BIOL 410 Population and Community Ecology

Predation

Intraguild Predation

- Occurs when one species not only competes with its heterospecific guild member, but also occasionally preys upon it

- Species 1 – Competitor & Occasional Predator
- Species 2 – Competitor & Occasional Prey

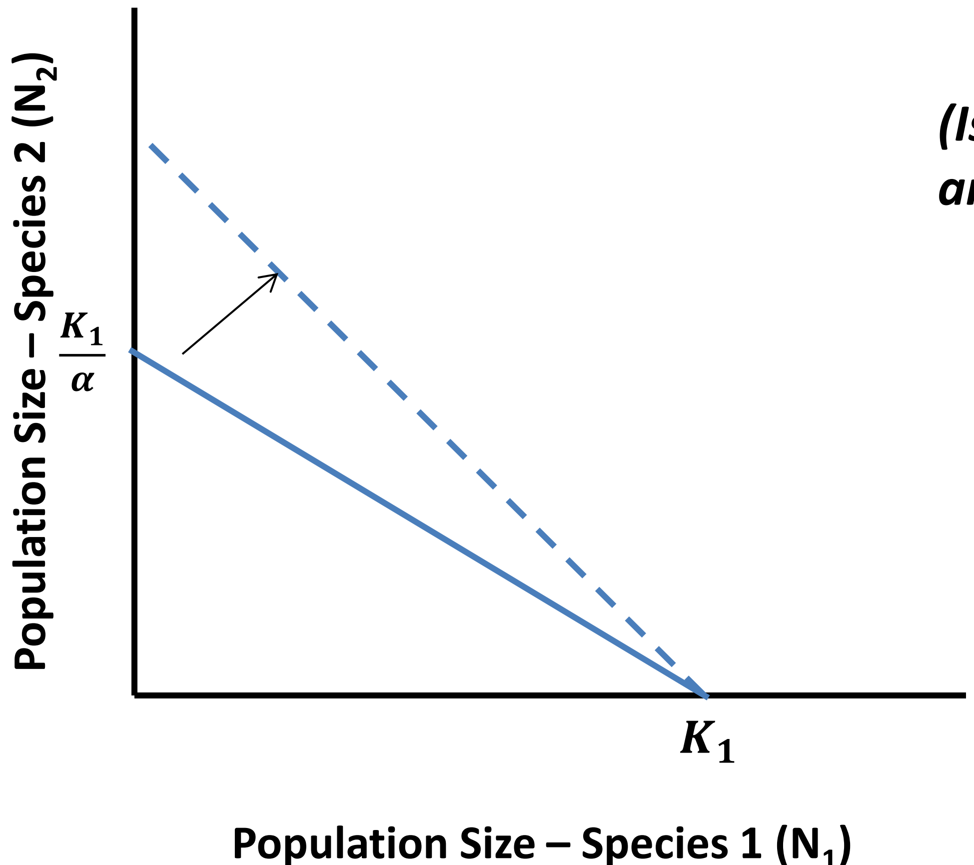
Intraguild Predation

- Species 1 – competitor and predator
- $\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha N_2}{K_1}\right) + \gamma N_1 N_2$

- Species 2 – competitor and prey
- $\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \beta N_1}{K_2}\right) - \delta N_1 N_2$

Intraguild Predation and Isoclines

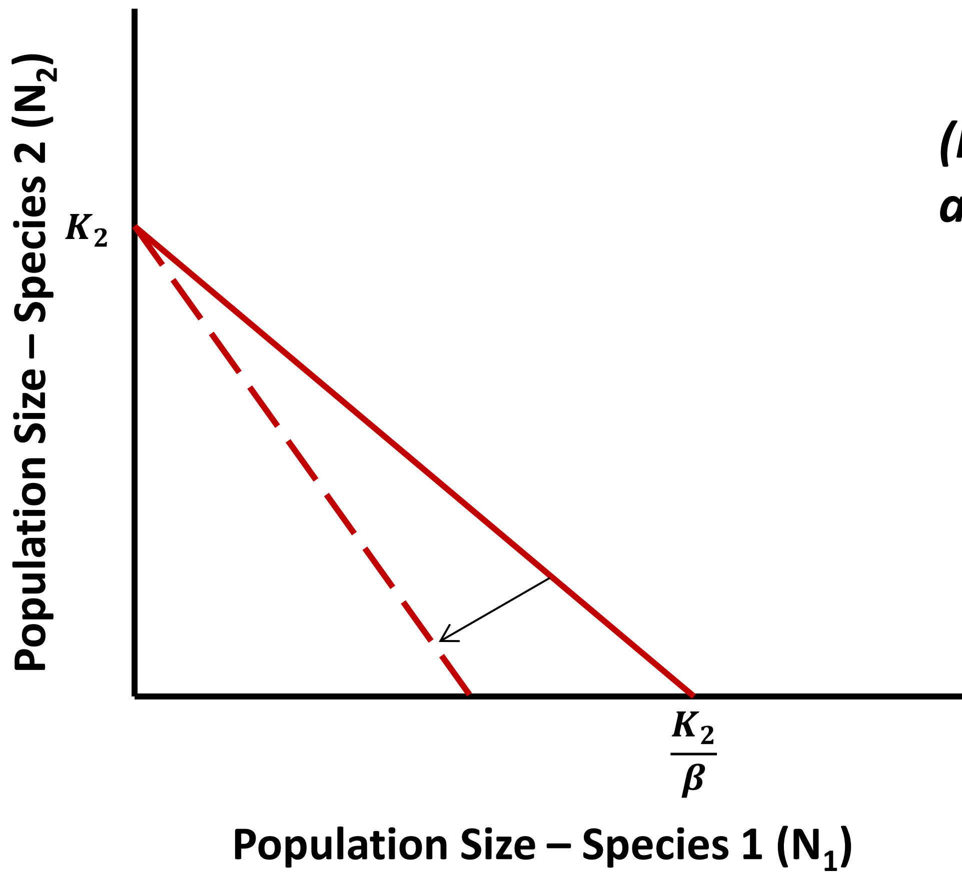
- Species 1 Isocline - Number of species 2 required to drive species 1 to extinction EXCEEDS K_1/α, as Species 2 losses individuals to predation.



(Isocline rotates, but K_1 and K_1/α do not change)

Intraguild Predation and Isoclines

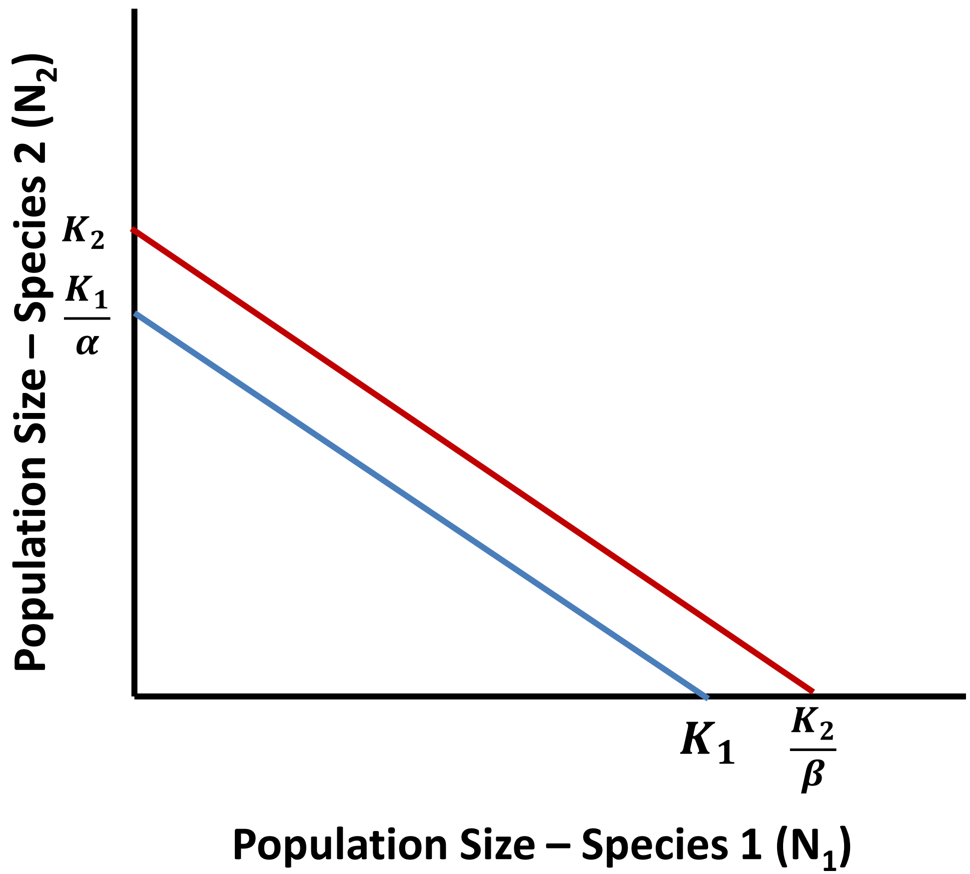
- Species 2 Isocline - Number of species 1 required to drive species 2 to extinction is LESS THAN K_2/β, as Species 1 both competes and preys on species 2.



(Isocline rotates, but K_2 and K_2/β do not change)

Intraguild Predation and Isoclines

- Adding this dynamic can now change the anticipated outcomes of state-space models



Species interactions

- Competition: -/-
  - Reciprocal negative interactions for both parties
- Mutualism: +/+
  - Both parties benefit from the interspecific interaction
- Commensalism: +/0
  - One party benefits from the interaction while the other experiences no benefit or harm
- Predation +/-
  - One party benefits at the expense of a second

Predation

- **Predation (directional interaction)**
  - **the predator (P) exerts a negative effect on the population of the prey ("Victim" – V)**
  - **the victims exert a positive effect on the predator population**

  - **Predation can include the partial consumption of one organism by another**
    - **Herbivory**
    - **Parasitism**
    - **Cannibalism**

    - **Negative impact at the population level**

Impacts of predation

- Death

- Foraging behaviour
- Habitat use
- Matting behaviour
- Defensive structures/chemicals, life history, behaviour

- Direct impact of predation vs. evolutionary and ecological costs
- Trade-offs
- What are the impacts for populations and communities?

