learning objectives

- Students should be able to
  - Define and explain the importance of consumer-resource interactions for understanding population dynamics
  - Analyze simple models of predator-prey population dynamics to answer the following:
    - Do predators regulate prey?
    - What is the Lotka-Volterra predator-prey model, and what does it predict about the interactions between predators and their prey?
    - Is predator behavior relevant to predator-prey population dynamics?
  - Explain some evolutionary consequences of predation

What is a consumer?

- Consumers are species that remove/utilize energy by consuming other organisms (in contrast to producers which capture/add energy from the abiotic environment)

Functional types of consumers

1. Those that remove prey from prey populations (i.e. kill them):

   Predators – kill and eat prey

   Parasitoids – capture prey, lay eggs on/in it, and kids feed on prey

   e.g. wasps and flies will use caterpillars and spiders

   Cannibalism – kill and eat own species

Functional types of consumers

2. Those that harm other species by consuming some of their resources (i.e. don't kill)

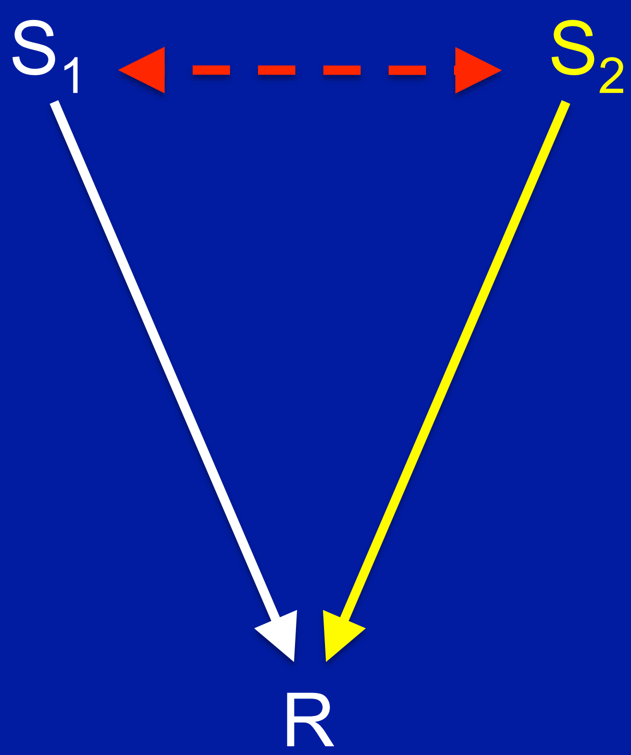
   Herbivores – eat plants or seeds (usually don't consume entire plant)

   Parasites – consume part of an organism or resources inside organisms

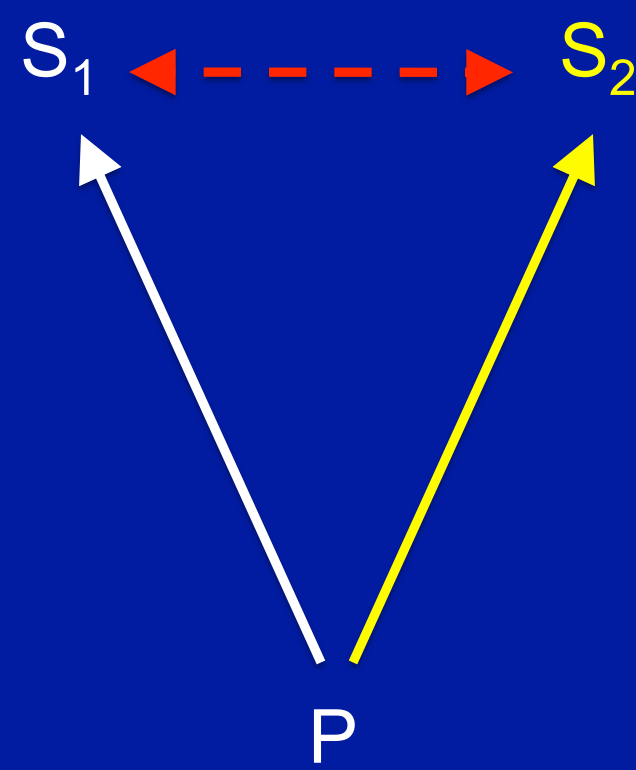
   Social parasites – parasitize parental care of other species

   - e.g. brood parasites in birds, fish, insects

Species interactions



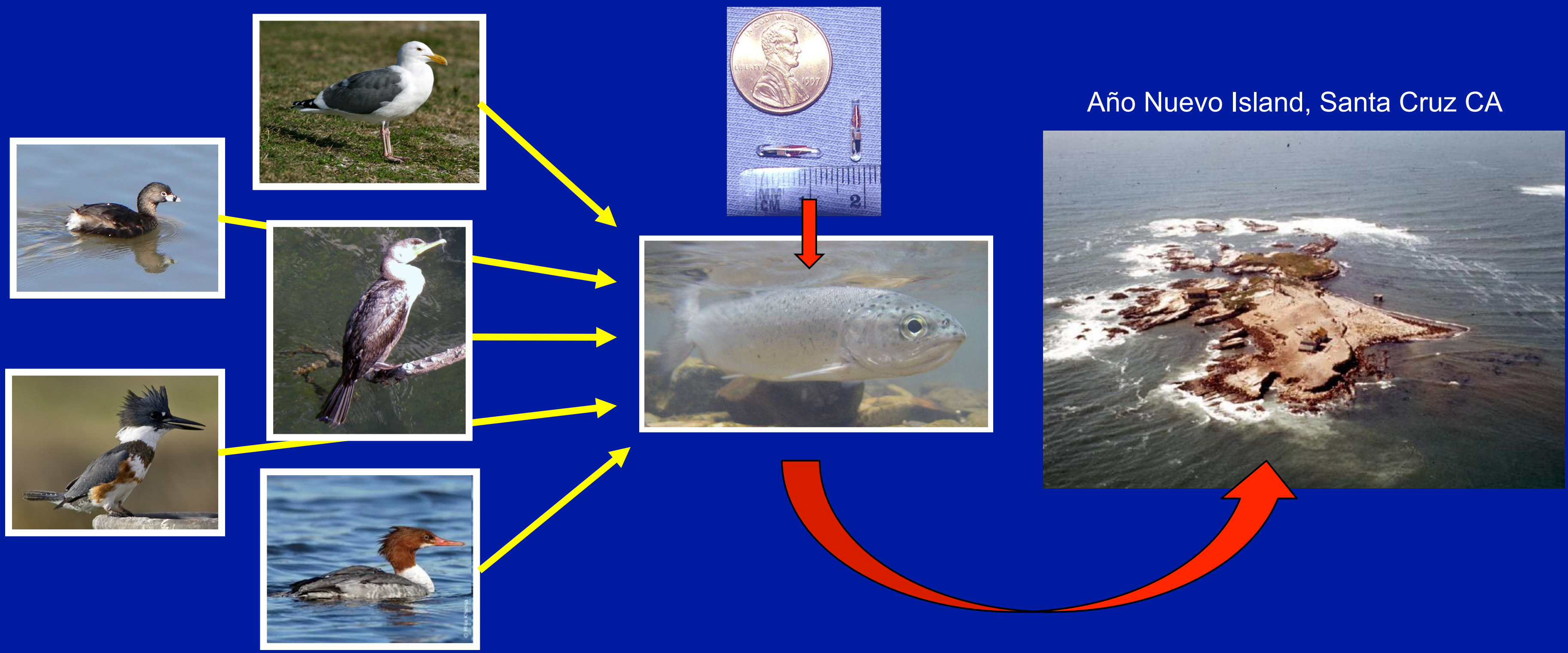
Exploitative Competition
(competition between S_1 and S_2 for a common limiting resource)



