Competition

Key concepts

- Classification of species interactions
- Ecological niche (barnacles)
- Exploitative competition (diatoms and mud snails)
  - R* Theory
- Interference competition (shore crabs)
  - Lotka-Volterra Theory

Classes of Interspecific Interactions

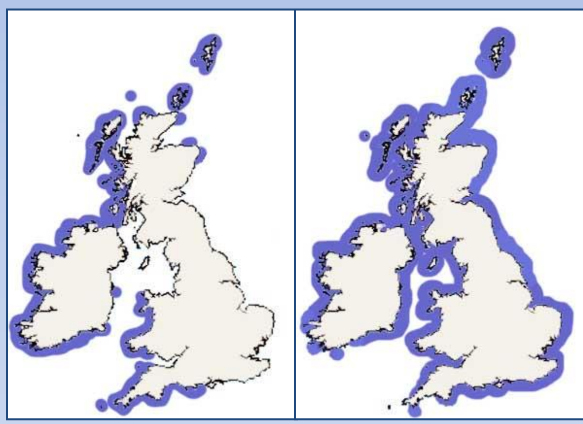
(Species 1/Species 2)	Interaction
(-/-)	Competition
(+/+)	Mutualism
(+/-)	Antagonistic Plant-Herbivore Predator-Prey Host-Parasite

Competition among sedentary, filter-feeding animals

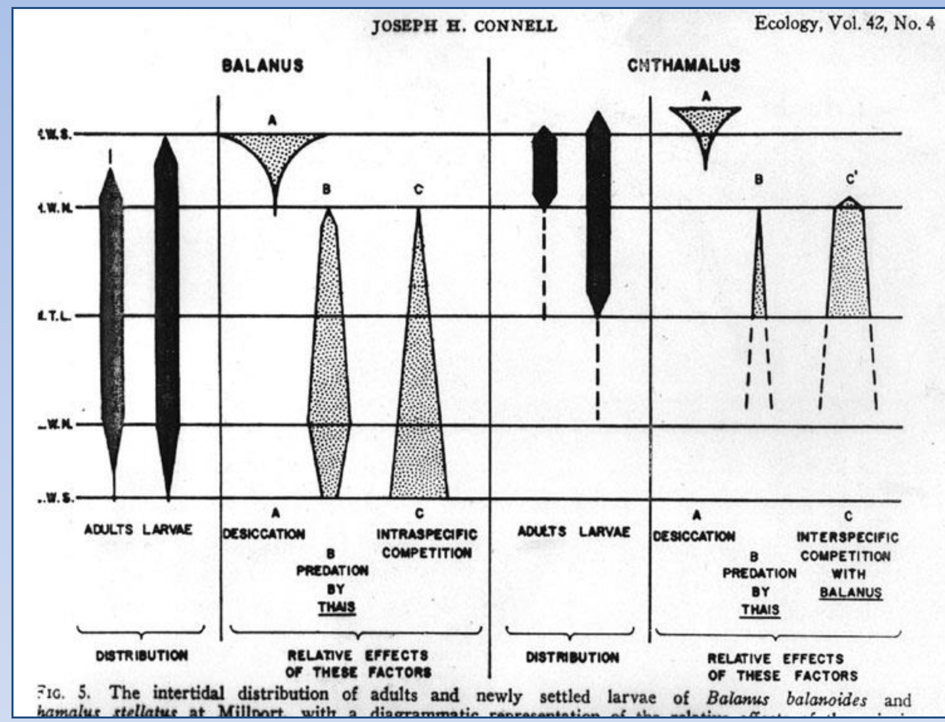
Stellate barnacle *Chthamalus stellatus*

Acorn barnacle *Semibalanus balanoides*

Geographical overlap and spatial segregation



Chthamalus stellatus *Semibalanus balanoides*

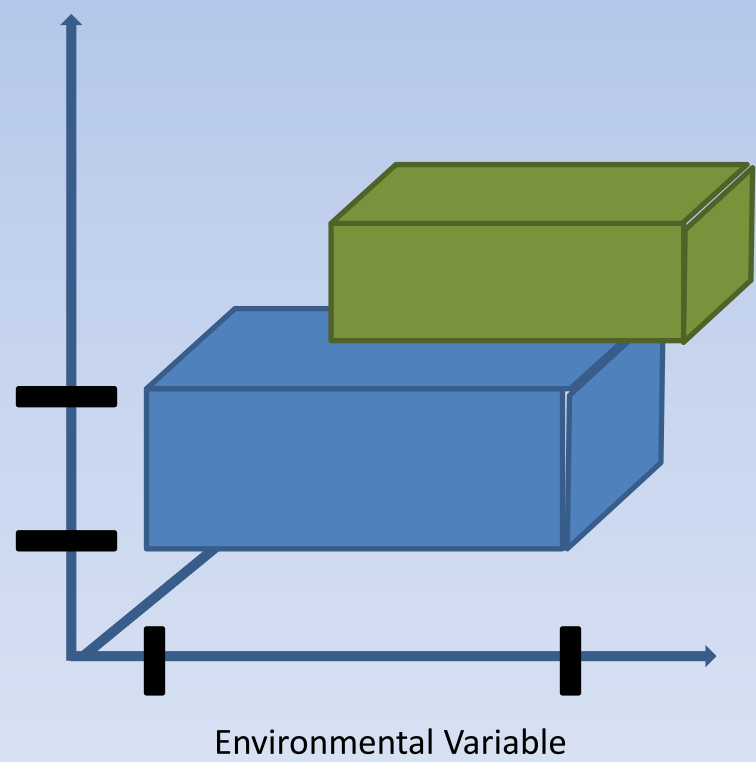


Why do these species spatially segregate?

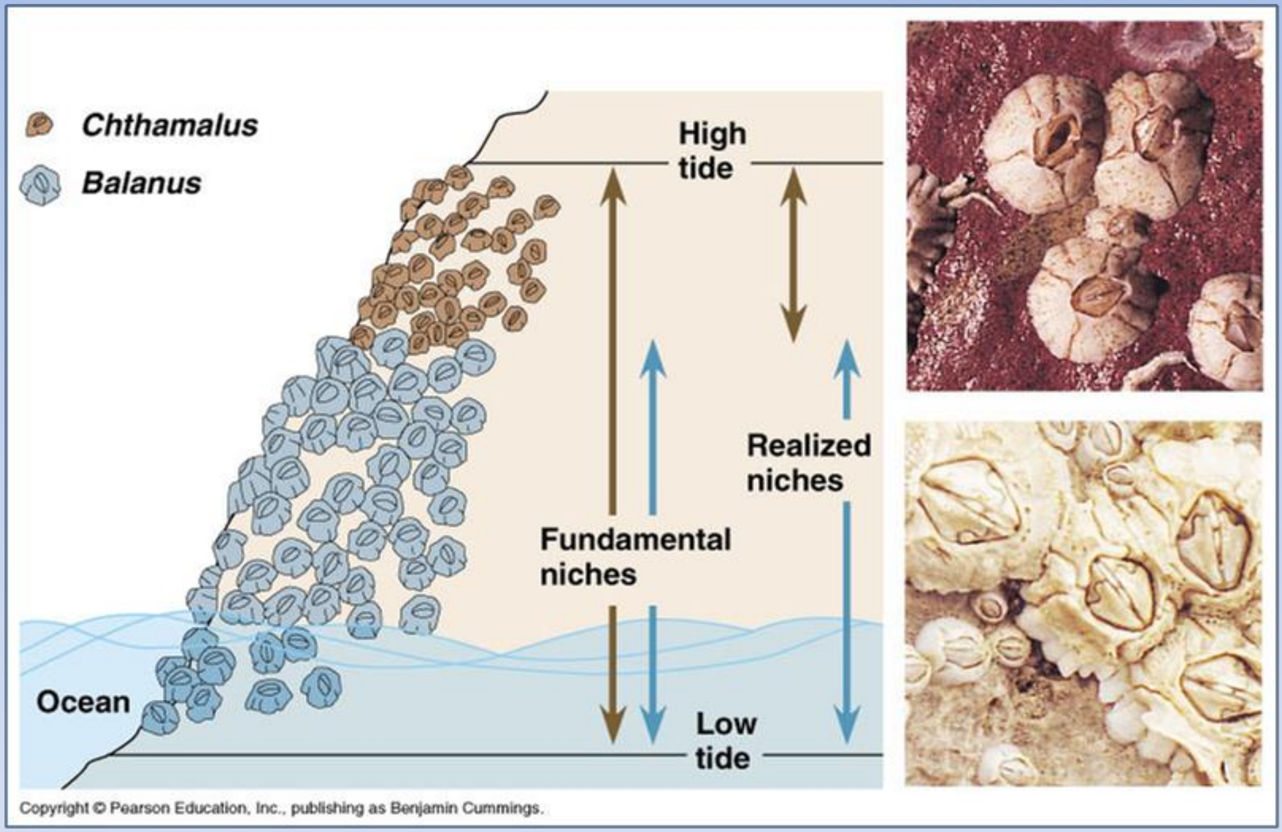
- H_1: Habitat preferences
- H_2: Interactions

Fundamental Niche (def.)
The set of environmental conditions (*n*) under which a population of a species can persist

"n-dimensional hypervolume"