Predator and prey dynamics

- Prey population growth

$$\frac{dV}{dt} = f(V, P)$$

V : victim; prey population size (equivalent to N_{prey})

P : predator population size (i.e. $N_{predator}$)

Predator and prey dynamics

- Population growth of prey under predation
  - r : intrinsic rate of prey growth

$$\frac{dV}{dt} = rV$$

- Negative impact of predator

$$\frac{dV}{dt} = rV - \alpha VP$$

  - α : capture efficiency (not competition coefficient)
    - Measure of the effect of the predator on per capita growth rate of prey

$$\left(\frac{1}{V}\frac{dV}{dt}\right)$$

    - units for α are : victims / (victim • time • predator)].

Predator and prey dynamics

- Negative impact of predator

$$\frac{dV}{dt} = rV - \alpha VP$$

  - αV : functional response of the predator
  - α : capture efficiency(impact of a single predator)
    - Large α : Baleen whale impact on krill
    - Small α : Small fish impact on krill

Predator and prey dynamics

- Predator population growth

$$\frac{dP}{dt} = rP$$

$$\Downarrow$$

$$\frac{dP}{dt} = \beta VP - qP$$

Positive impact of prey on predator population growth

- Specialist predator , no alternative prey

Predator death rate

- Separation of birth and death

Predator and prey dynamics

- Predator population growth
  - *V* : prey population size (equivalent to N_{prey})
  - *P* : predator population size (i.e. $N_{predator}$)
  - *q :* per capita death rate (equivalent to *d*)

$$\frac{dP}{dt} = \beta VP - qP$$

- β – conversion efficiency (not competition coefficient)
  - measure of the ability of predator to convert consumed prey into per capita growth rate for the predator population

$$\left(\frac{1}{P}\frac{dP}{dt}\right)$$

  - units for β are
    - predators / (predator • time • victim)

Equilibrium prey population

- What is the predator population (P) where the prey population can sustain a stable population growth rate (dV/dt = 0)?

$$\frac{dV}{dt} = rV - \alpha VP$$

$$0 = rV - \alpha VP$$

$$\alpha VP = rV$$

$$\alpha P = r$$

Prey intrinsic growth rate

Number of predators needed to limit prey population

$$\hat{P} = \frac{r}{\alpha}$$

Predator capture efficiency (number of prey each predator can capture)

Independent of prey population size

Equilibrium predator population

- What is the minimum prey population (V) needed to sustain the predator population (dP/dt = 0)?

$$\frac{dP}{dt} = \beta V P - qP$$

$$0 = \beta V P - qP$$

$$qP = \beta V P$$

$$q = \beta V$$

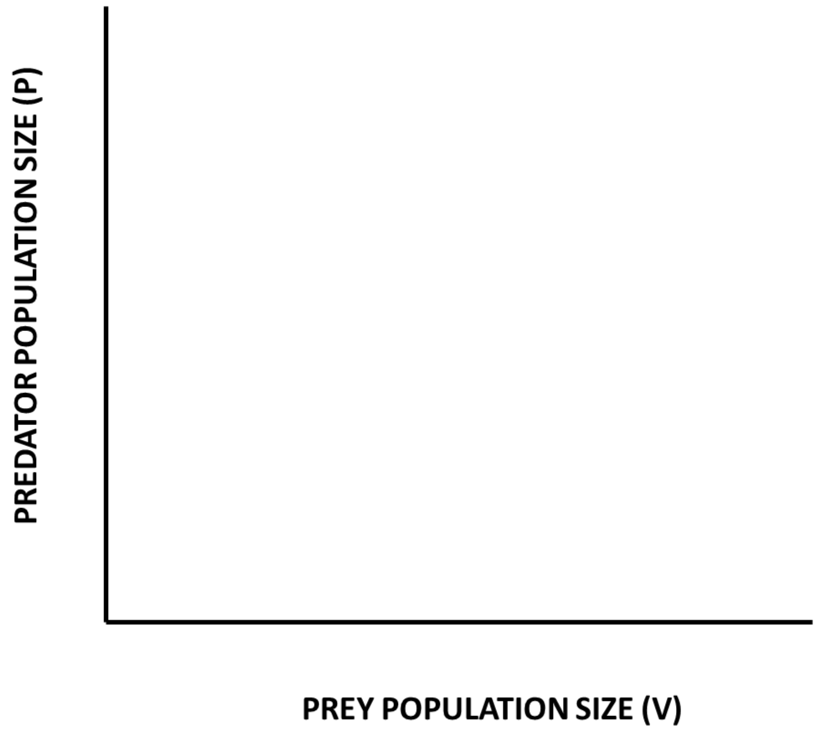
Predator death rate

$$\hat{V} = \frac{q}{\beta}$$

Conversion efficiency of predators

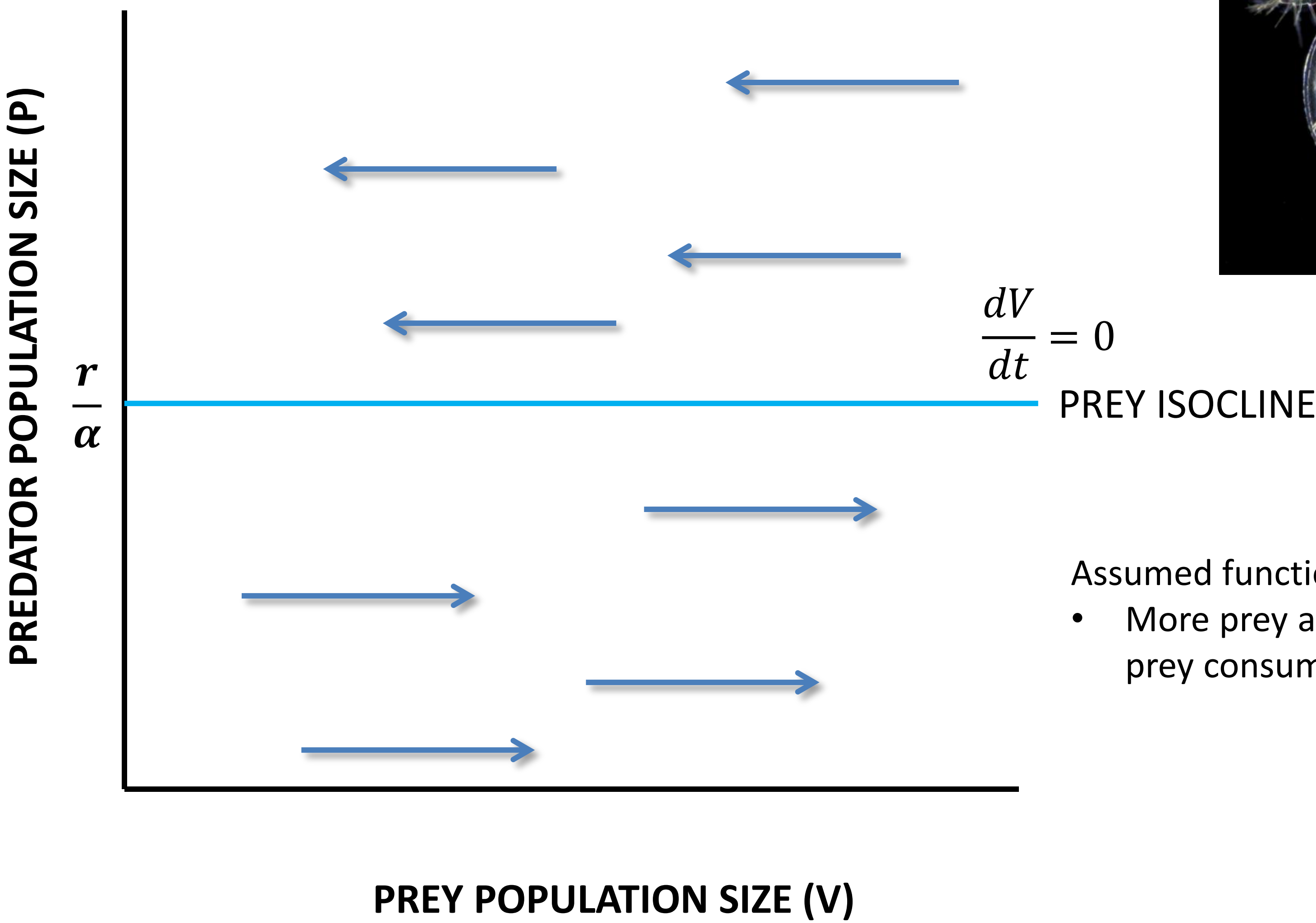
Number of prey items needed to maintain predator population