Apparent Competition
(competition between S_1 and S_2 induced by a common predator)

Avian Impacts on Local Salmon Smolts

Interaction between birds and salmon smolts



Rough estimates suggest birds consume 5% of smolts

Our goal is to better understand this interaction

Avian Impacts on Local Salmon Smolts

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Radio tagging birds to determine presence/absence at creeks

Each bird is scanned for PIT tags

Conducting regular surveys and observations of predation

Scan for new PIT tags at Año Nuevo Island and other sites

Gulls and watershed birds

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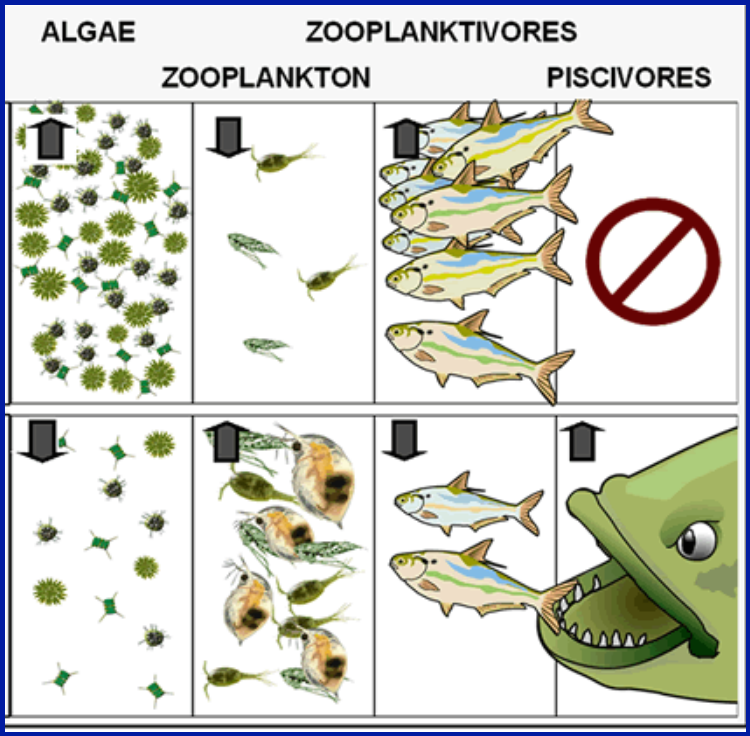
Funded by California Sea Grant

Predation

- Predation can restrict the distribution of prey
  - Could be good (e.g., if prey is pest) or bad (e.g., if predator is an introduced/invasive species)

Predation

- Predation can a have major affect on community structure (*i.e.*, the number and type of species found in a particular place/time)

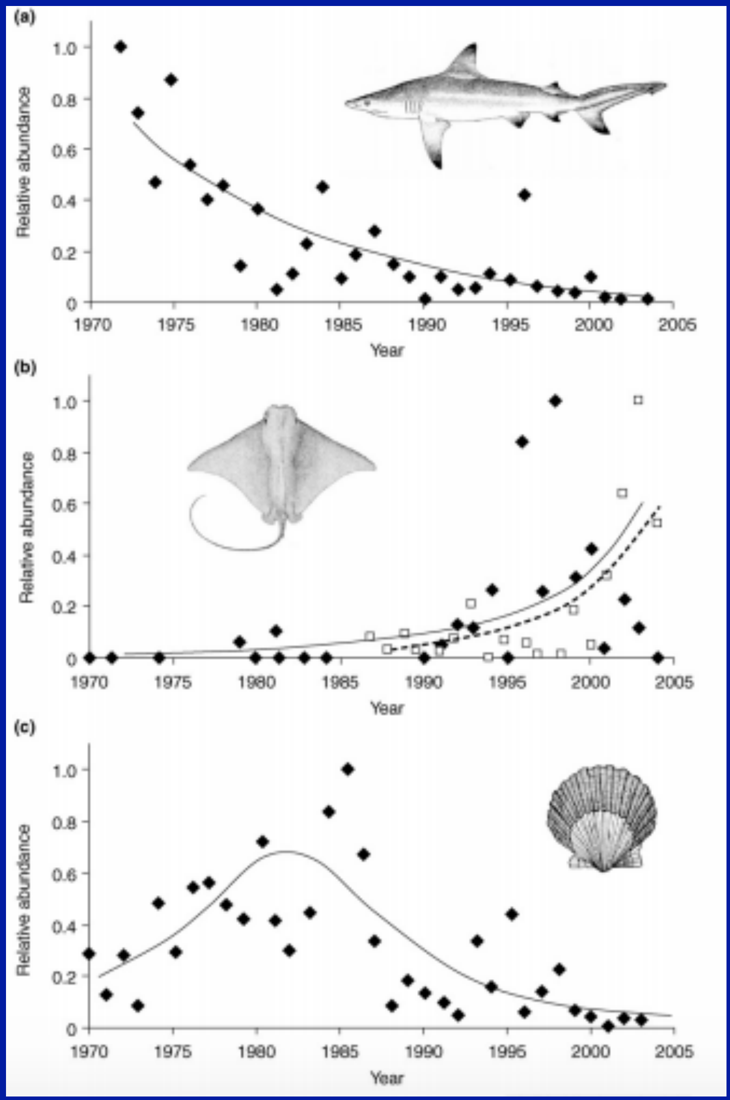


Predation

- Predation can be a major force of selection
  - Driver of coevolution in many species (Red queen hypothesis)

Think-pair -share

- Suppose that sharks eat rays and rays eat scallops. Sharks are in decline, and rays will avoid any area with a relative abundance of sharks above 0.2. What do you expect the relative abundance curves of rays and scallops to look like?



Predation Studies

- Lab-based studies
  - Studies on paramecium and mites
  - Can show cycles over shorter time scales
  - Show environmental heterogeneity
  - Great for theory development
  - Can be limiting

- Field-based studies
  - Many examples (Lynx & rabbits, wolves & caribou)
  - Longer time cycles
  - Test theory
  - Great for studying selection, coevolution, conservation management

Do predators regulate prey?

Evidence: Many predator removal studies lead to an increase in prey density

What is regulation?