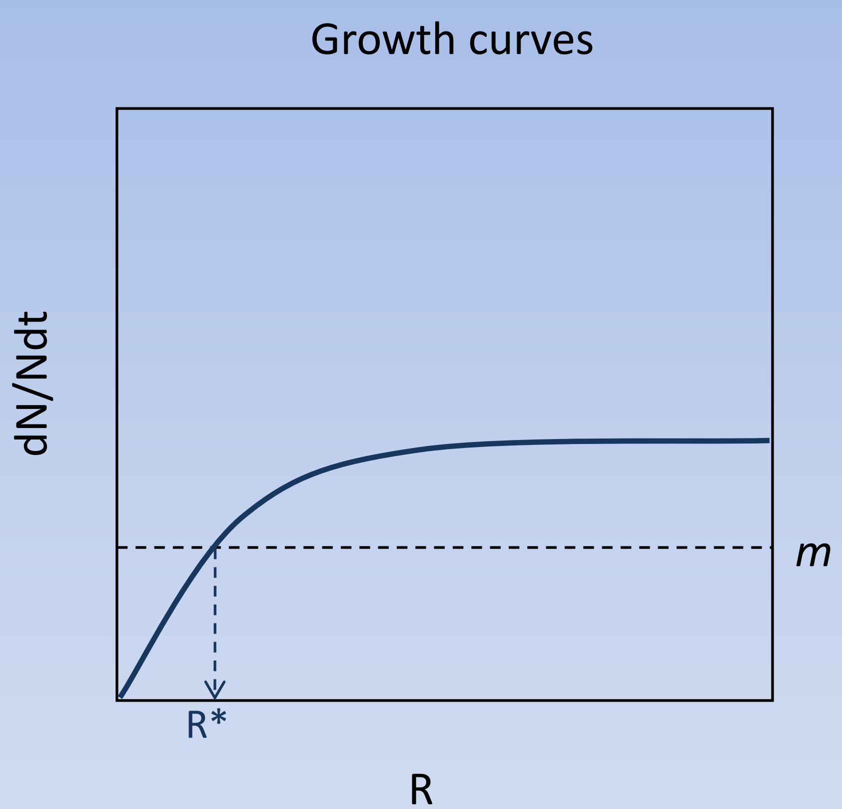


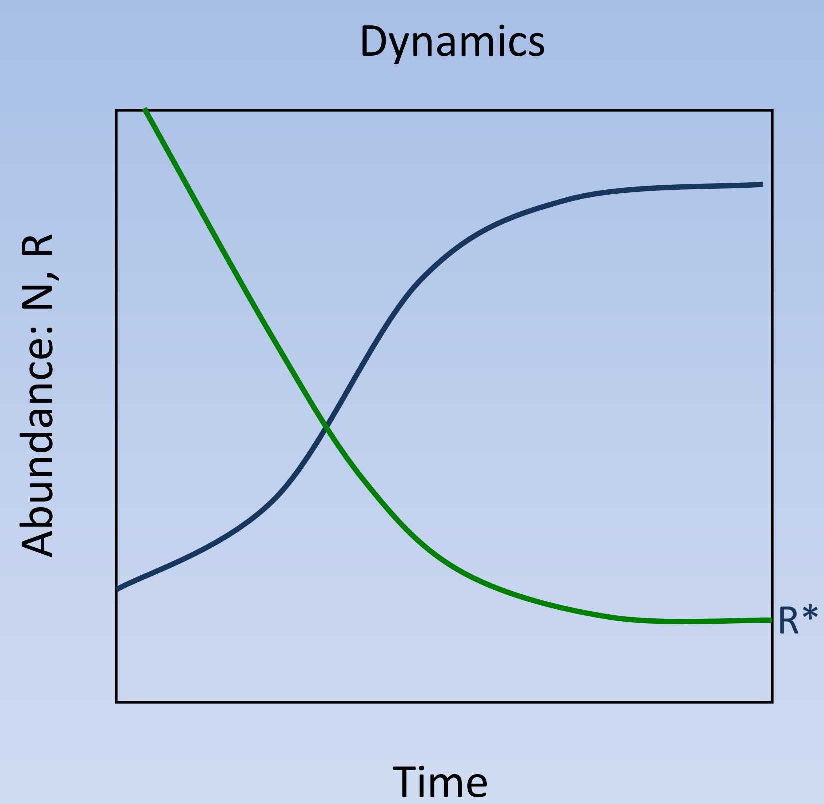
Exploitative Competition for Resources



Realized Niche (def.): That portion of the set of environmental conditions in which an organism can survive in the presence of competition, or that portion actually occupied; a subset of the fundamental niche.

Resource Competition Theory





Where R=resource abundance

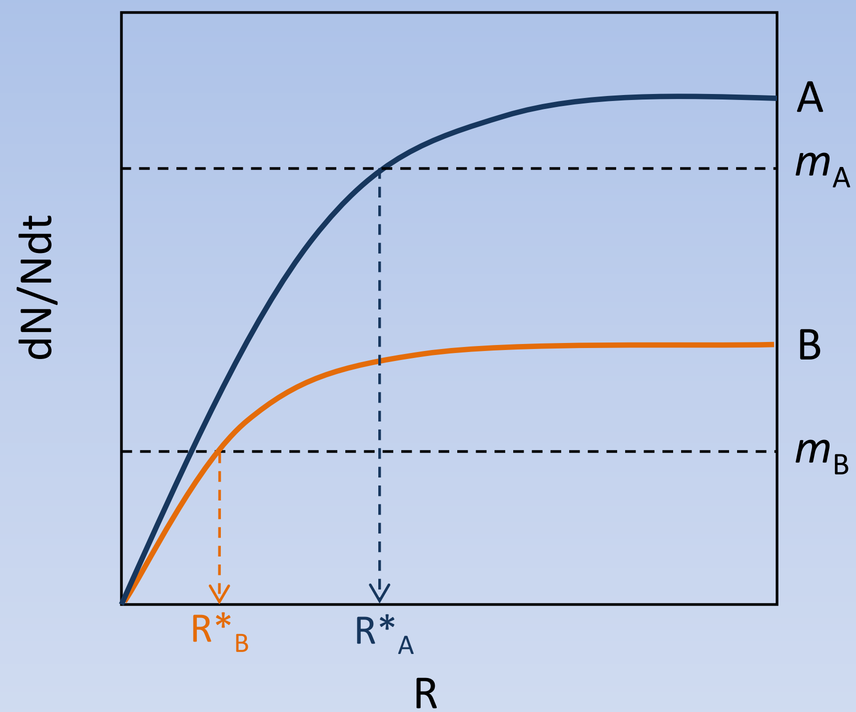
N=abundance of species *i*

m=per capita mortality rate of species *i*

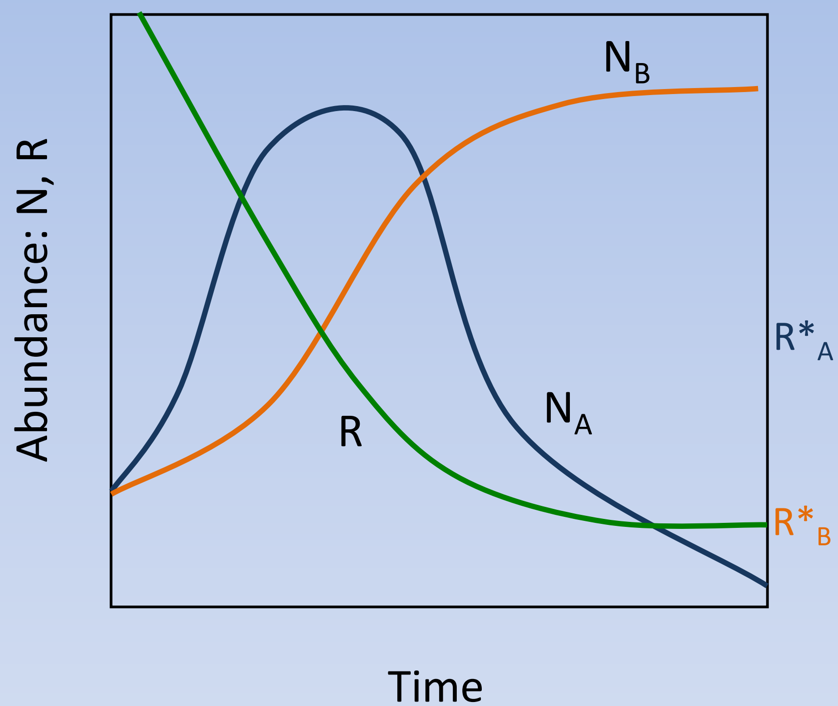
Tilman (1982)

Resource Competition Theory

Growth curves



Dynamics



Where R=resource abundance

N_i=abundance of species i

m_i=per capita mortality rate of species i

Tilman (1982)

Interspecific competition between diatoms for silicate

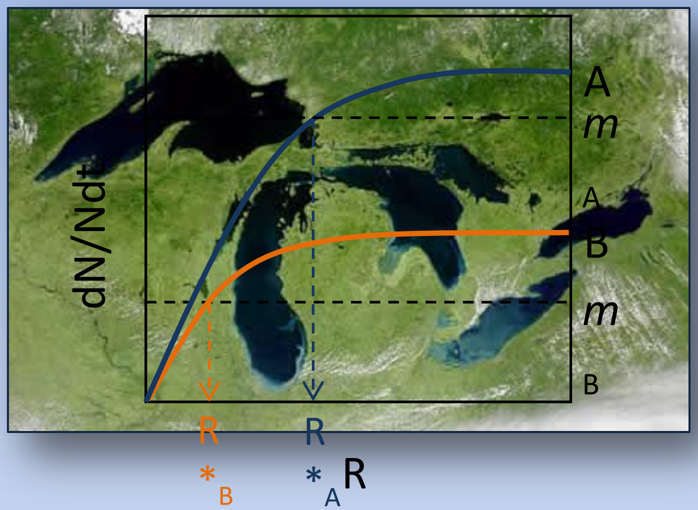
Diatoms are planktonic algae that form the basis of the food web in most mid-latitude mesotrophic lakes