State space representation of predator and prey dynamics



Lotka-Volterra models

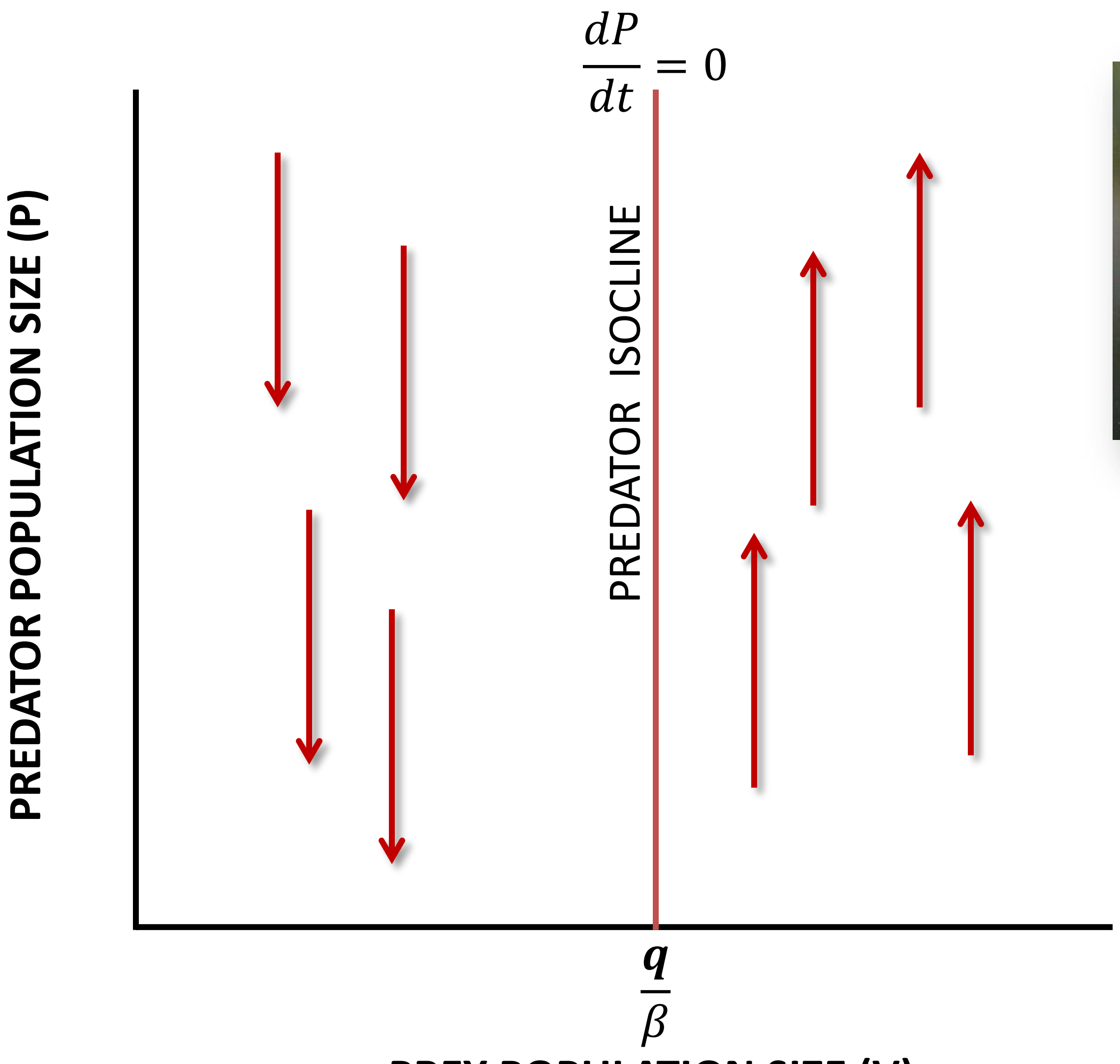
Lotka-Volterra Models – Predator/Prey dynamics



Assumed functional response

- More prey available, more prey consumed

Lotka-Volterra Models – Predator/Prey dynamics



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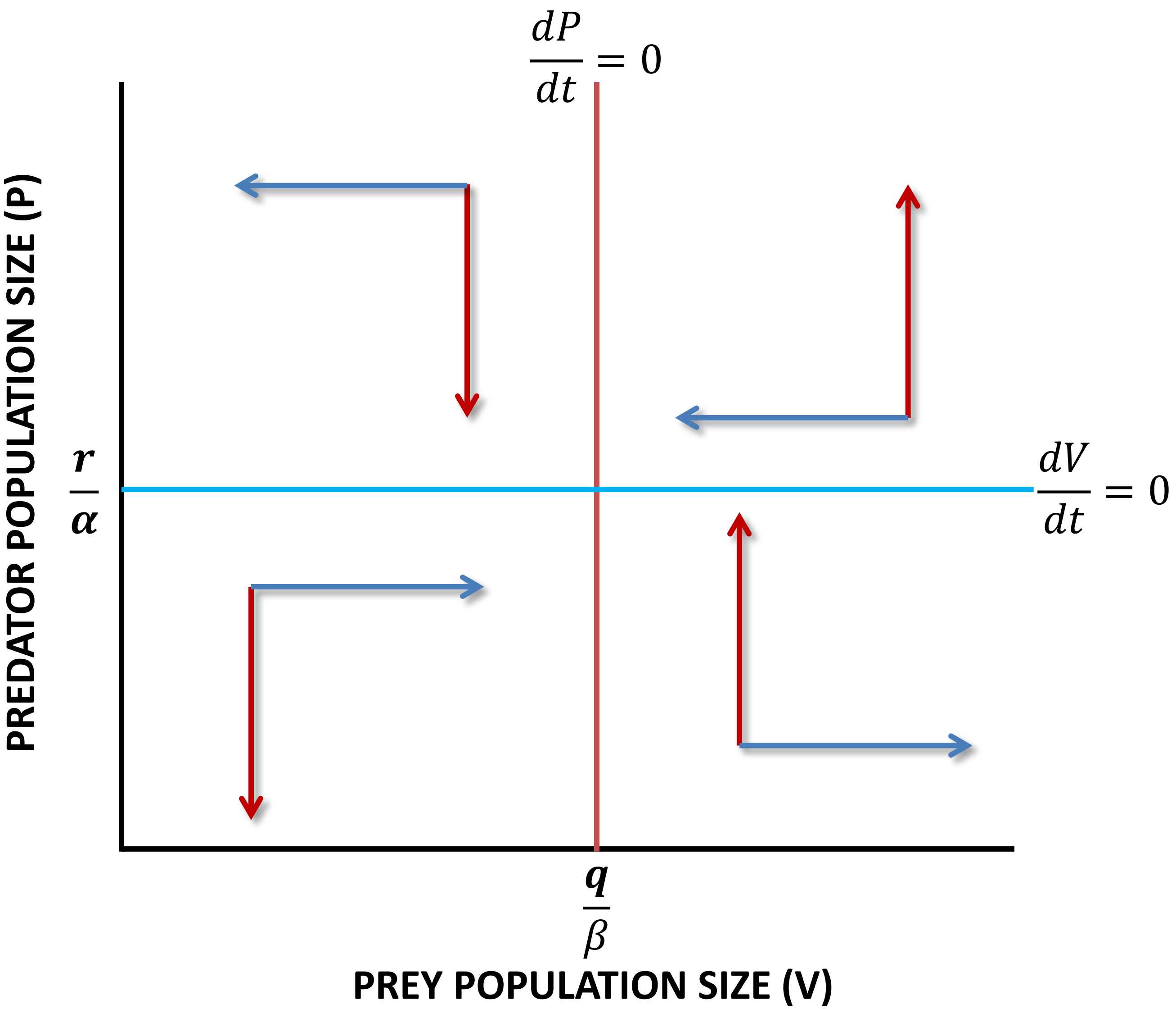

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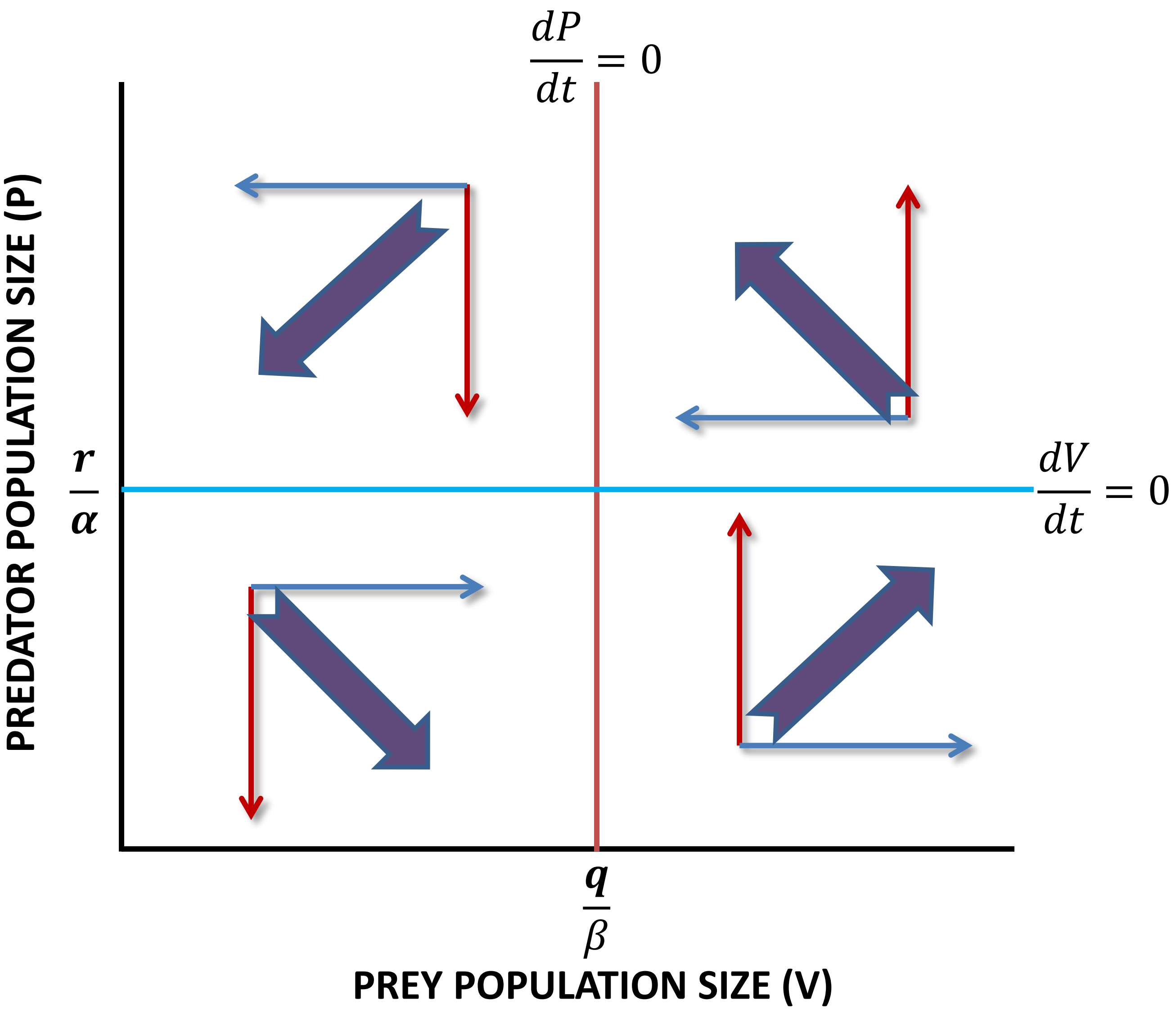