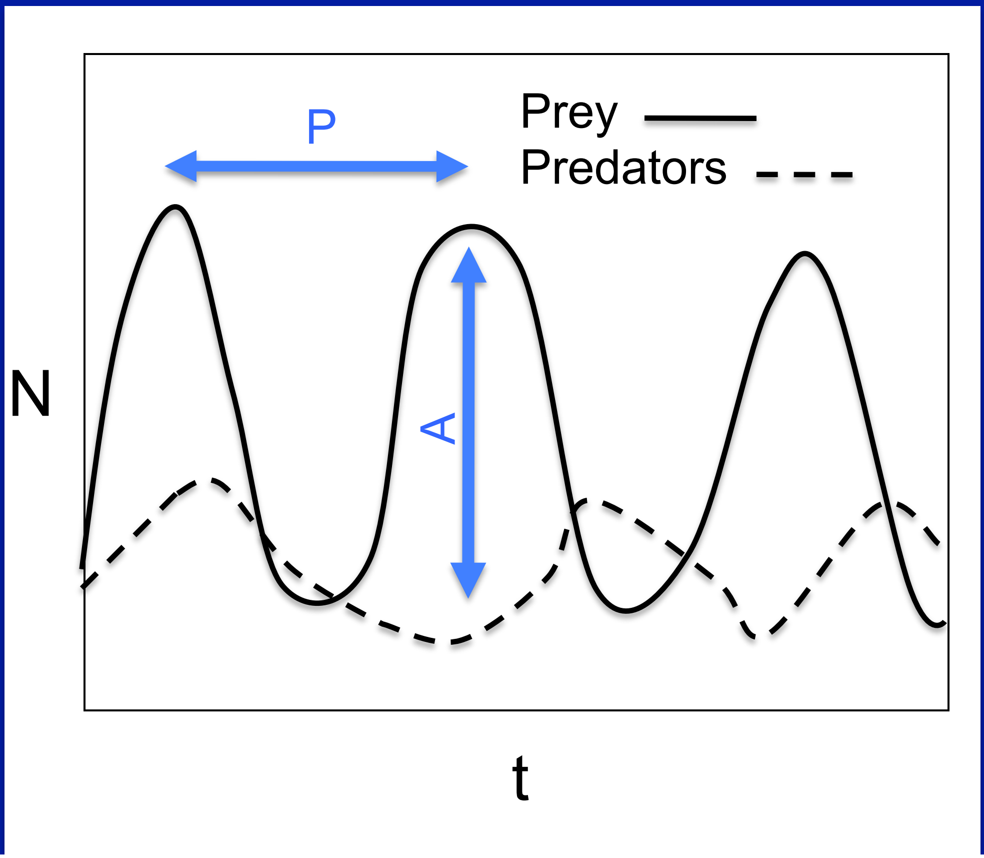
Density-dependence in birth and/or death rates

How do predators regulate prey?

Increase in predation with increase in prey density

Do predators regulate prey?

Many predator and prey populations show regular/correlated fluctuations in density

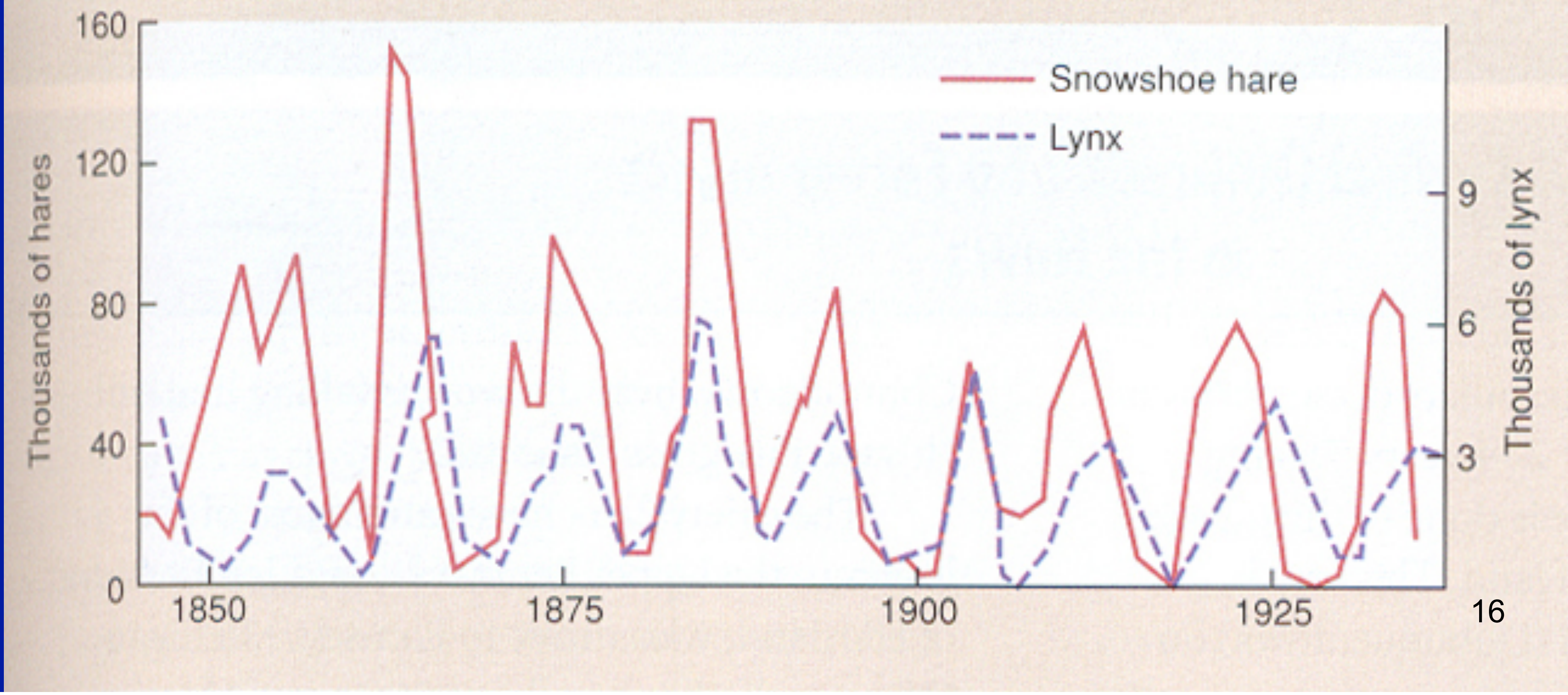


A: amplitude – how big the change in density is from lowest to highest levels (e.g. lemmings -500 individuals from year to year)

P: period – how much time it takes for density cycle to repeat itself (e.g. ptarmigan and lemming densities peak every 4 years)

Do predators regulate prey?

Elton and Nicholson1942



Do predators regulate prey?

Pattern: Many predator and prey populations show very regular fluctuations in density

Questions: Does predation cause these cycles?

or

Do prey cycle for other reasons and predator cycles are a result of prey cycles? - Why might prey cycle?

Lotka-Volterra predator-prey models

Can use Lotka-Volterra prey models to ask whether or not predation alone can lead to cycles in predators and prey:

We will construct models without intraspecific competition in prey

See if we can still get cyclic fluctuations in prey density without this form of density-dependence

Building a Lotka-Volterra predator-prey model

Assume: - 1 species prey, 1 species predator

Predator affects death rate of prey

Prey: V = victim

α = capture efficiency (i.e. effect of predator on the per capita growth rate of victim population)

Prey affects birth rate of predator

Predator: P = predator

β = conversion efficiency (i.e. ability of the predator to convert each victim into per capita growth of the predator)