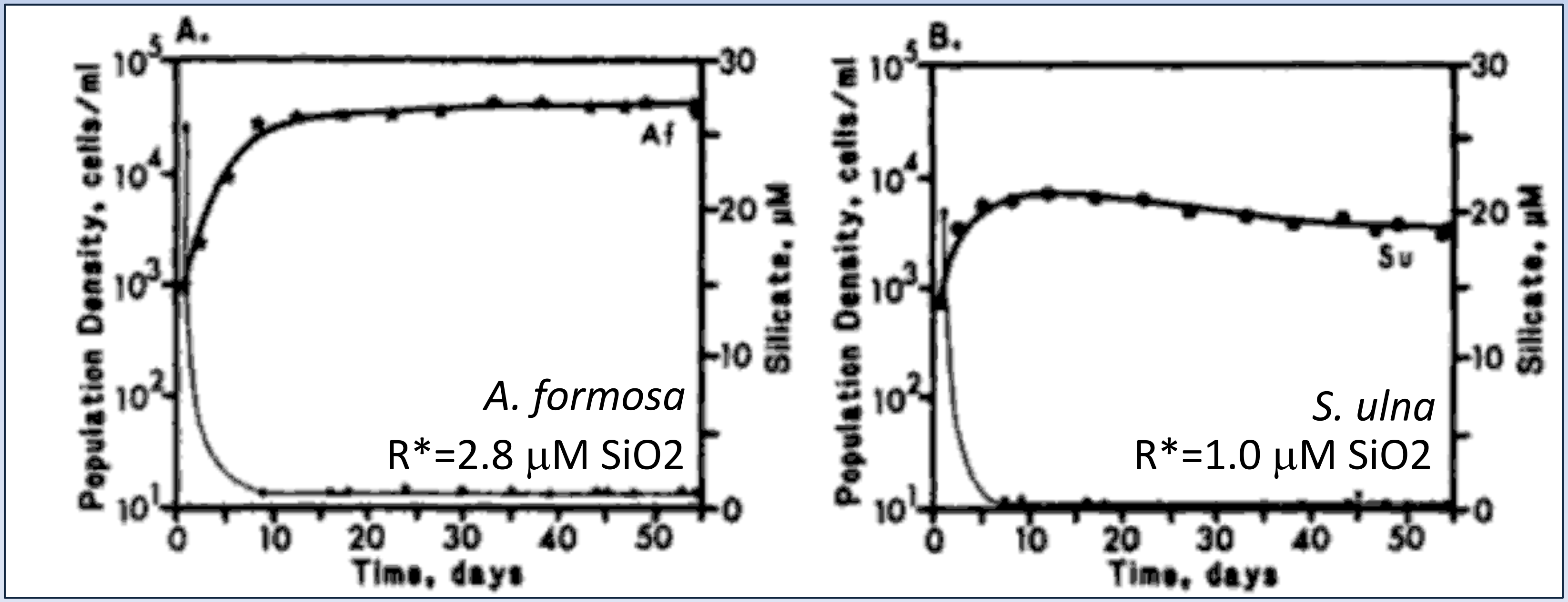
Asterionella formosa is a dominant species throughout Lake Michigan

Synedra ulna limited to near shore areas

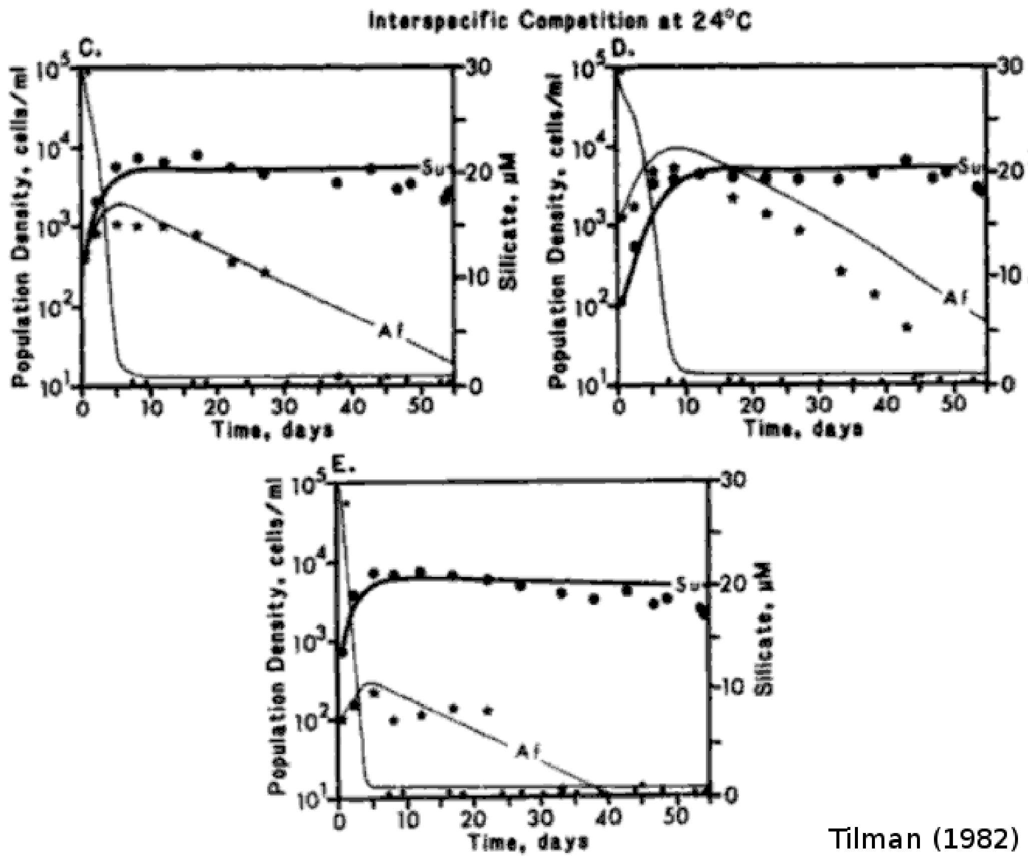
Which species has the lower R*?

Growth curves



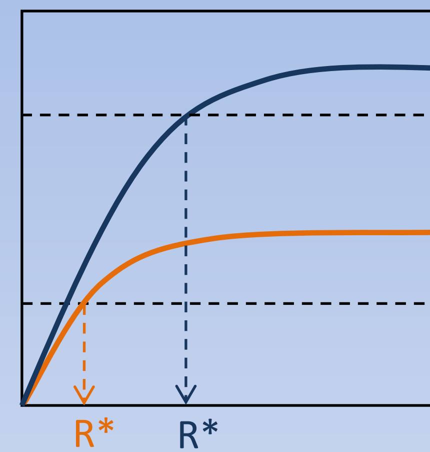


Which species should win in a competition for silicate?

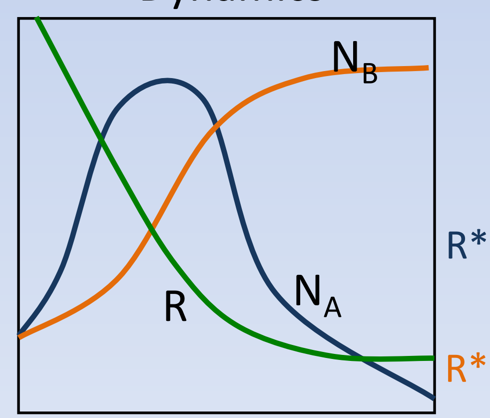


Tilman (1982)

Growth curves



Dynamics



Time

Will the invasive *Batillaria attramentaria* replace the native *Cerithidea californica?*

Batillaria attramentaria

(Non-native)

Cerithidea californica

(Native)

Can we use resource competition theory to answer this question?