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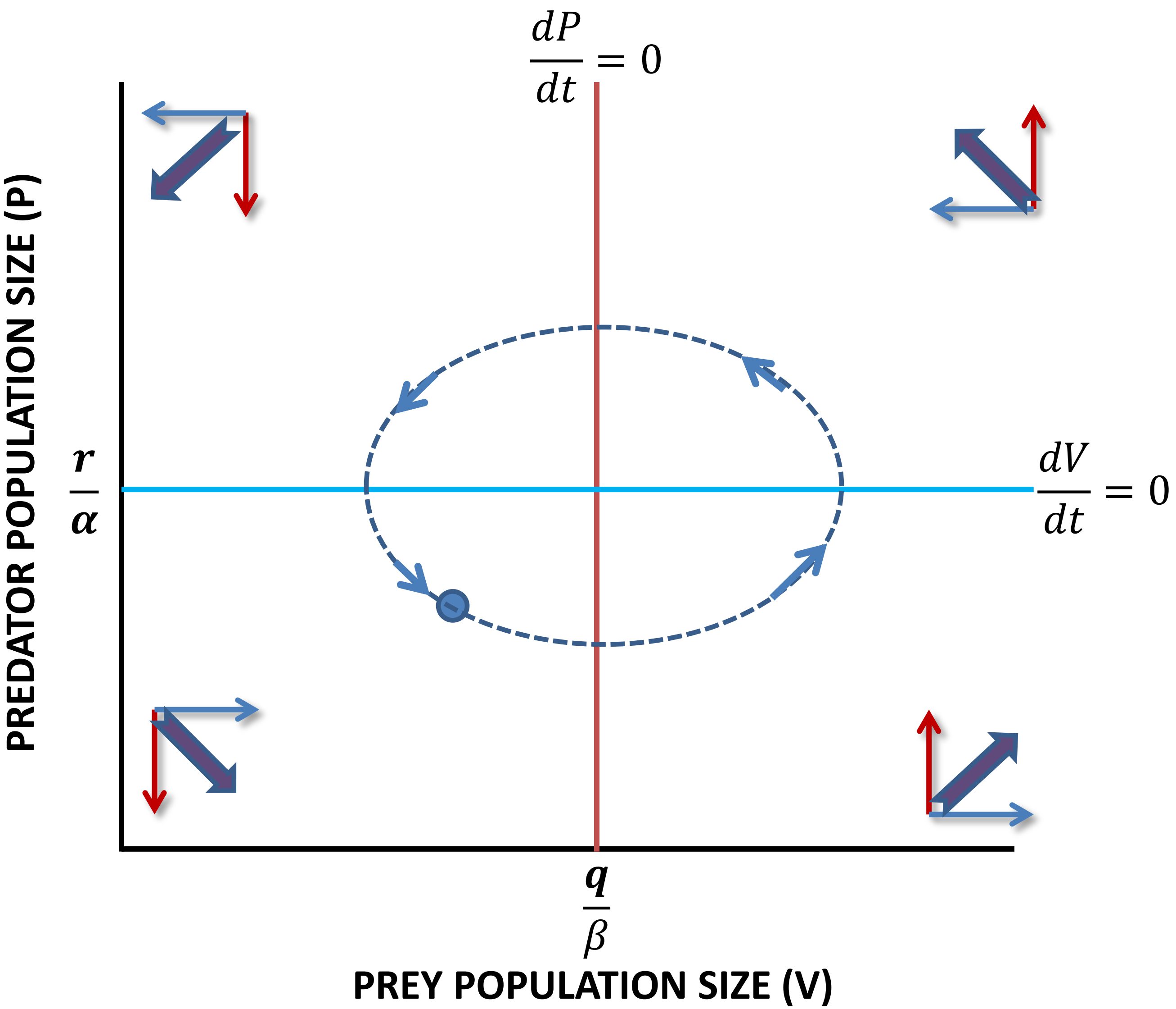

