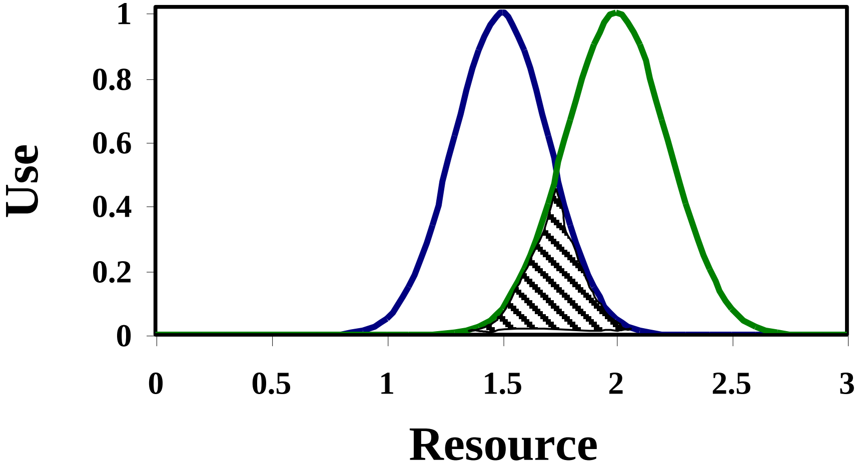
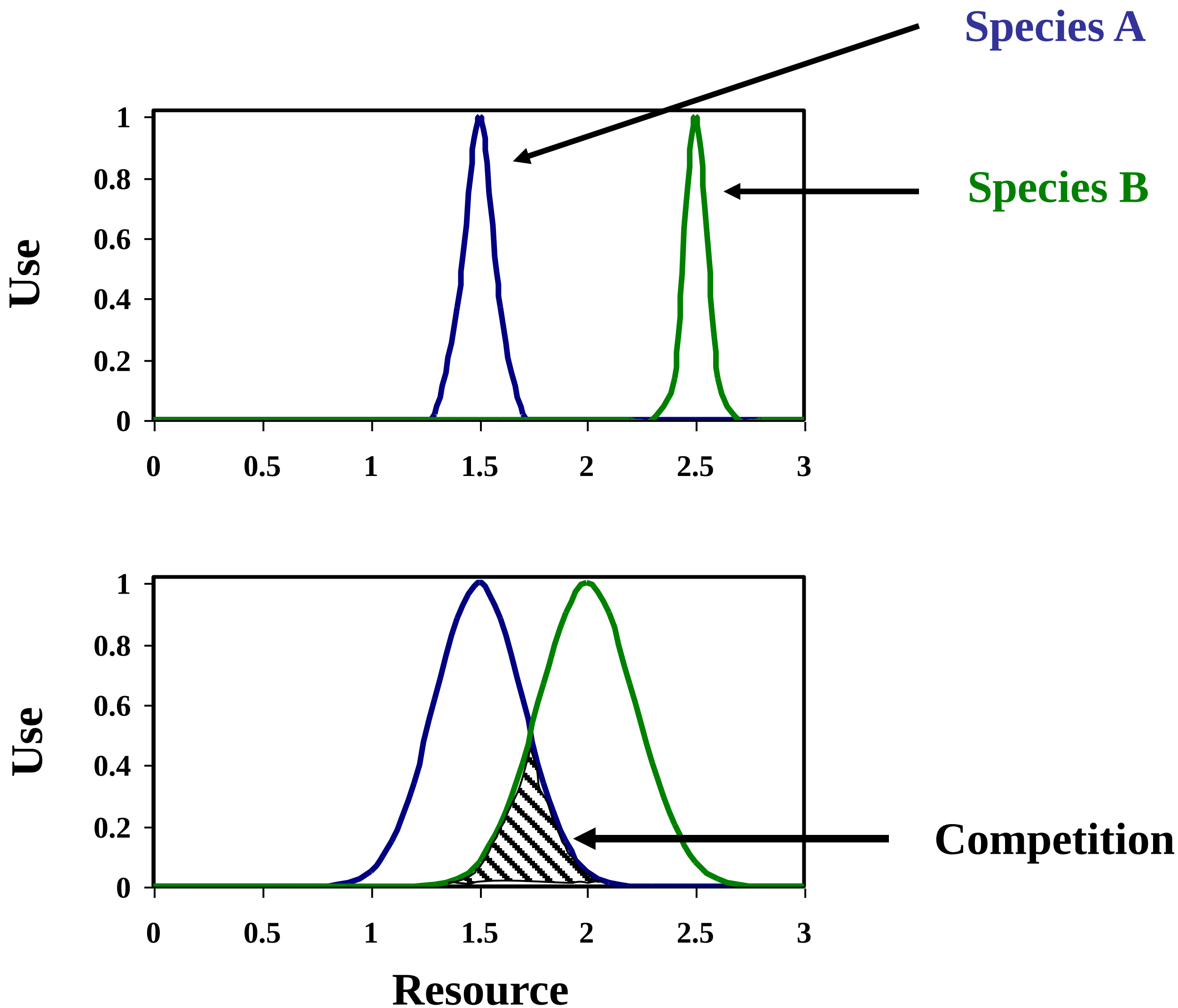
Interspecific Competition