$$\frac{dN}{dt} = births - deaths = \alpha_N \varepsilon_N R_N N - m_N N$$

Derivation of R*

$$0 = \alpha_N \varepsilon_N R^*{}_N N - m_N N$$

$$\alpha_N \varepsilon_N R^*{}_N N = m_N N$$

$$R^*{}_N = \frac{m_N}{\alpha_N \varepsilon_N}$$

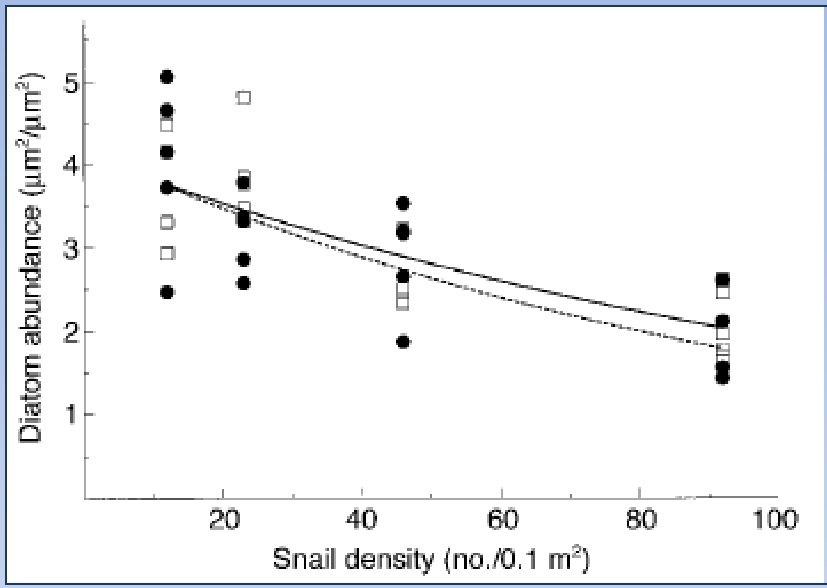
Condition for displacement

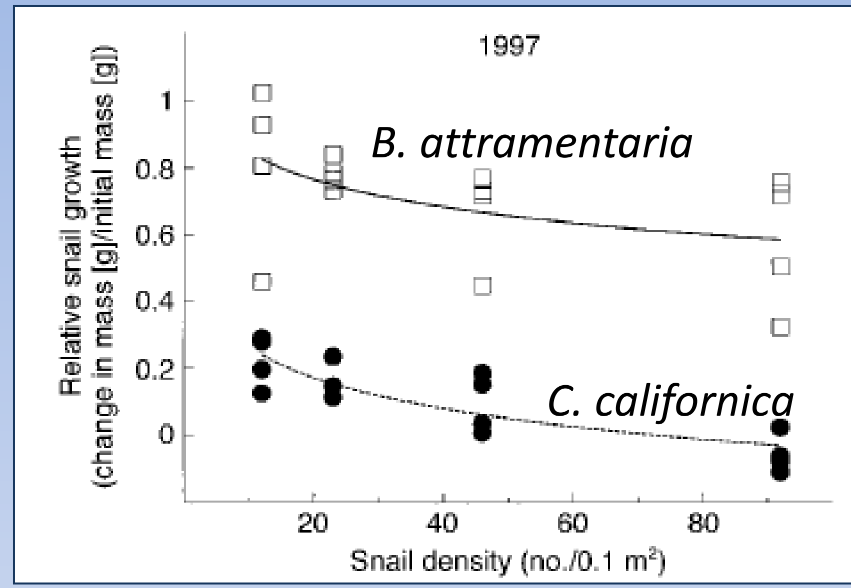
$$R^*{}_N = \frac{m_N}{\alpha_N \varepsilon_N} \quad R^*{}_I = \frac{m_I}{\alpha_I \varepsilon_I}$$

$$R^*{}_N > R^*{}_I$$

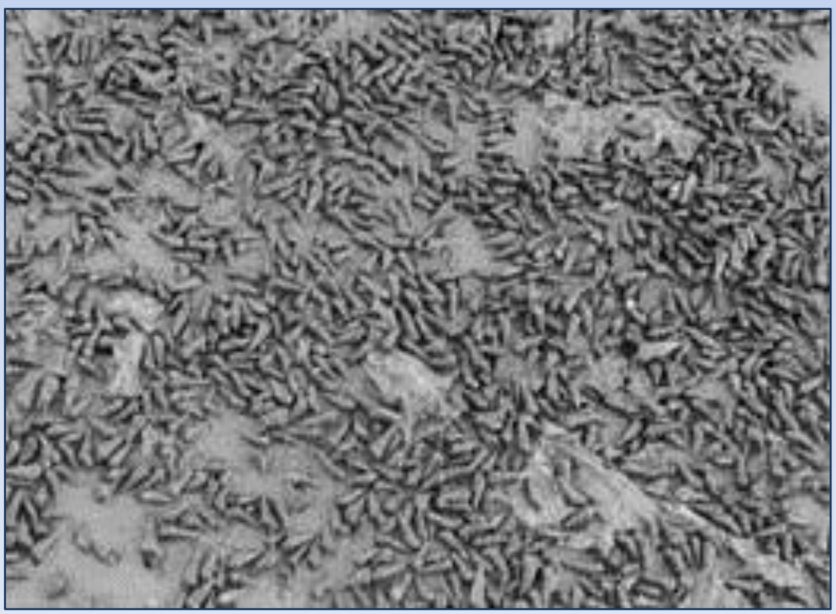
$$\frac{m_N}{\alpha_N \varepsilon_N} > \frac{m_I}{\alpha_I \varepsilon_I}$$

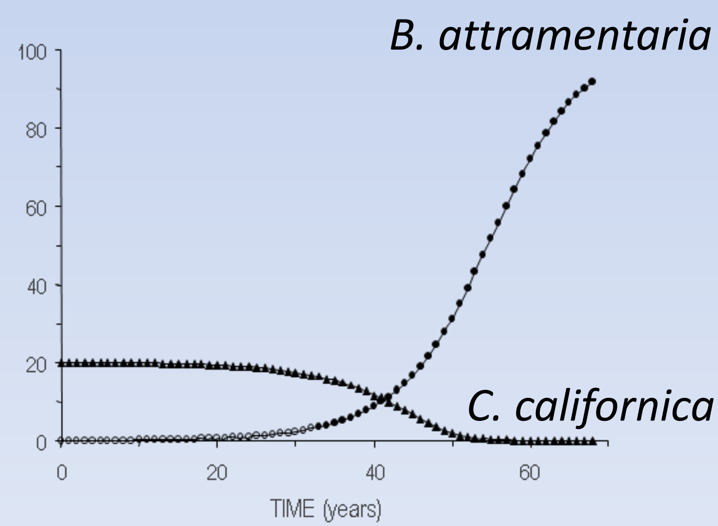
Experimental data test R* theory for invasive snails





Byers (2000)





Interference Competition

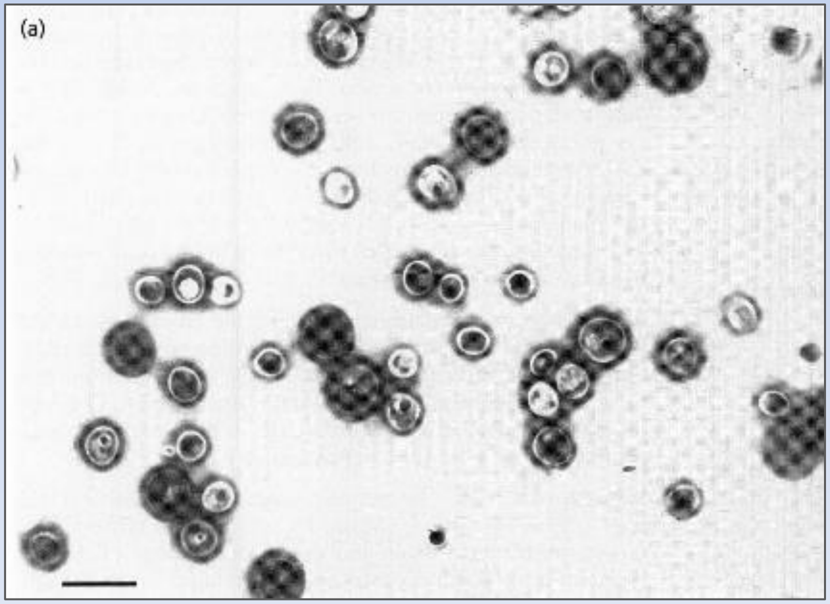
Interference competition (def.)
An interactions between organisms in which one species prevents another species from accessing resources in a way that diminishes fitness beyond the costs of resource competition.

Allelopathy in Garlic mustard *Alliaria petiolata*

Interference competition in seasonal anurans

Common frog, *Rana temporaria*

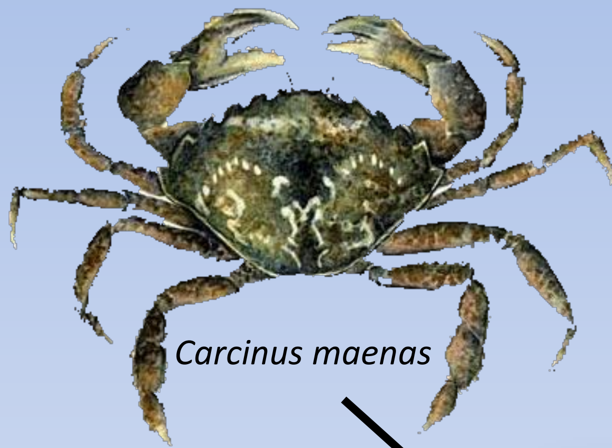
Natterjack toad, *Bufo calamita*



Phase-contrast microscopic image of protist pathogen *Anurofeca richardsi*

Image: Baker *et al*. (1999) Microbiology 145:1777-1784

Competition in invasive shore crabs



Carcinus maenas

Hemigrapsus sanguineus

Mytilus edulis

General (Lotka-Volterra) Competition Theory

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1}{K_1} \right) \qquad \frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - N_2}{K_1} \right)$$

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{12} N_2}{K_1} \right)$$

10 individuals of Species 2 = 1 individual of species 1

Total effect on Species 1 = $(N1 + N2 * 1/10)$

↑

Competition coefficient α_{12}

General (Lotka-Volterra) Competition Theory

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{12} N_2}{K_1} \right)$$

$$\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \alpha_{21} N_1}{K_2} \right)$$