Building a Lotka-Volterra predator-prey model

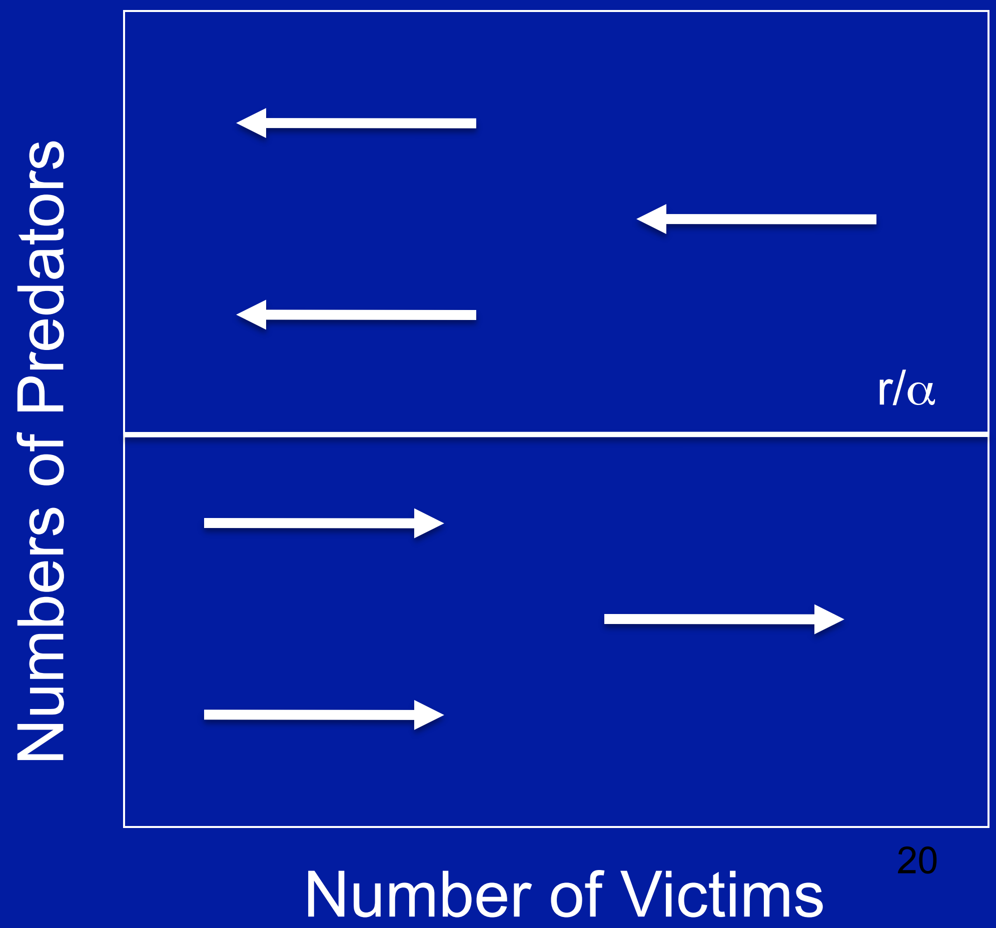
Finding prey zero isocline:

$$dV/dt = rV - \alpha VP$$

$$0 = rV - \alpha VP$$

$$rV = \alpha VP$$

$$P = r/\alpha$$



Building a Lotka-Volterra predator-prey model

Finding predator isocline:

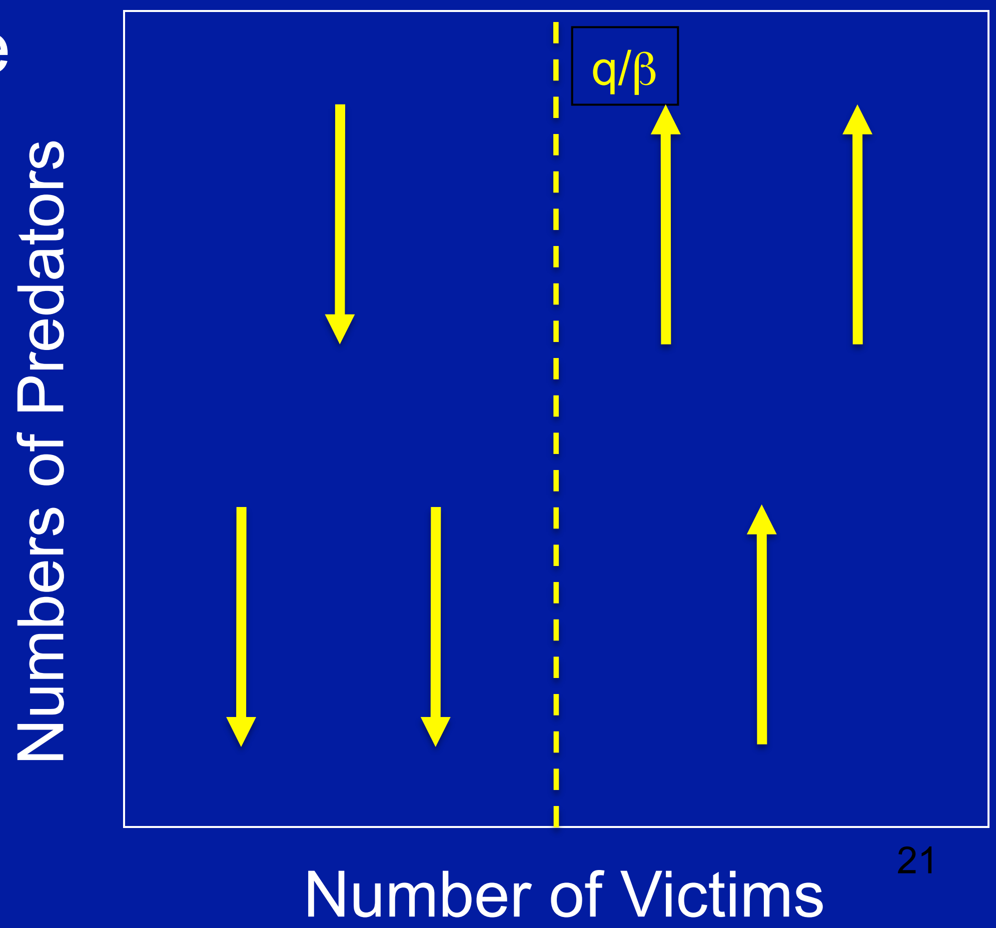
q = per capita death rate

$$dP/dt = \beta VP - qP$$

$$0 = \beta VP - qP$$

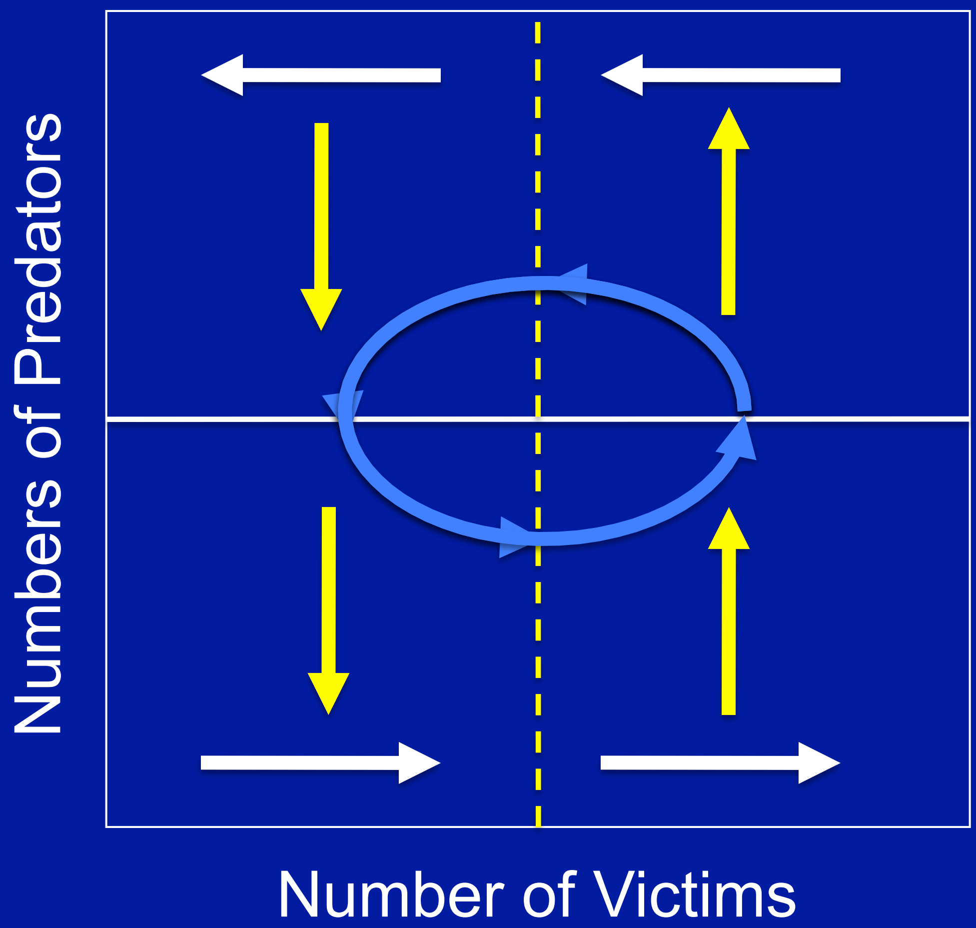
$$\beta VP = qP$$

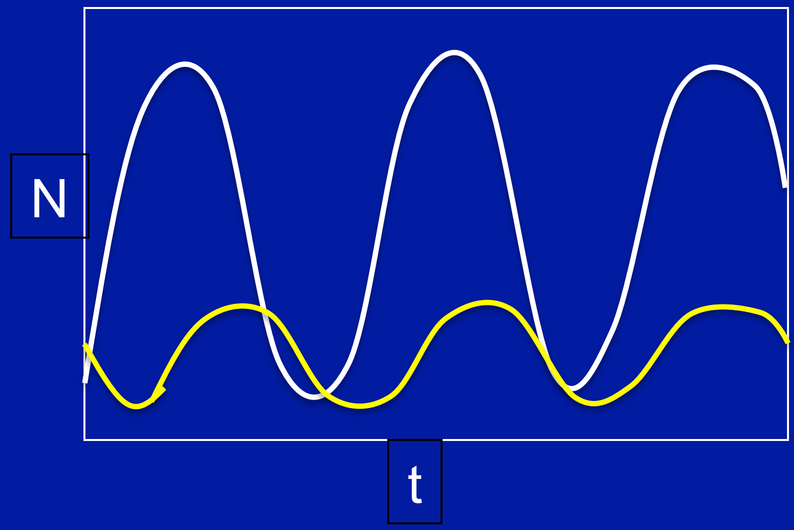
$$V = q/\beta$$



Building a Lotka-Volterra predator-prey model

Putting prey and predator isoclines together:





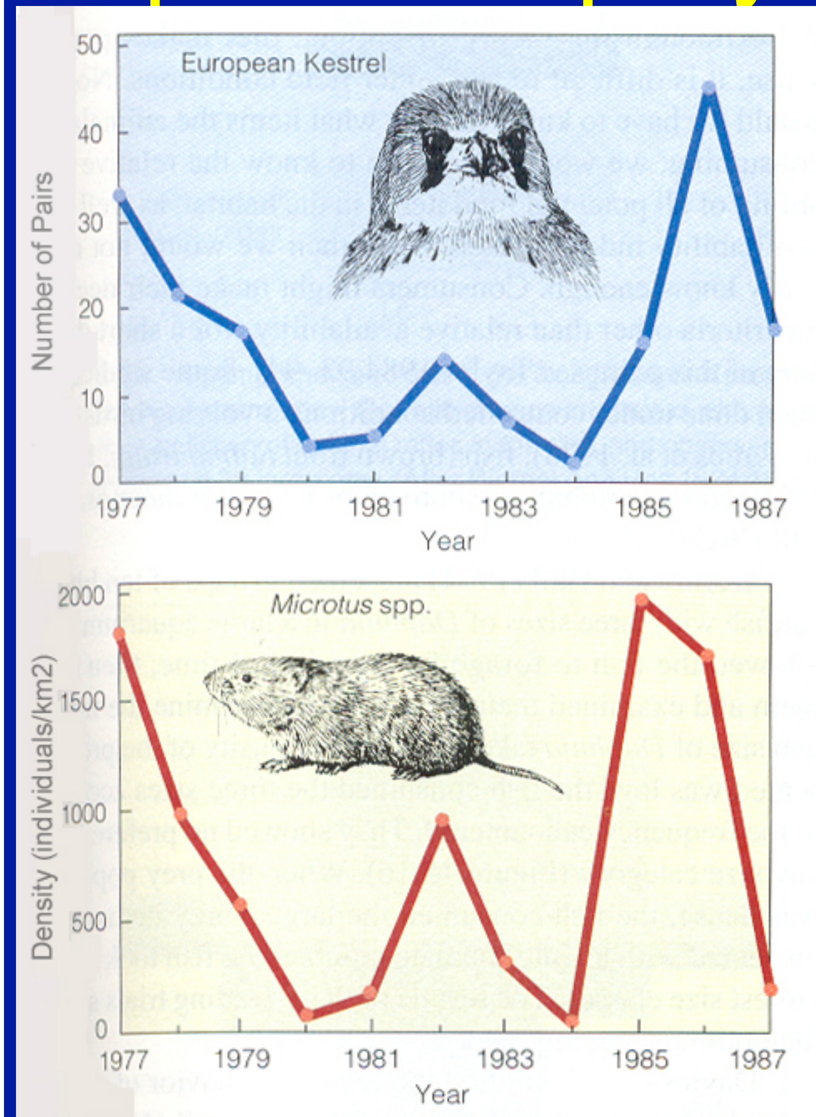
Predator behavior influences predator-prey population dynamics

There are two types of predator behavior (responses to prey) that add stability to these predator-prey population dynamics:

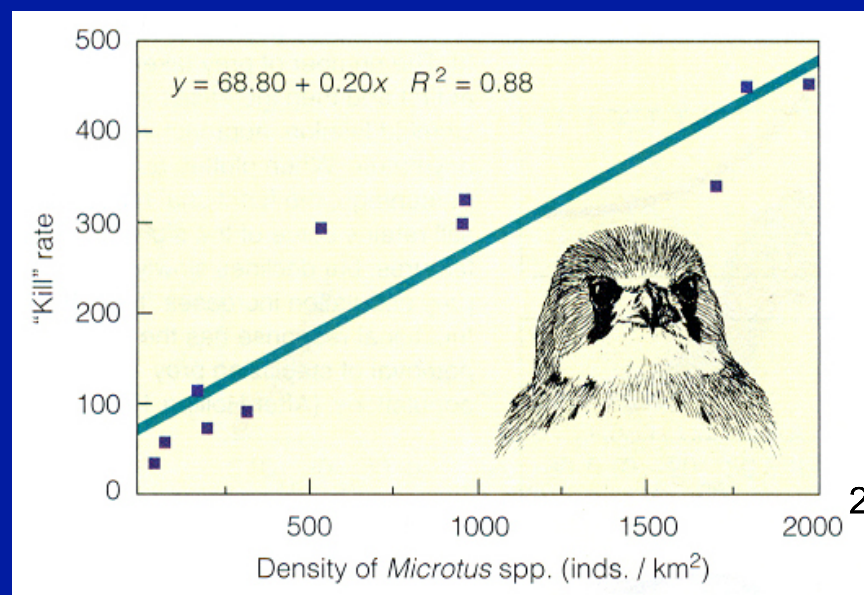
1. <u>Numerical response</u> – number of predators increases with prey density (# prey consumed per predator constant but total # predators ↑)

2. <u>Functional response</u> – predation rates increase w/ prey density (# prey consumed/predator ↑)

Predator behavior influences predator-prey population dynamics



Example of numerical and functional responses in European kestrel predation on voles