The niche and interspecific competition



When niches overlap, competition results

Interspecific Competition

Interspecific competition* –** Individuals of one species suffer a reduction in fecundity, survivorship, or growth as a result of resource ***exploitation or ***interference*** by individuals of another species.

Two types of competition:

1. *Exploitation* – Individuals of one species inhibit individuals of another species ***INDIRECTLY*** through the consumption of a shared resource.

2. *Interference* – Individuals of one species inhibit individuals of another species ***DIRECTLY*** by preventing their consumption of a shared resource.

Exploitation competition: *Paramecia*

Paramecium aurelia

Paramecium bursaria

Oatmeal

Yeast

G.F. Gause (1934, 1935)

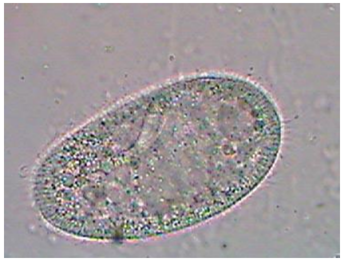
Paramecium caudatum

Exploitation competition

- **Gause began by growing each species in isolation**

Paramecium aurelia

Paramecium caudatum



Paramecium bursaria

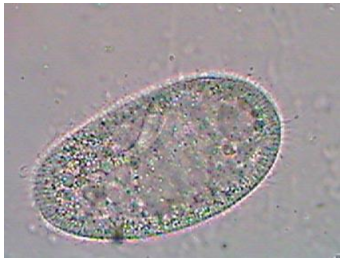
G.F. Gause (1934, 1935)

Exploitation competition

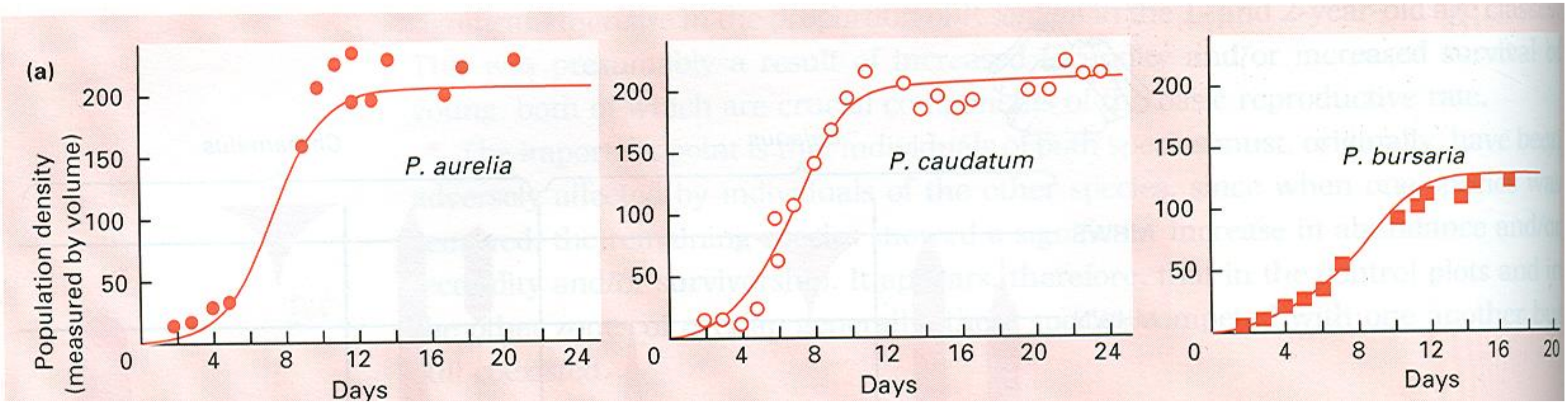
• **In isolation, each species grew logistically**