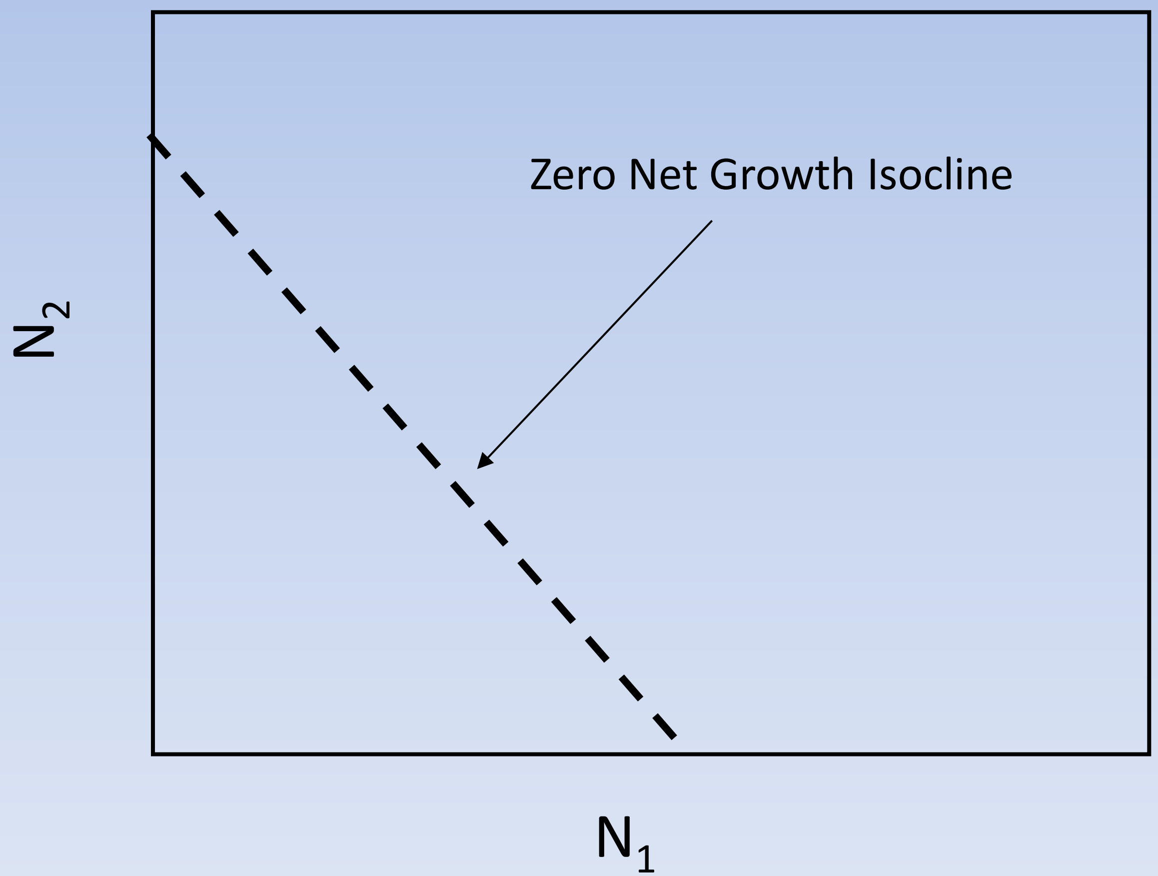
If 2 individuals of sp. 2 = 1 of sp. 1

α_{12} = 1/2 = 0.5

If 1 individuals of sp. 2 = 2 of sp. 1

α_{12} = 2/1 = 2

Phase Plane Diagram



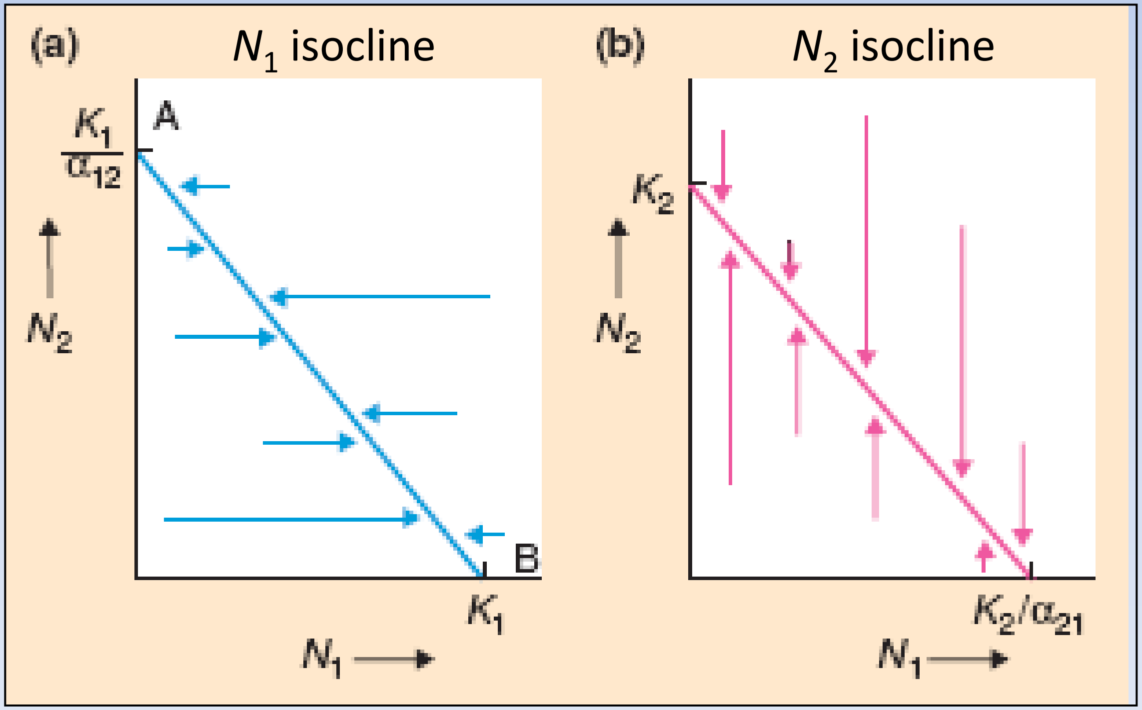
Zero Net Growth Isoclines (ZNGIs)

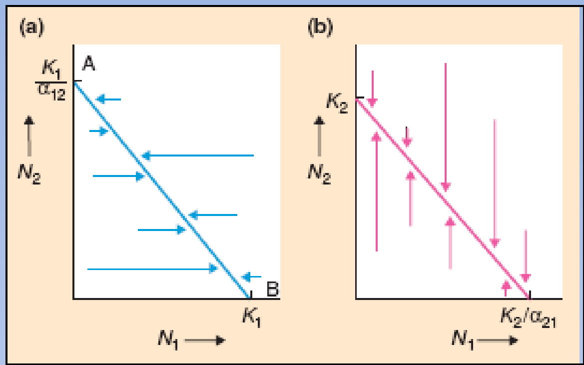
At equilibrium, $dN_1/dt = 0$

$$0 = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{12} N_2}{K_1} \right)$$

Rearranging:

$$N_1 = K_1 - \alpha_{12} N_2$$





Add vectors together to determine direction of system

$K_1/\alpha_{12}>K_2$ & $K_1>K_2/\alpha_{21}$

N_1 excludes N_2

$K_1/\alpha_{12}<K_2$ & $K_1<K_2/\alpha_{21}$

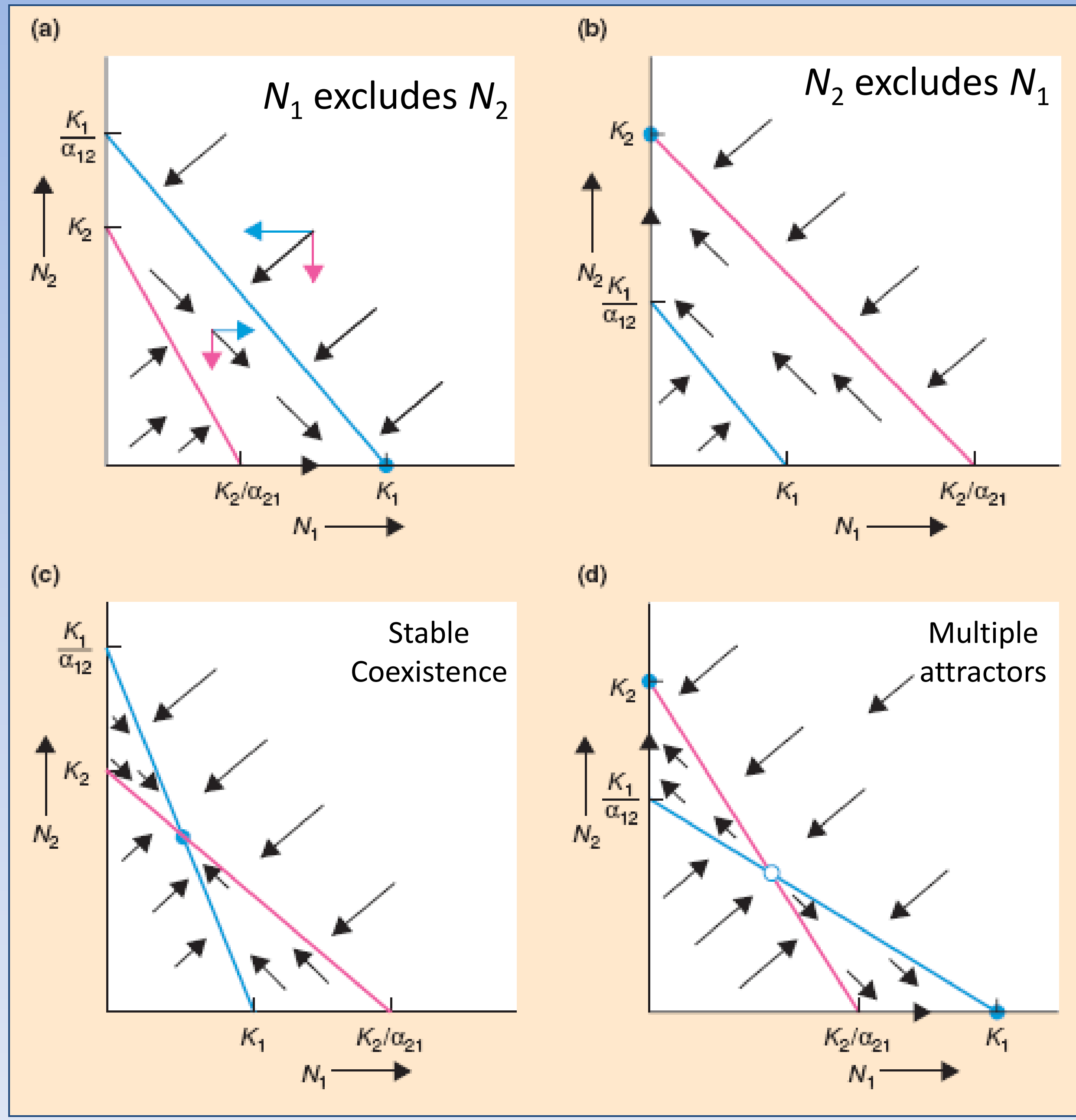
N_2 excludes N_1

$K_1<K_2/\alpha_{21}$ & $K_2<K_1/\alpha_{12}$

Stable Coexistence

$K_1>K_2/\alpha_{21}$ & $K_2>K_1/\alpha_{12}$

Multiple attractors



A constraint on stable coexistence

$$K_1 < K_2 / \alpha_{21}$$

$$K_2 < K_1 / \alpha_{12}$$

$$K_2 < (K_2 / \alpha_{21}) / \alpha_{12}$$

$$K_2 < K_2 / (\alpha_{21} \times \alpha_{12})$$

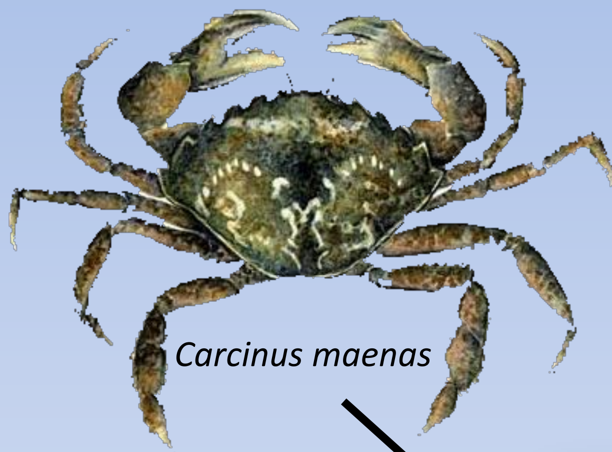
$$1 < 1 / (\alpha_{21} \times \alpha_{12})$$

$$\alpha_{21} \times \alpha_{12} < 1$$

For stable coexistence of both species, the product of the competition coefficients must be less than 1