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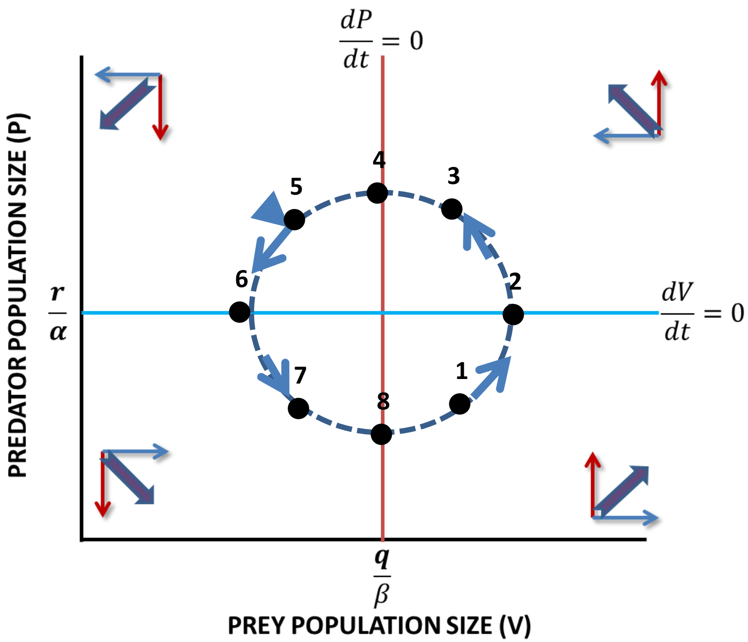
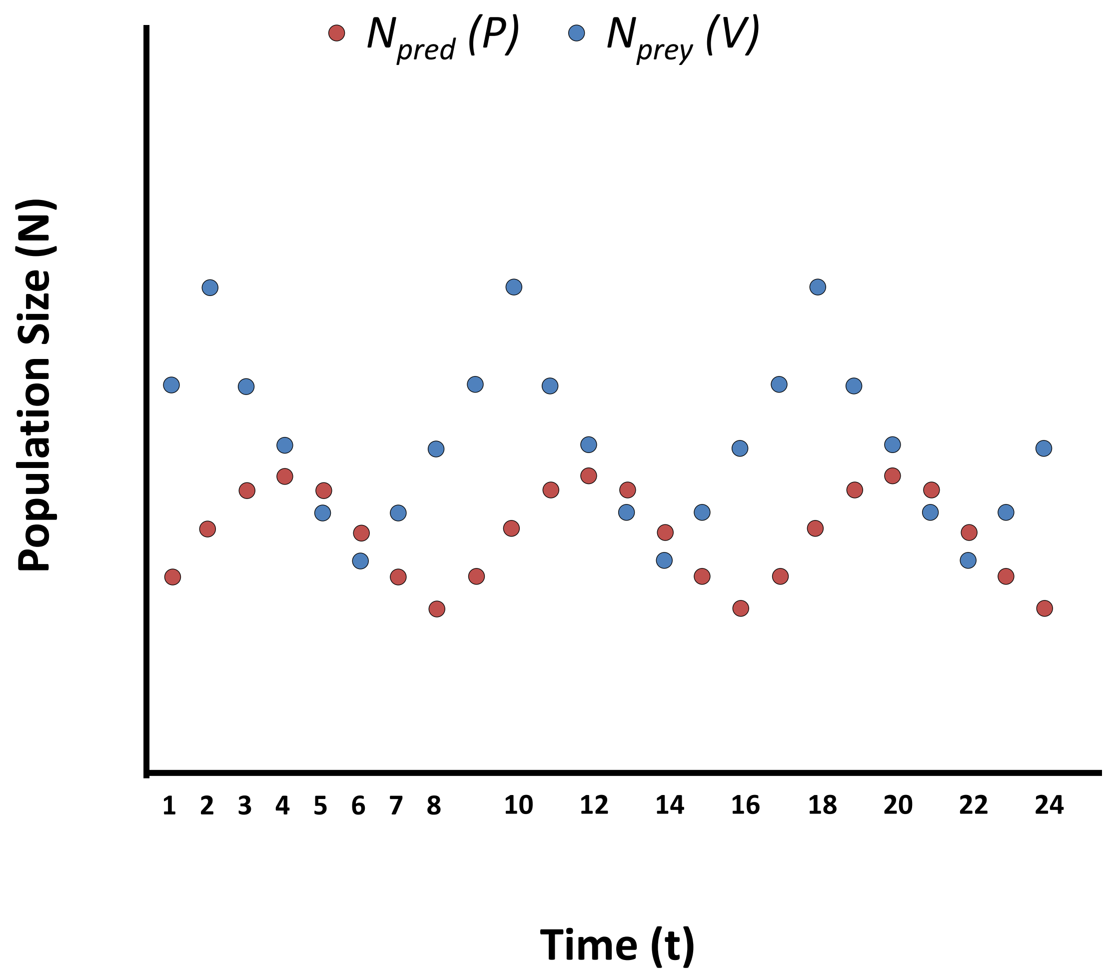
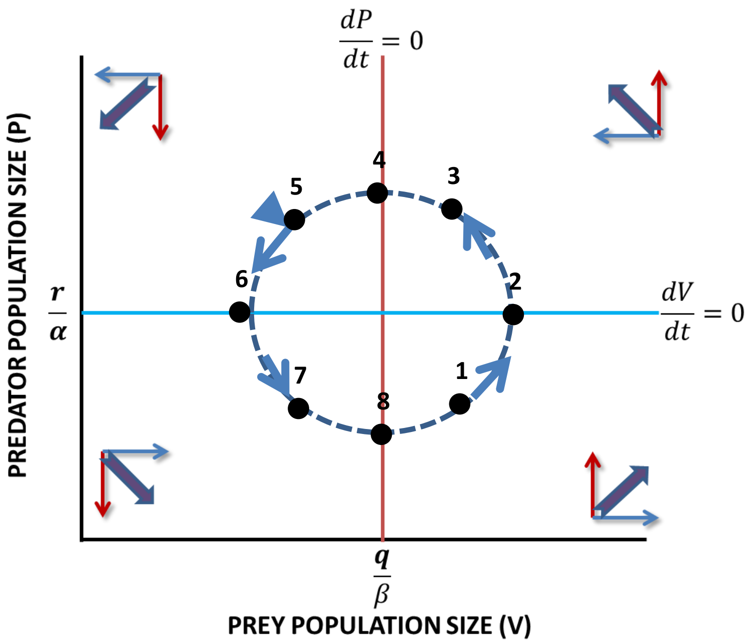
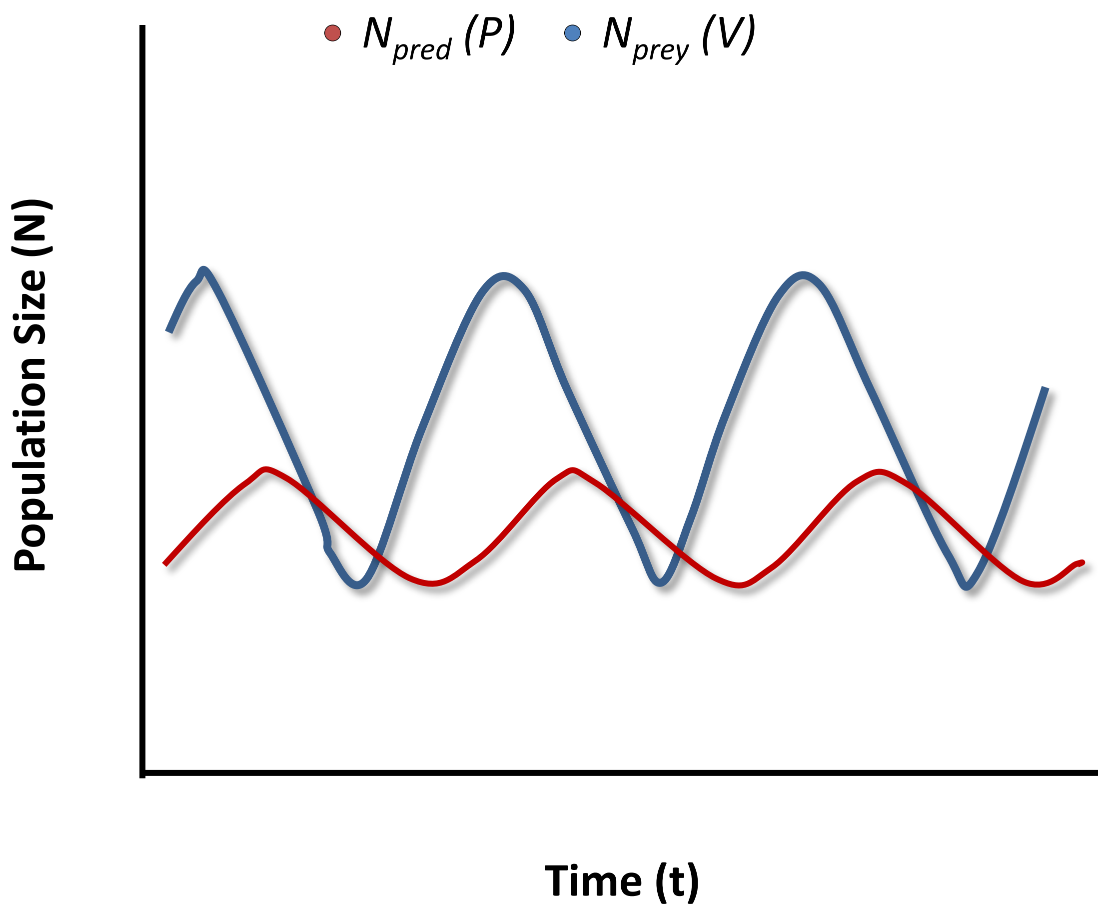




Lotka-Volterra Models – Predator/Prey dynamics

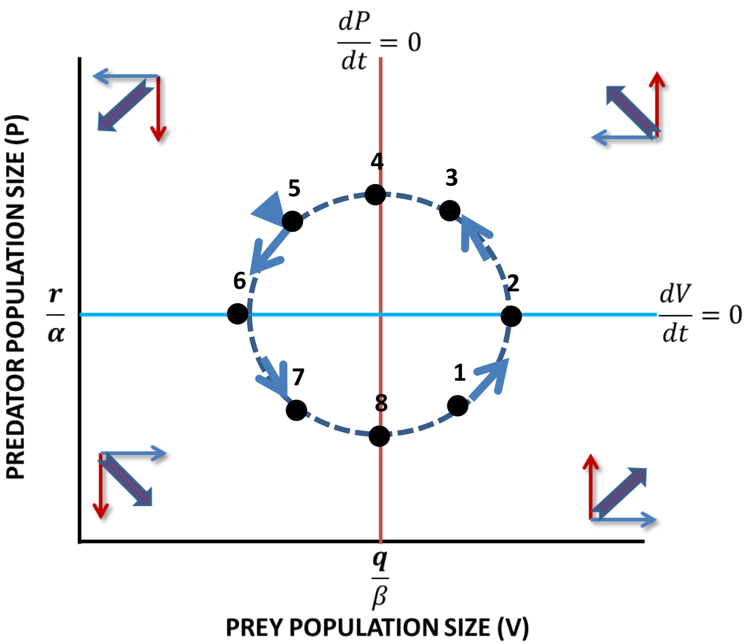


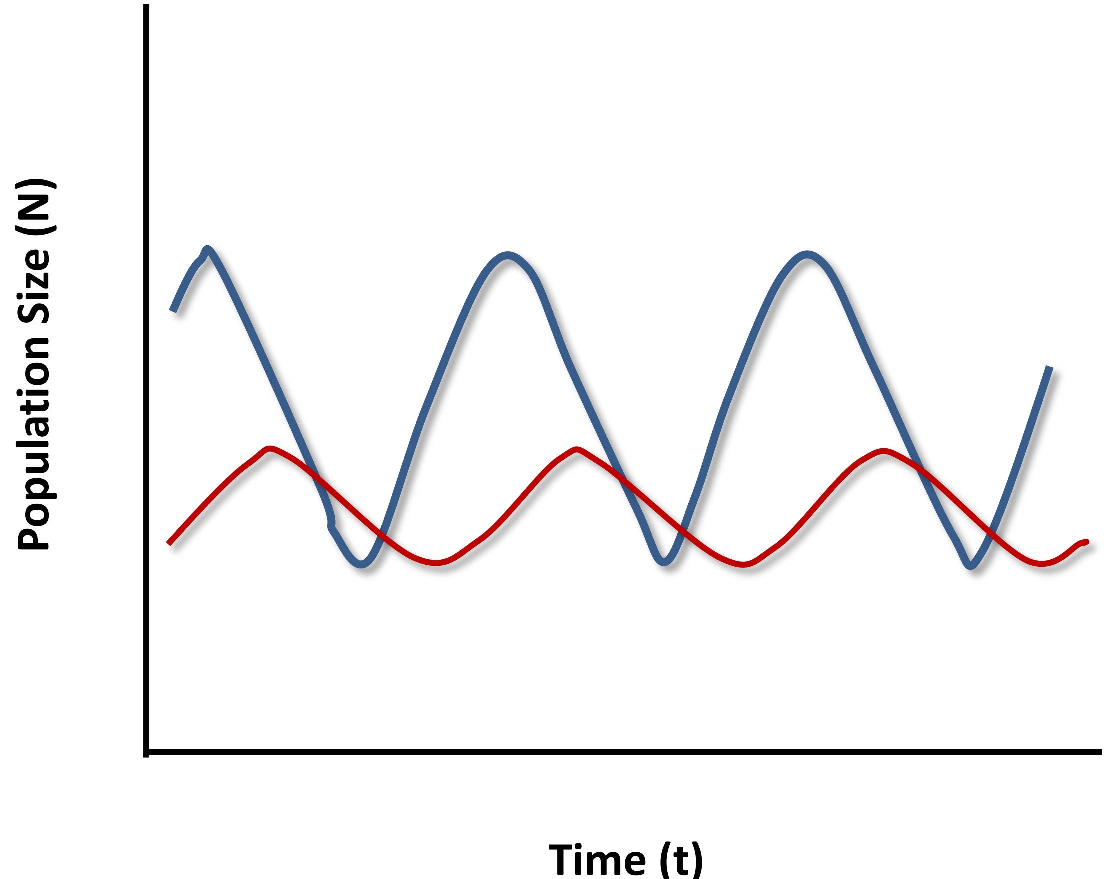


Peak of Predator population (P) occurs at mid-point of declining prey population (V)

Peak of Prey population (V) occurs at mid-point of increasing predator population (P)