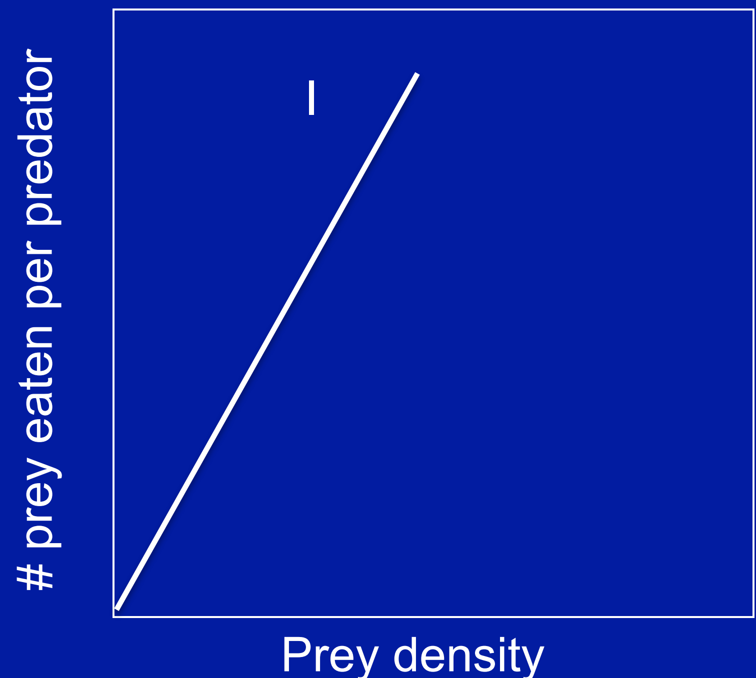


Different types of functional responses:

Type I – predator consumes more as prey density ↑

What L-V models assume

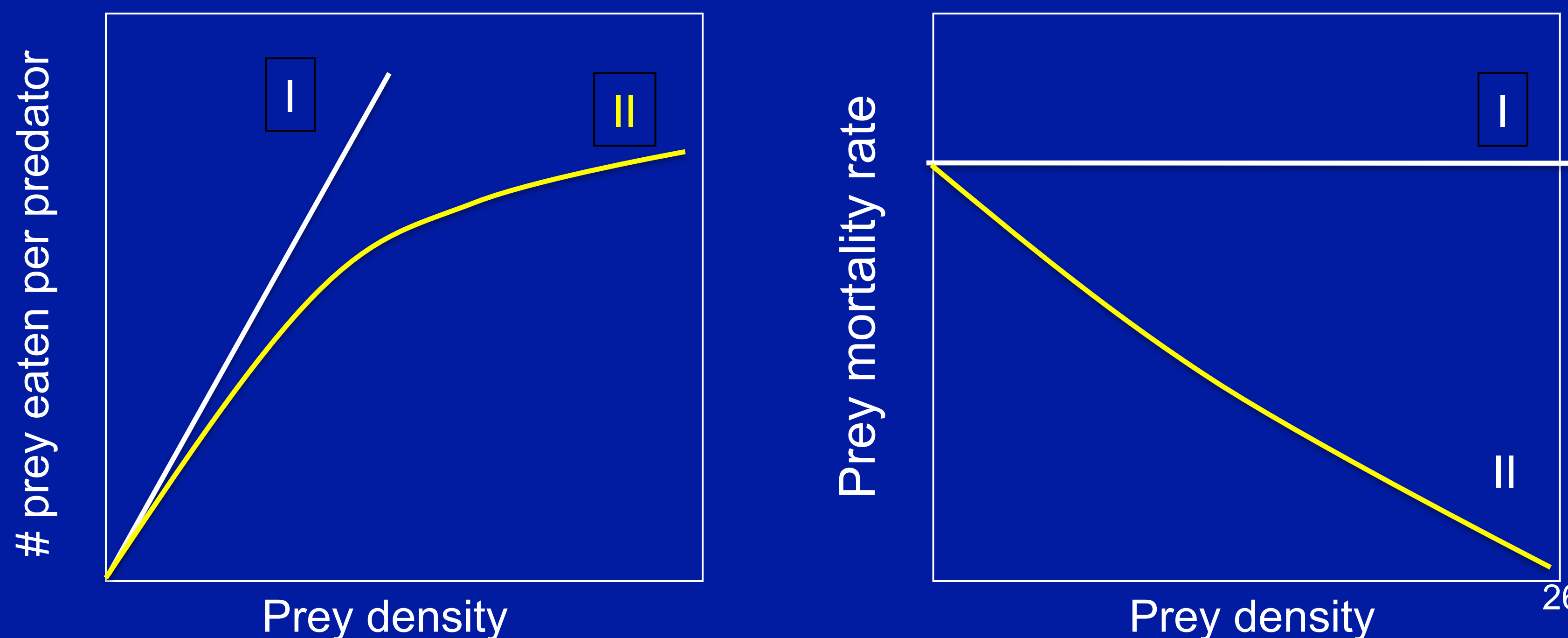
But unrealistic b/c of satiation and handling time



Different types of functional responses:

Type II – predator consumes more as prey density ↑ but at a decreasing rate (diminishing returns)

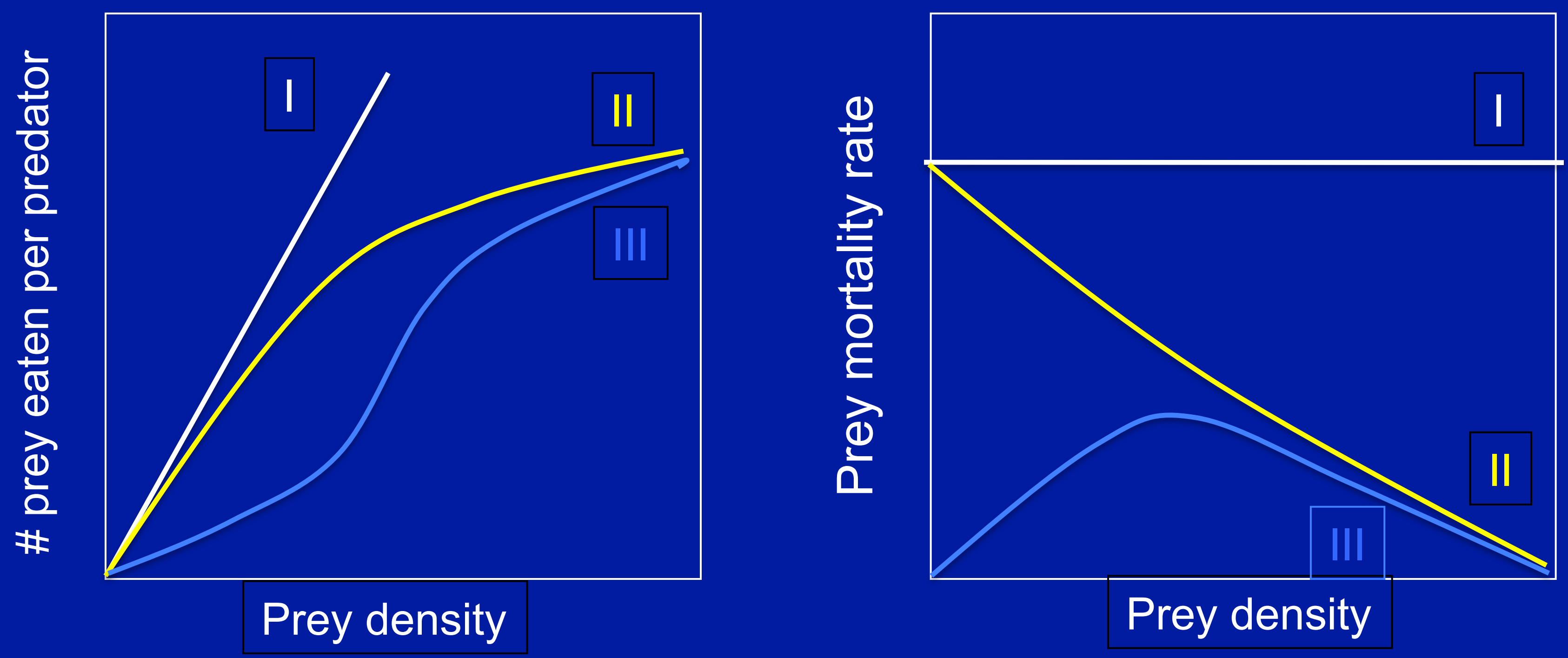
Incorporates satiation and handling time