Overall, interspecific competition must be less than intraspecific competition

Competition in invasive shorecrabs

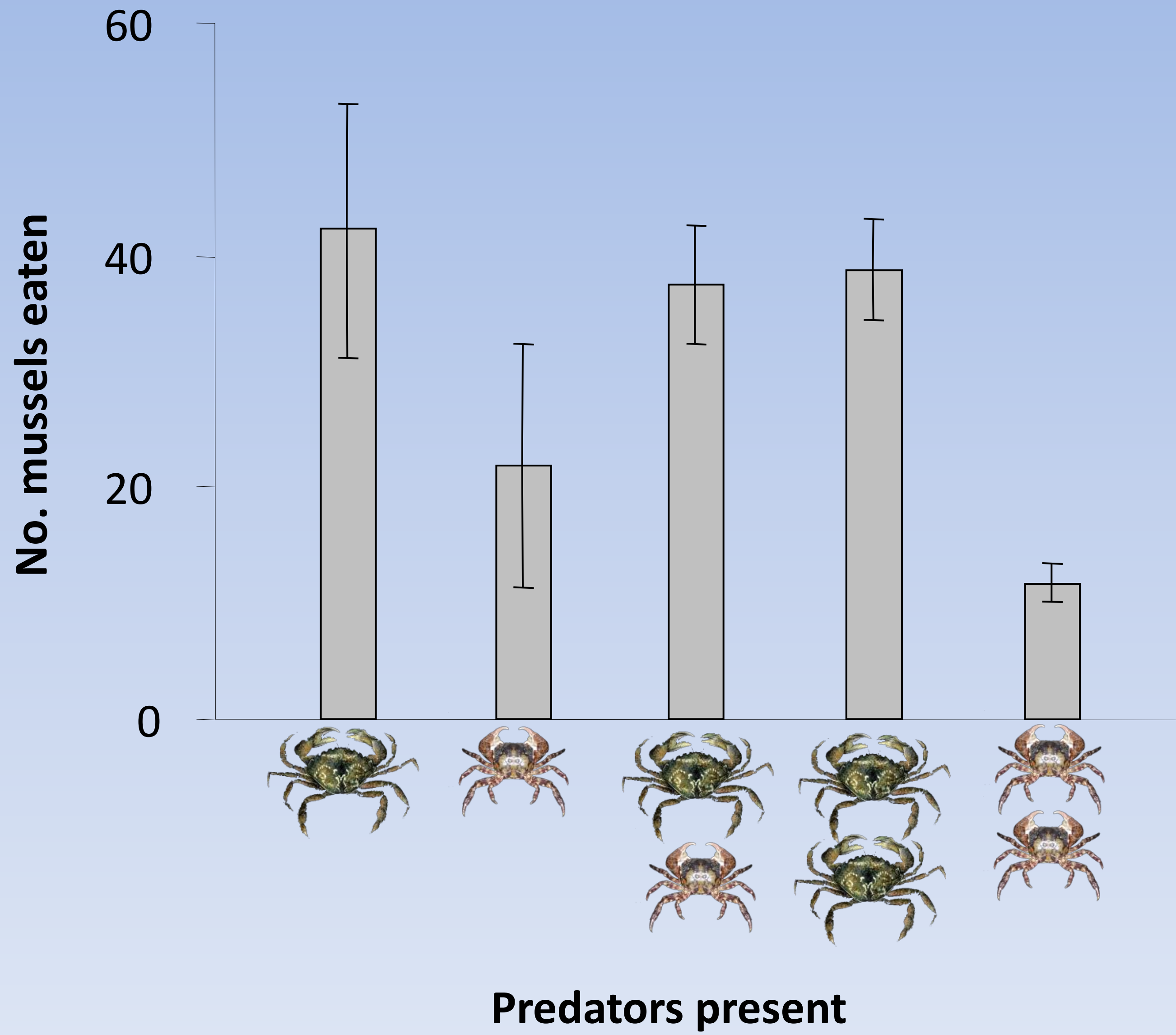


Carcinus maenas

Hemigrapsus sanguineus

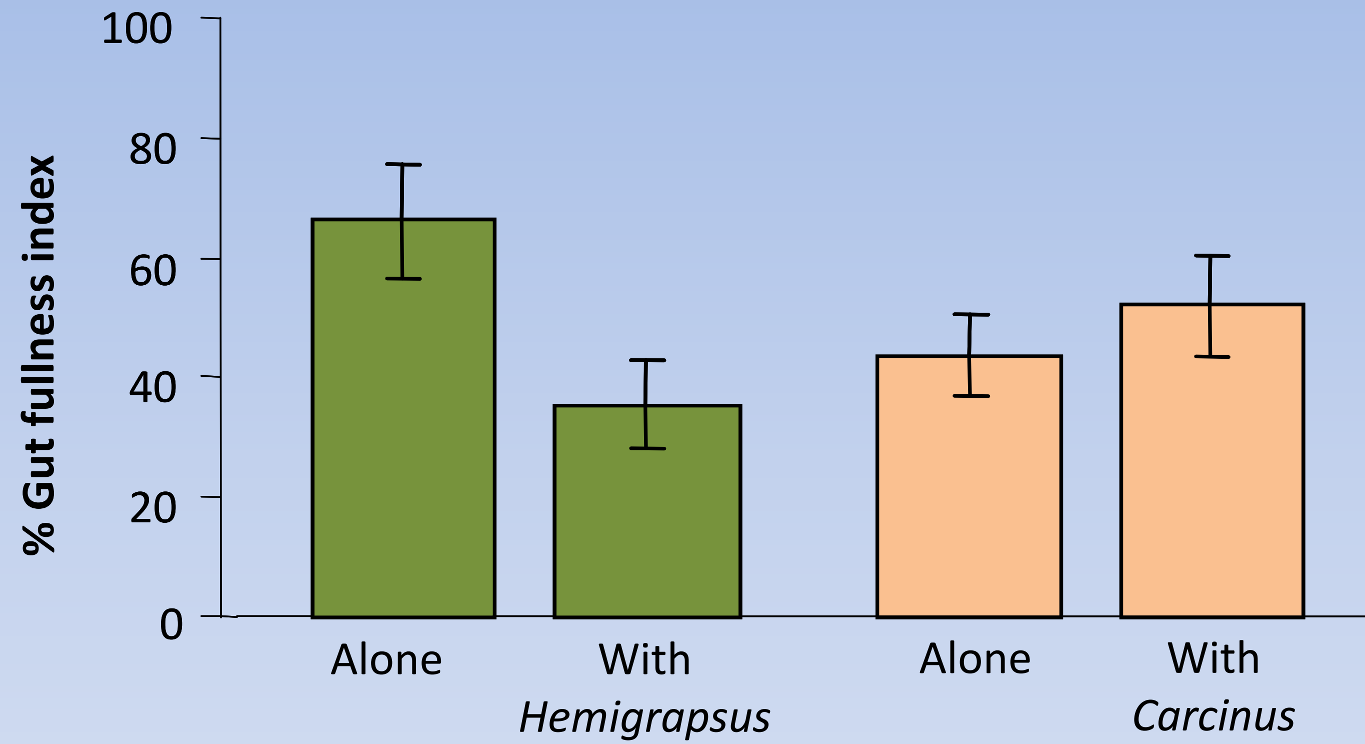
Mytilus edulis

Predation rates on mussels



Griffen (2006)

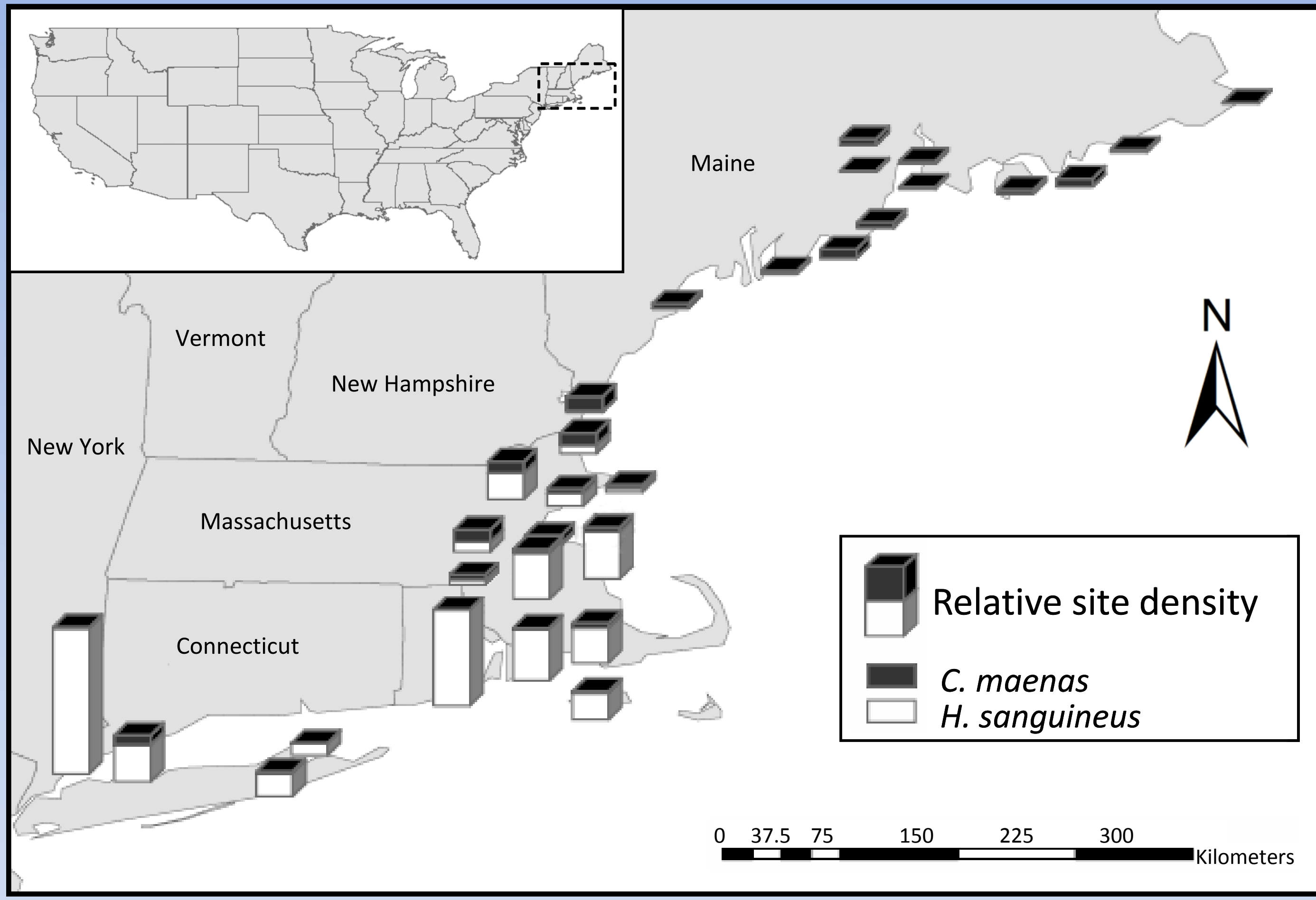
Foraging success



α_{12} is large

α_{21} is small

Griffen et al. (2007)



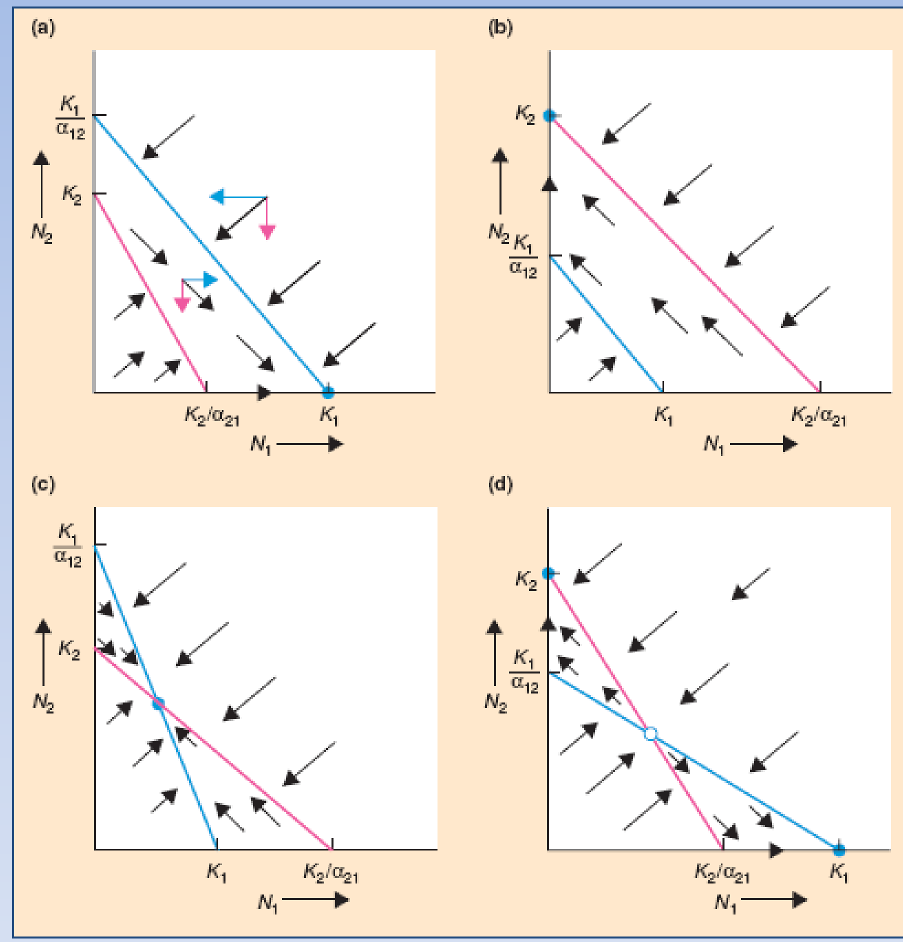
K_1 is small

K_2 is large

Griffen &Delaney (2007)

Challenge Problem

Which scenario does the Lotka-Volterra theory of competition predict will occur when *Hemigrapsus* is introduced to a location occupied by *Carcinus*?