Lotka-Volterra Models – Predator/Prey dynamics





Amplitude of the cycle determined by initial population size

Period of the cycle (c) approximately: $$C = \frac{2\pi}{\sqrt{rq}}$$

No population cycling when:

- Victims and predators at the isocline intersection
- If starting point is too extreme it hits one of the axis

Model Assumptions

- Standards associated with Exponential Growth
- *(no immigration, no age or genetic structure, no time lags…)*

- Additional

1. Growth of the prey population is limited only by predation
2. The predator is a specialist that can persist only if the prey population is present
3. Individual predators can consume an infinite number of prey
4. Predator and prey encounter one another randomly in an homogeneous environment

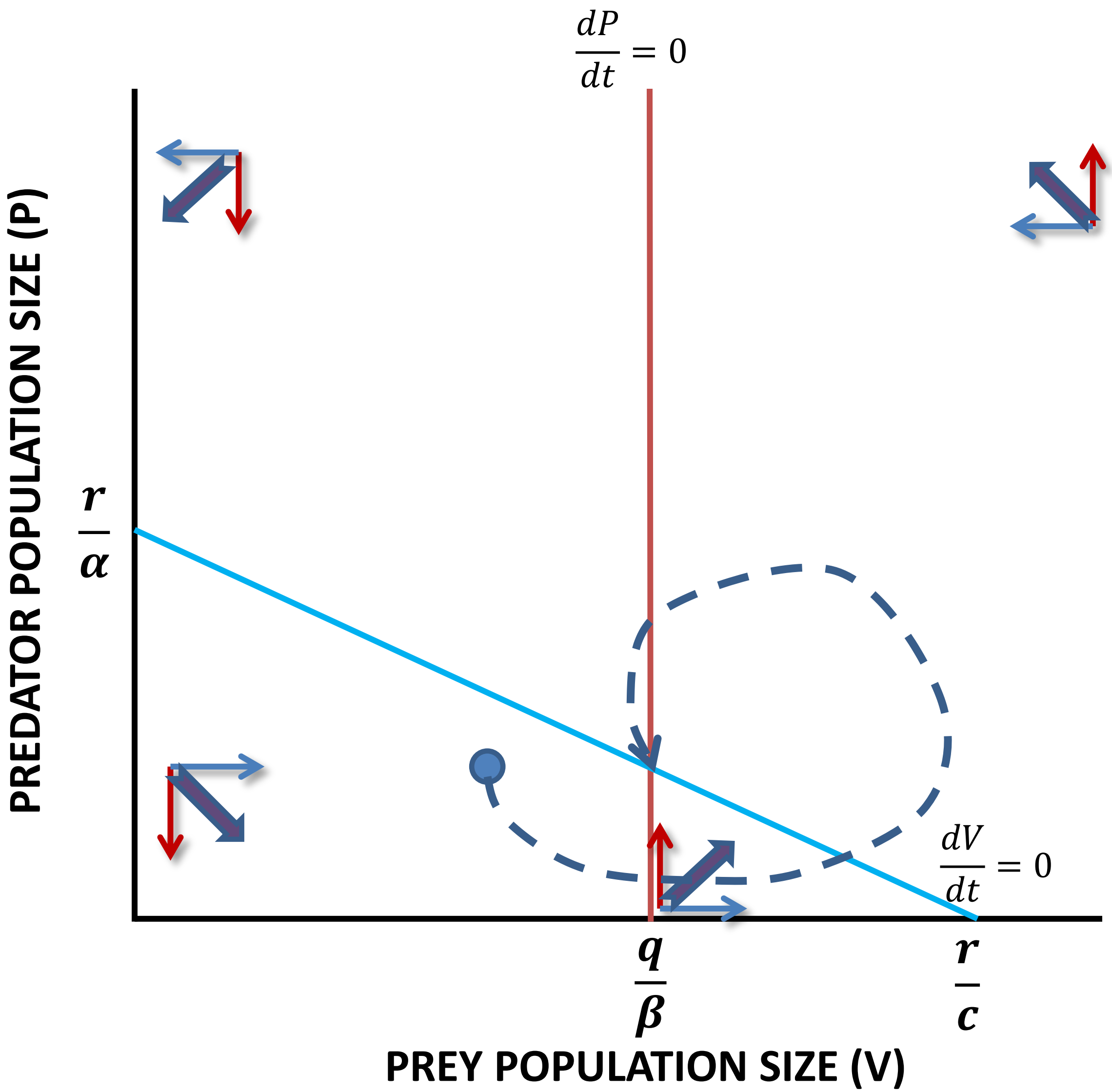
Integrating Prey Carrying-Capacity

- As prey population increases, intraspecific competition will also limit growth rates independent of predator

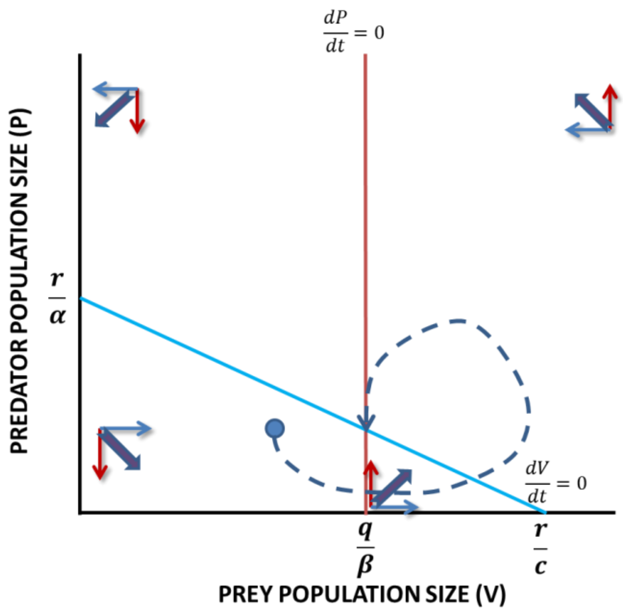
- Modify Prey Isocline to incorporate a carrying capacity
- $\frac{dV}{dt} = rV - \alpha VP - cV^2$
- c – constant reflecting the strength of density-dependence as prey population size increases

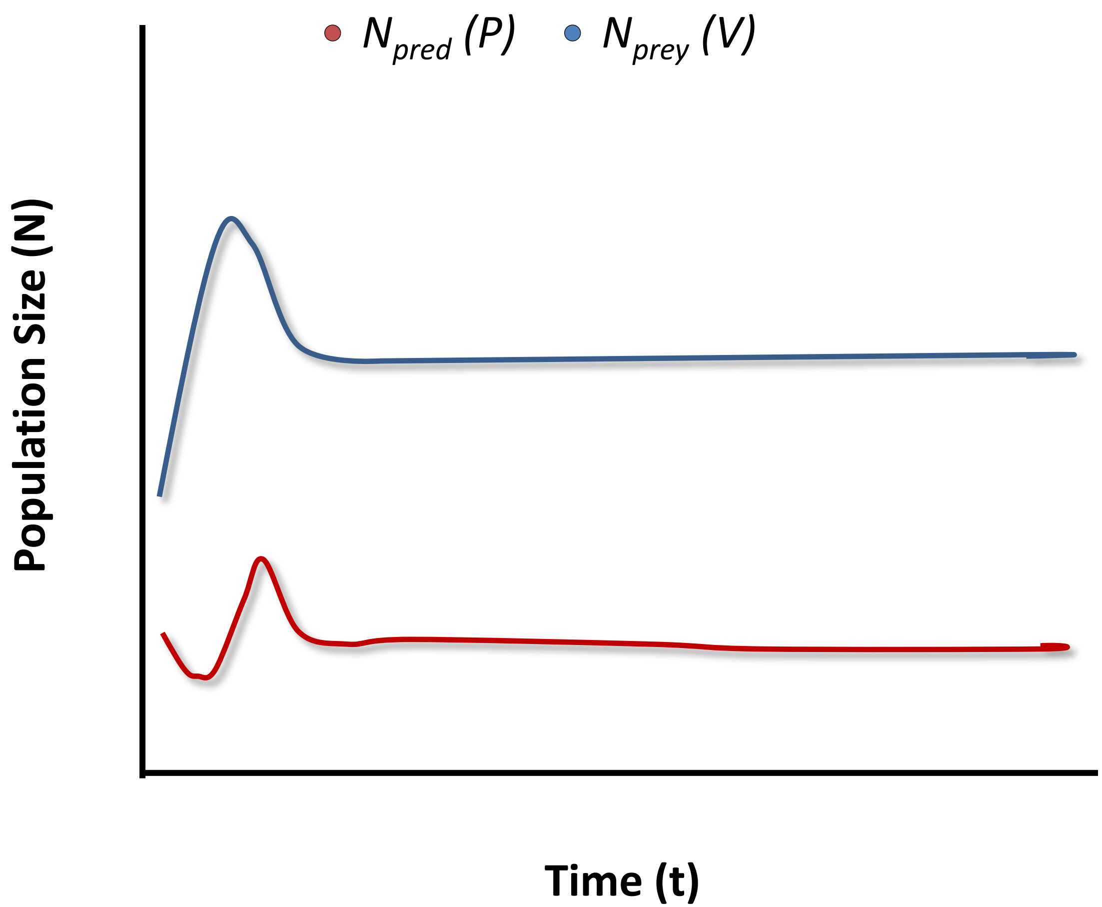
- *K_{prey} = r/c in the absence of predators*