Different types of functional responses:

Type III – predation rate is accelerated at low prey density but decreases at high prey density

Also incorporates satiation and handling time, plus…



Different types of functional responses:

What causes a Type III functional response?

At low prey densities:

- Prey-switching – when prey density is low generalist predators may switch to another species
- Search image - Predators notice prey more as their density increases
- Refugia for prey – there are enough hiding spots for prey at low prey densities, but at higher densities refugia fill up and prey death rates ↑

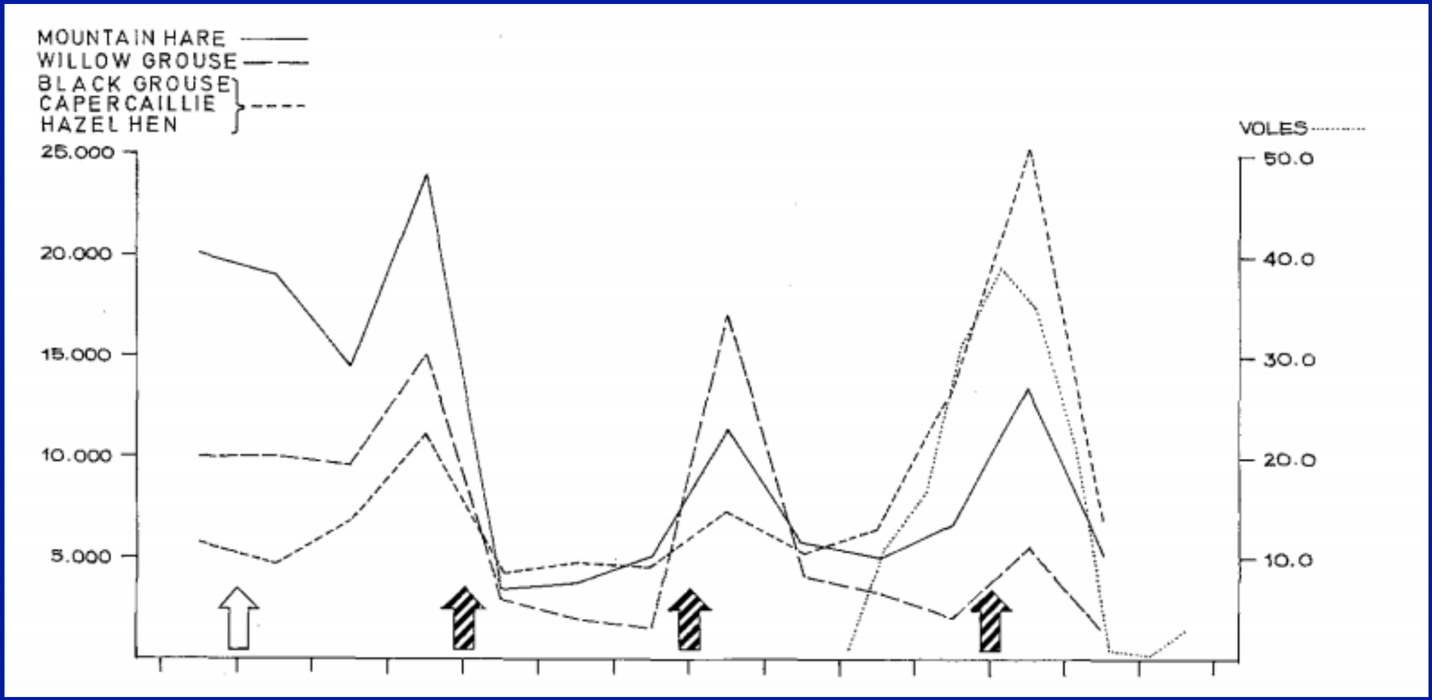
At high prey densities:

- Handling time and satiation prevent predator from being able to further control prey (converges on Type II)

Case study: rodent population cycles in Fennoscandia

Fennoscandia (Finland, Sweden)

Population dynamics of several different rodent species show cyclic fluctuations



Case study: rodent population cycles in Fennoscandia

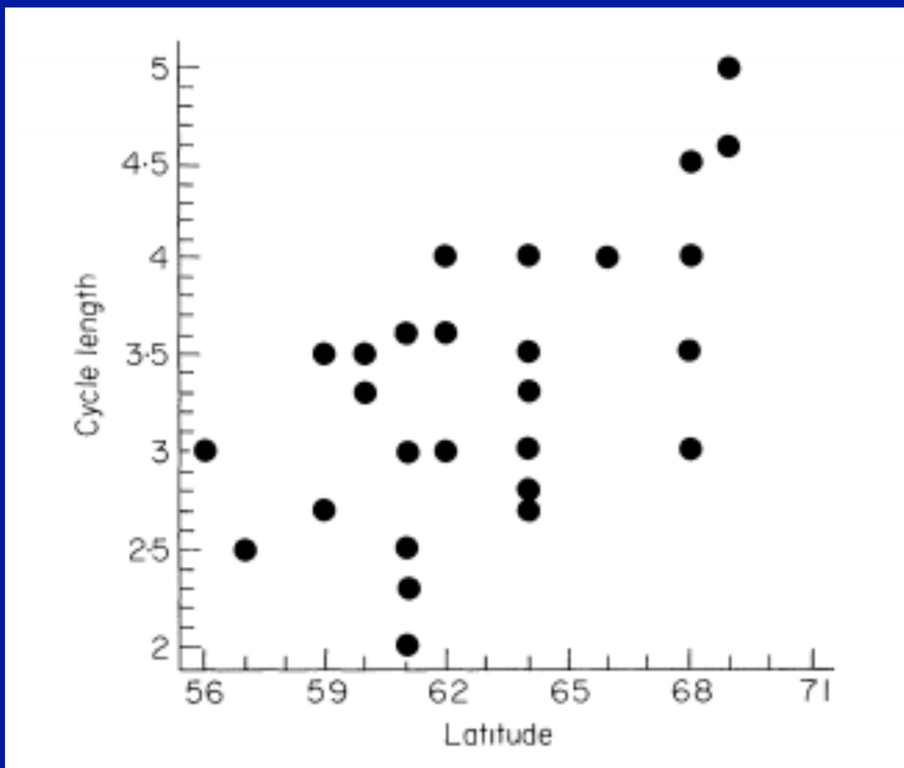
Fennoscandia (Finland, Sweden)