Challenge Problem

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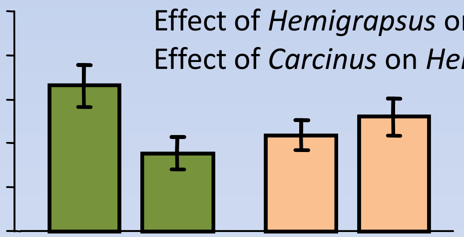
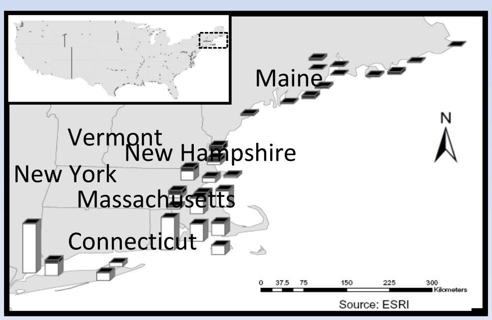
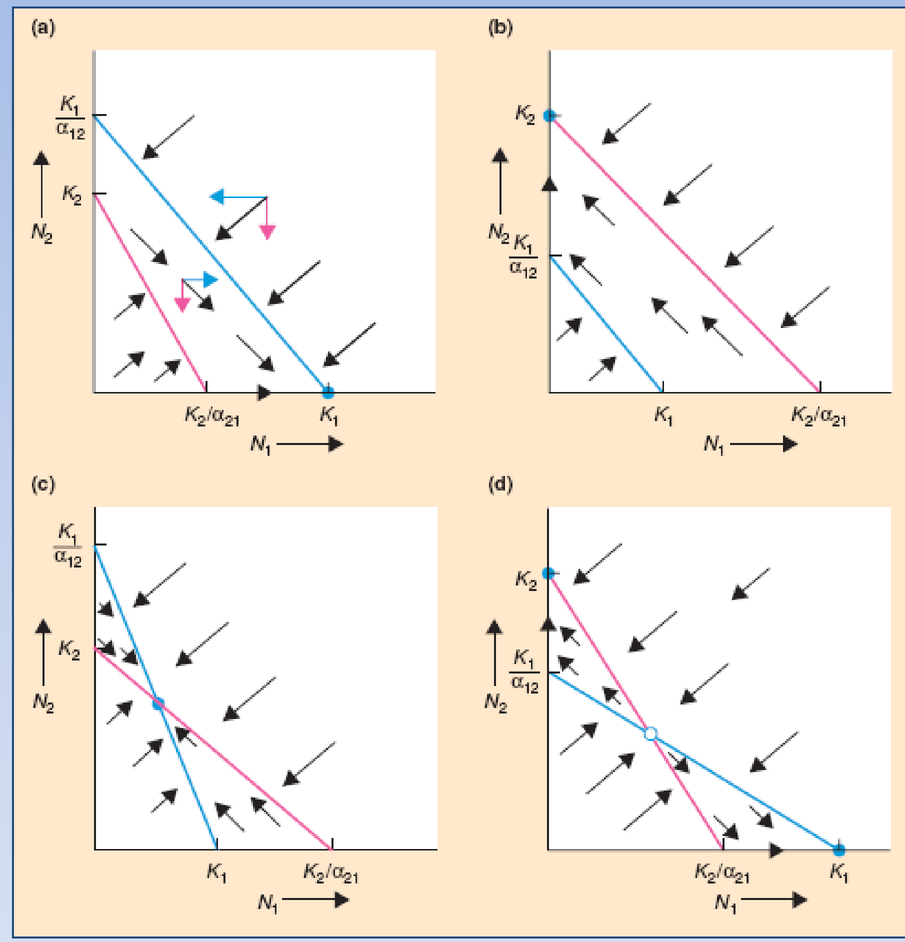


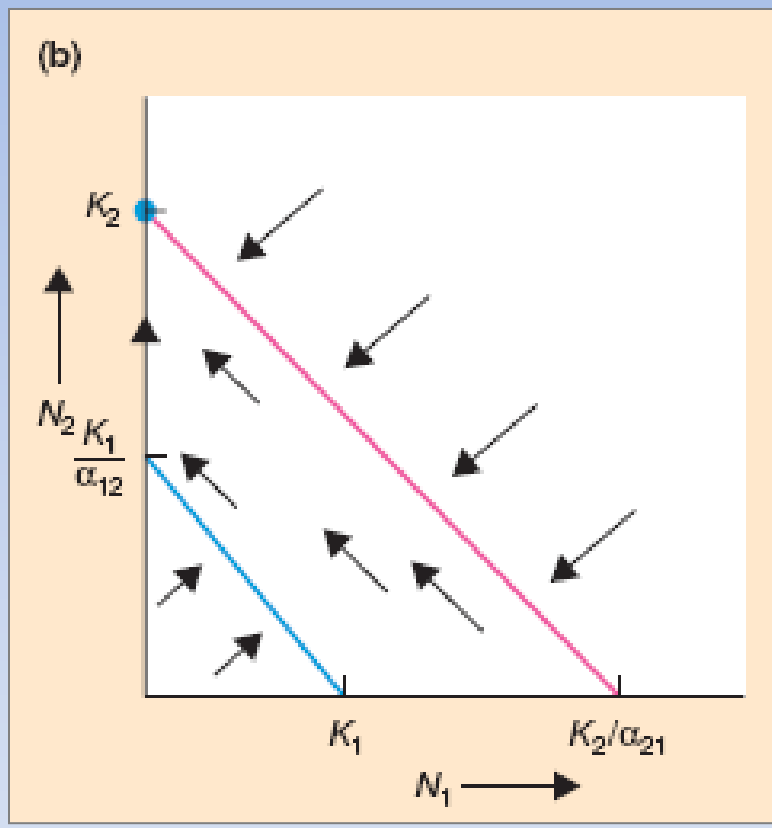
Effect of *Hemigrapsus* on *Carcinus* large
Effect of *Carcinus* on *Hemigrapsus* small



$K_1<K_2$



Theoretical Prediction



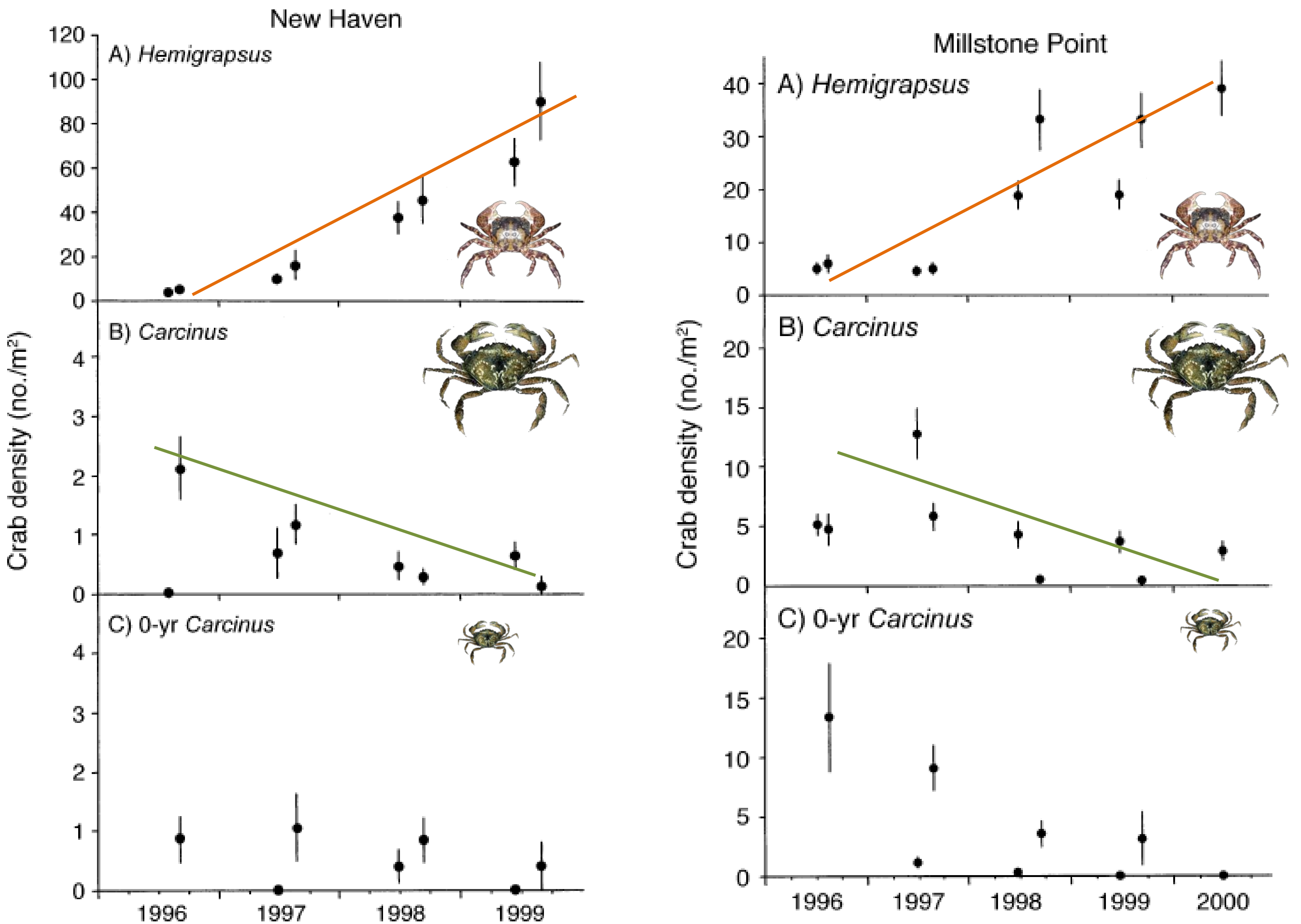
$K_1/\alpha_{12}<K_2$ & $K_1<K_2/\alpha_{21}$

N_2 excludes N_1

Effect of *Hemigrapsus* on *Carcinus* **large**
Effect of *Carcinus* on *Hemigrapsus* **small**

$K_1<K_2$

Competitive displacement of *Carcinus* by *Hemigrapsus*



Lohrer & Whitlatch (2002)

Key points

- Niche as an n-dimensional hypervolume
- Fundamental vs. realized niche
- R* theory for resource competition
- Lotka-Volterra theory
  - Replacement
  - Coexistence (product of competition coefficients < 1)
  - Alternative stable states