Integrating Prey Carrying-Capacity



Integrating Prey Carrying-Capacity

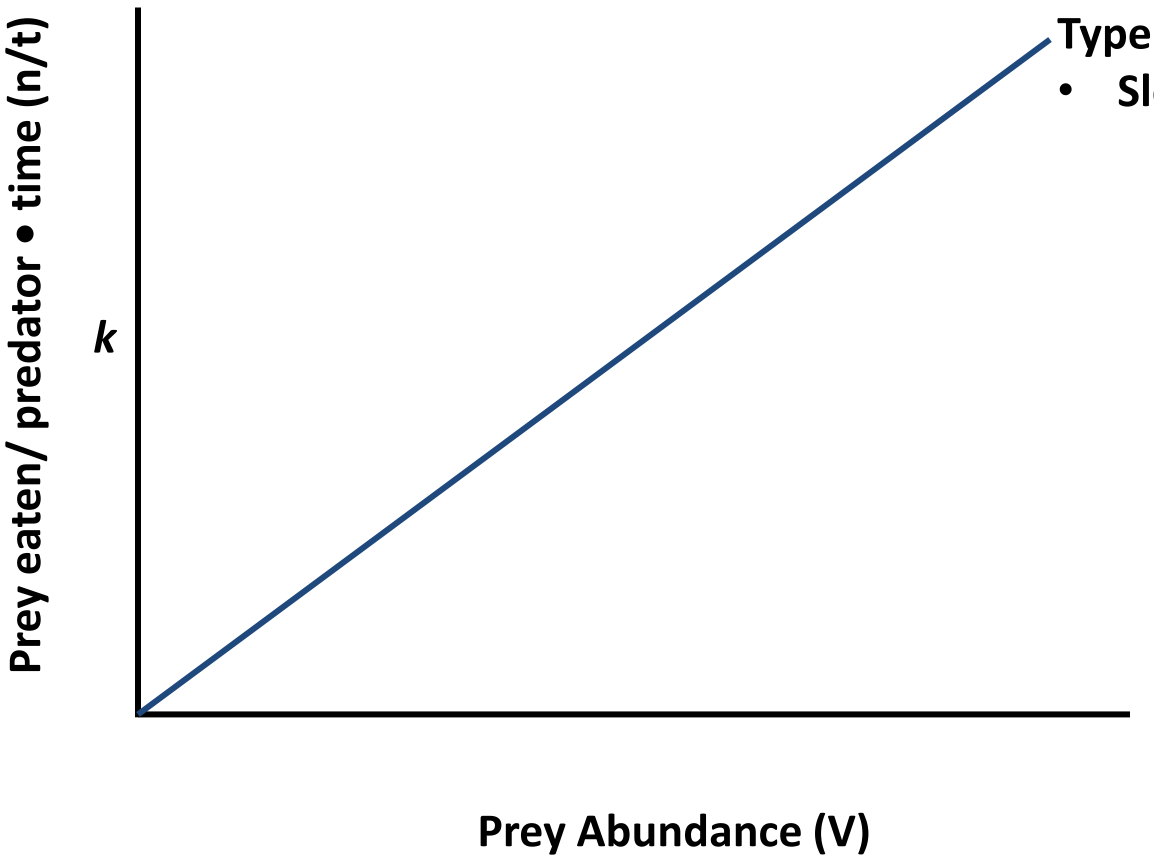




Stable equilibrium point of prey (V) and predator (P) population sizes.
Stable Prey population size will be lower in the presence of predator than it would be in the absence of predator (r/c). Predator numbers will be lower than r/α.

Functional Response of Predators

- Feeding rate/predator as a function of prey abundance



Type I Functional Response

- **Slope = capture efficiency (α)**

Functional Response of Predators

- Feeding rate per predator as a function of prey abundance
  - TYPE II Functional Response

- Impose Maximum Predator Feeding Rate (*k*) related to handling time per prey item (*h – capture and consume*)
- Each prey item captured requires search time (s)
- Total time to find and consume prey is:

$$t = t_s + t_h$$

Functional Response of Predators

$$t = t_s + t_h$$

- Time spent handling prey (t_h) is a function of the number of prey captured in a given time interval (n) and handling time/prey item (h)

$$t_h = nh$$

- total number of prey captured is a function of prey abundance (V), capture efficiency (α) and search time (t_s)

$$n = V\alpha t_s$$

Functional Response of Predators

$$t = t_s + t_h$$

- Sub values for t_s and t_h into total time equation
  - $t_h = nh$
  - $t_s = \frac{n}{\alpha V}$

$$t = \frac{n}{\alpha V} + nh$$

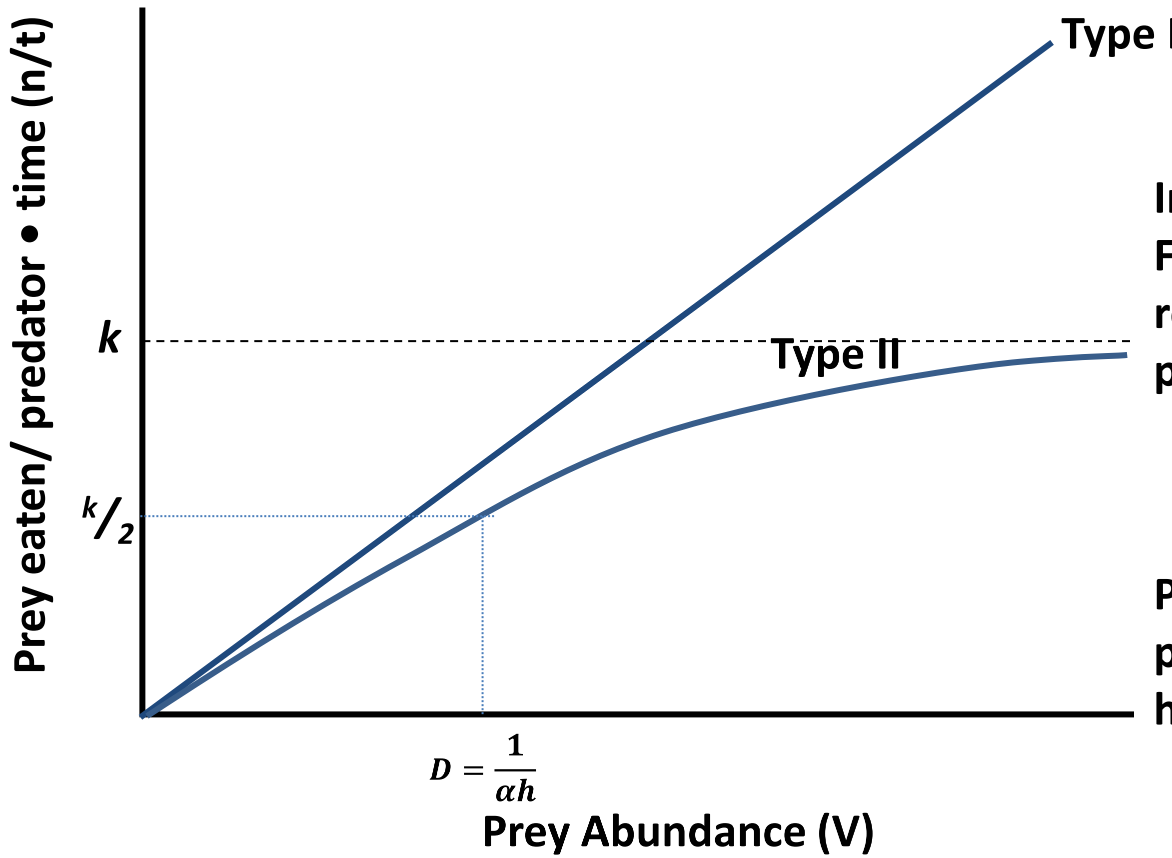
$$t = n\left(\frac{1 + \alpha V h}{\alpha V}\right)$$

- Use to solve for feeding rate (n/t)

$$\frac{n}{t} = \frac{\alpha V}{1 + \alpha V h}$$

Functional Response of Predators

- TYPE II Functional Response: $$\frac{n}{t} = \frac{kV}{D+V}$$



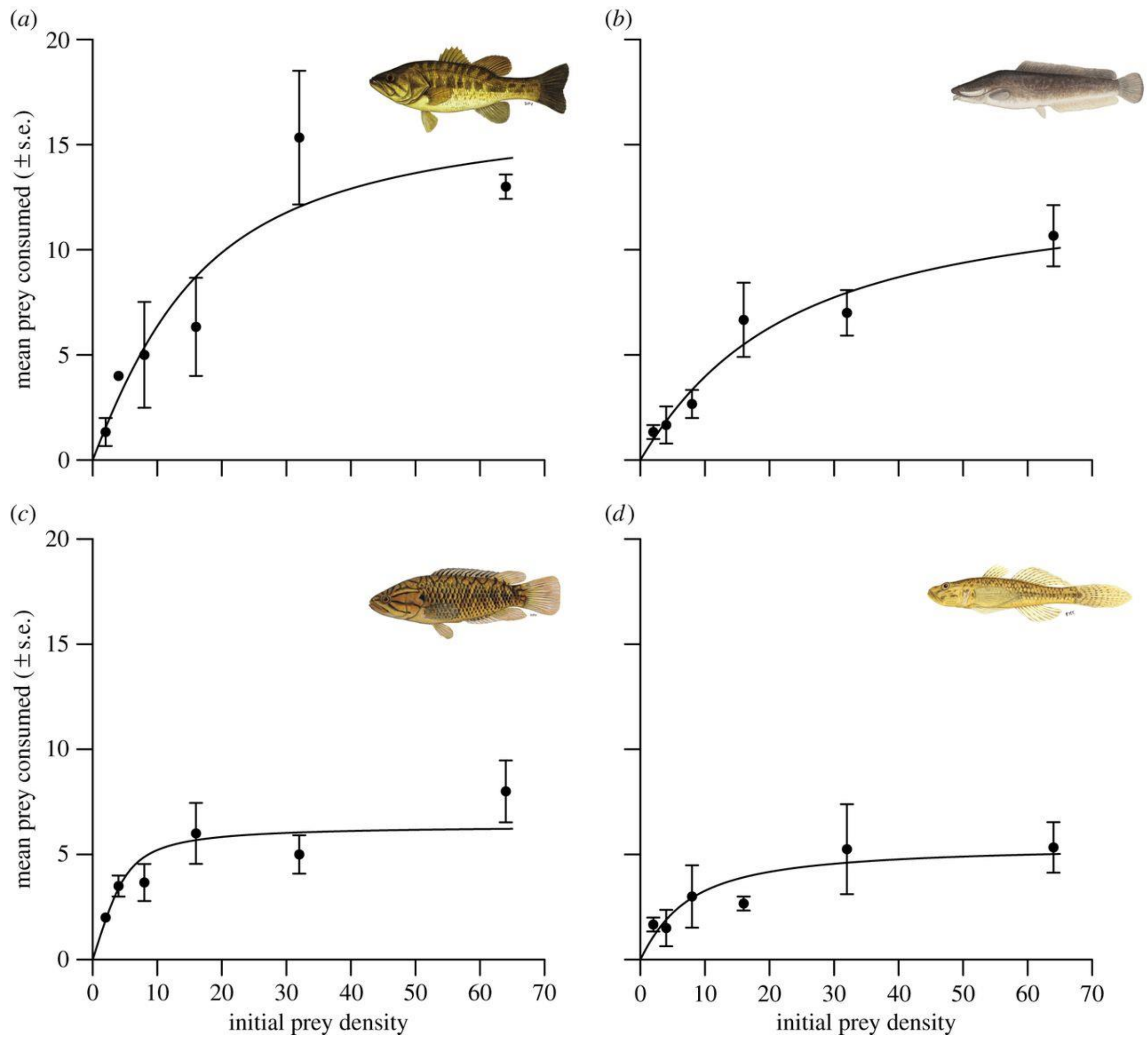
Impose Maximal Predator Feeding Rate (*k*) which is related to handling time per prey item (*h*)