Population dynamics of several different rodent species show cyclic fluctuations

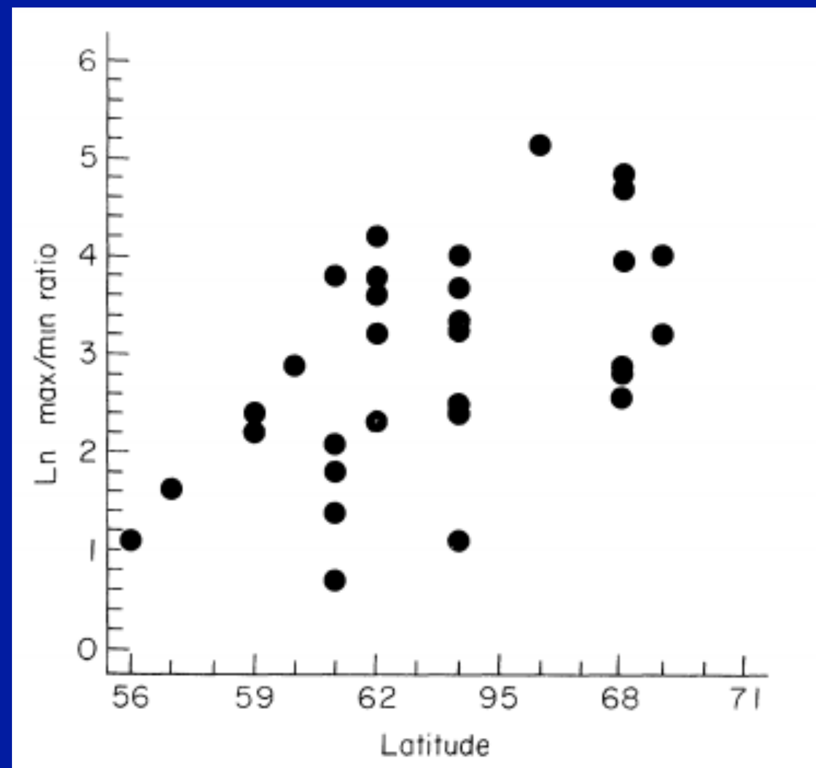
Observations:

- Magnitude of fluctuations varies between N and S
- Fluctuation magnitude & timing depend on the predator type feeding on the rodent population

Case study: rodent population cycles in Fennoscandia



Cycle length increases with latitude



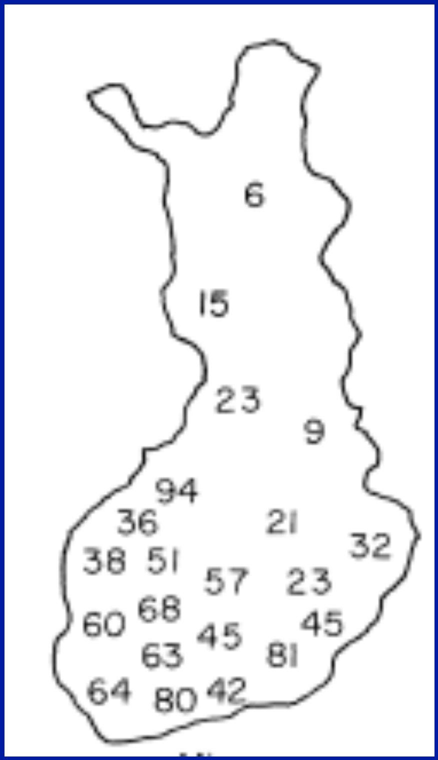
Cycle amplitude increases with latitude

Case study: rodent population cycles in Fennoscandia

Why do rodent population cycles vary in their magnitude between the North and South?

There is also a latitudinal gradient in types of predators:

- North – mostly a specialist predator that does not prey-switch (weasel)
- South - mostly generalist predators, all are prey-switchers (cats, birds of prey, foxes)

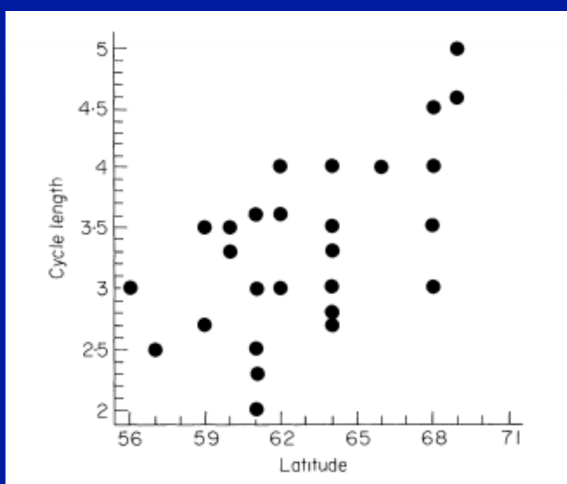


Specialist

Generalist

Think-pair-share

- Suppose that you observe the data we have just discussed. Can you propose a mechanistic link between the specialists/ generalist predator gradient and the observed prey population cycle length/amplitude data?



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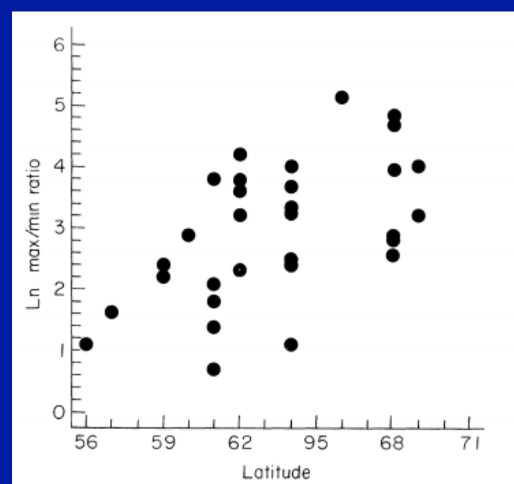

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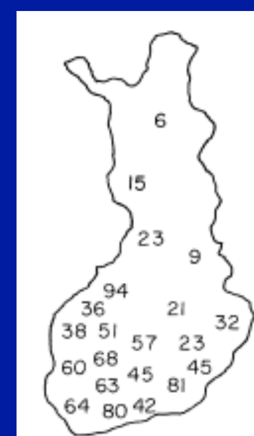

Specialist

Generalist

Predation & Selection

- Coevolution is the evolutionary change in two or more interacting species
- Evolve an 'arms race' between predators and prey
- Greater selection pressure on prey
  - Prey loses its life
  - Predator loses a meal
  - 'Life-dinner principle'

Evolutionary responses to predation

Coevolution is the evolutionary outcome of species interactions (reciprocal evolutionary response)

Aposomatism – warning coloration

Mimicry – having a phenotype similar to a different species

- Mullerian mimicry: several different species that are each toxic/nasty converge on same signal
- Batesian mimicry: non-toxic species mimicking a toxic species

Evolutionary responses to predation

Why mimic?

- Benefit from lesson learned by predators

How does this work when nasty species are lethal?

- Dead predators can't learn!

Natural selection favors those individuals with innate ability to recognize toxic species

Friend of Foe?

Coral Snake
Venomous

King Snake
Non-venomous

Evolutionary responses to predation

Case history #1: Experiment to test for innate recognition of toxic species by predators (Smith)

Predator: Mot-mots (eats snakes)

Question: do Mot-mots have innate recognition of coral snake pattern?

Mot-mots raised in captivity (no snake experience)

Evolutionary responses to predation

Case history #1: Experiment to test for innate recognition of toxic species by predators (Smith)

Results:

Mot-mots only attacked snakes without the coloration pattern similar to coral-snakes

No previous experience was necessary – birds had innate recognition of toxic species!