$$k = \frac{1}{h}$$

Prey abundance where predator feeding rate is at half maximum (D) is:

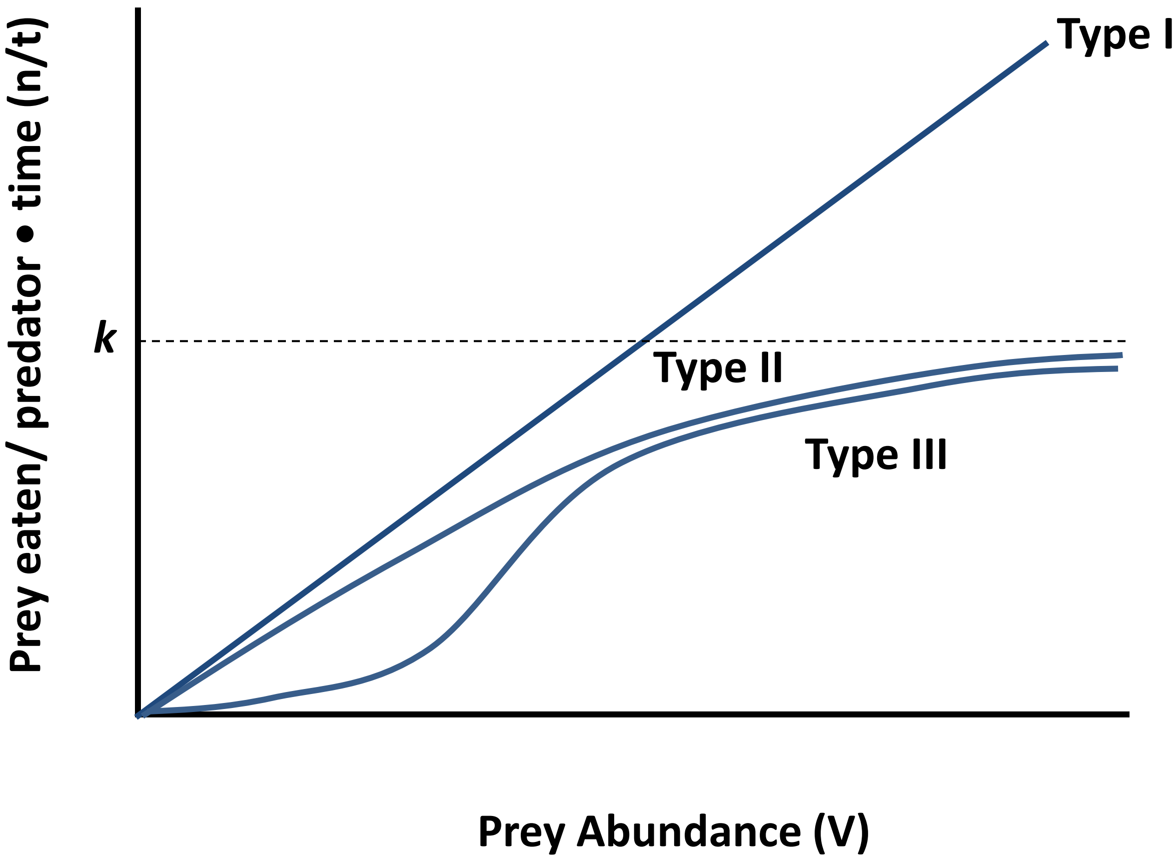
$$D = \frac{1}{\alpha h}$$

Type II functional response



Functional Response of Predators

- TYPE III Functional Response: $\frac{n}{t} = \frac{kV^2}{D^2+V^2}$



Prey switching
Predator learning

Relevance of Different Functional Responses

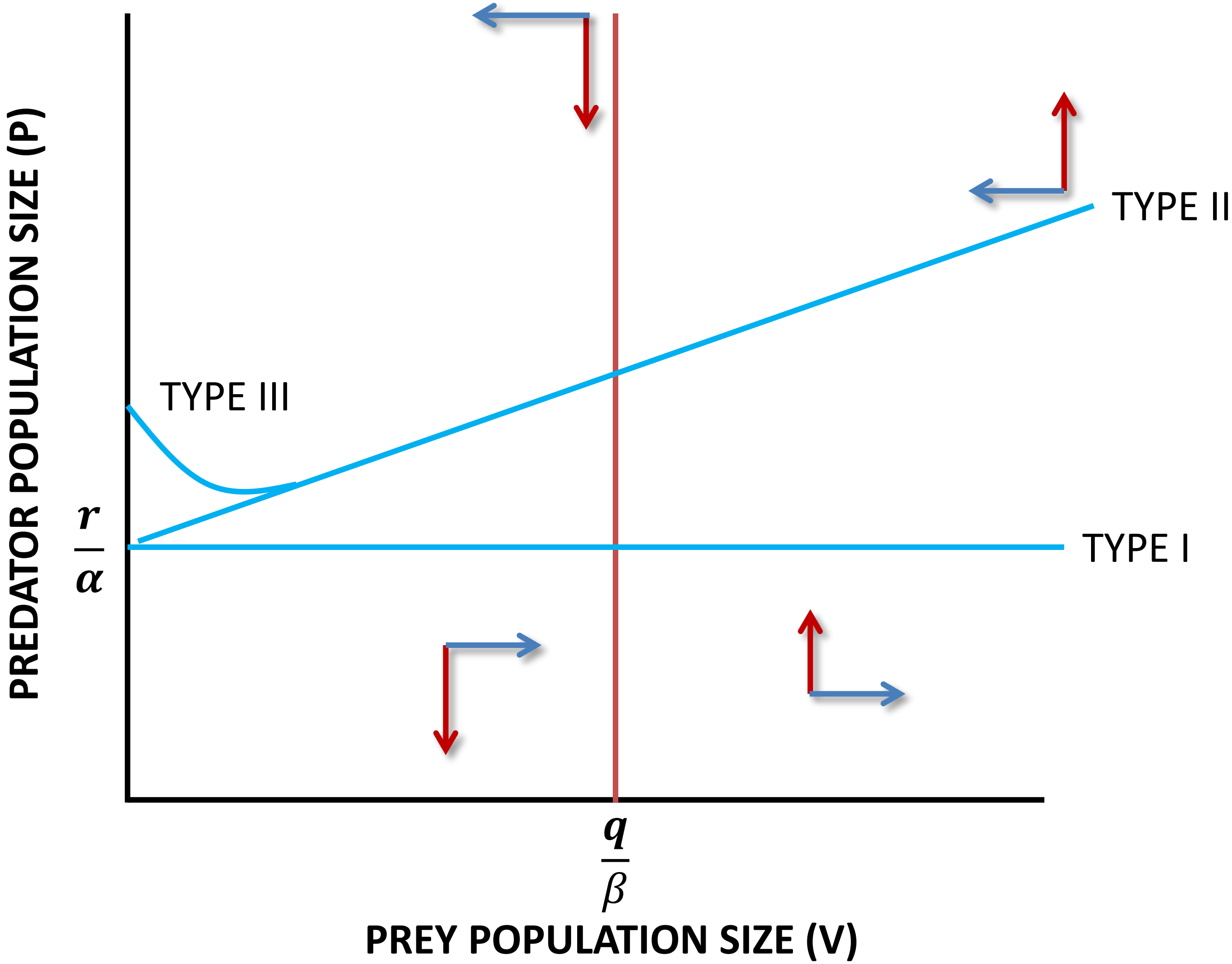
- Shape of the Functional Response changes the Prey Isocline in State-space graph
- Type II – proportion of prey population consumed decreases steadily as prey numbers increase

$$\boldsymbol{\frac{dV}{dt} = rV - \left(\frac{kV}{V + D}\right)P}$$

- Type III – proportion of prey population consumed is low at both low and high prey populations, but peaks at intermediate levels

$$\boldsymbol{\frac{dV}{dt} = rV - \left(\frac{kV^2}{D^2 + V^2}\right)P}$$

Functional Responses and Prey Isoclines



Functional Responses and Prey Isoclines