Paramecium aurelia

Paramecium caudatum



Paramecium bursaria



G.F. Gause (1934, 1935)

Exploitation competition

• **Gause then placed pairs of species in the same beaker**

Paramecium aurelia

Paramecium caudatum

Paramecium caudatum

Paramecium bursaria

G.F. Gause (1934, 1935)

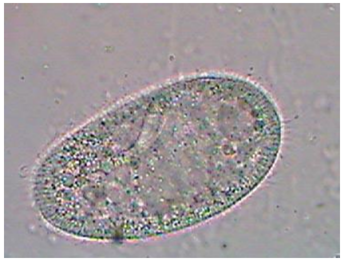
Exploitation competition

- **Gause found that the species had very different growth curves when grown together**

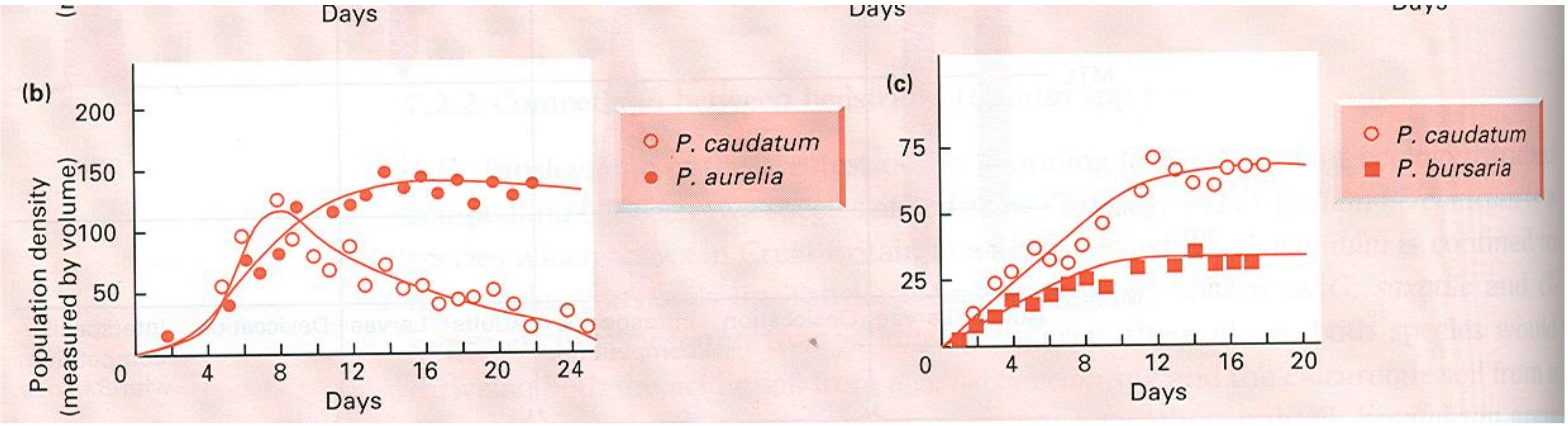
Paramecium aurelia

Paramecium caudatum

Paramecium caudatum



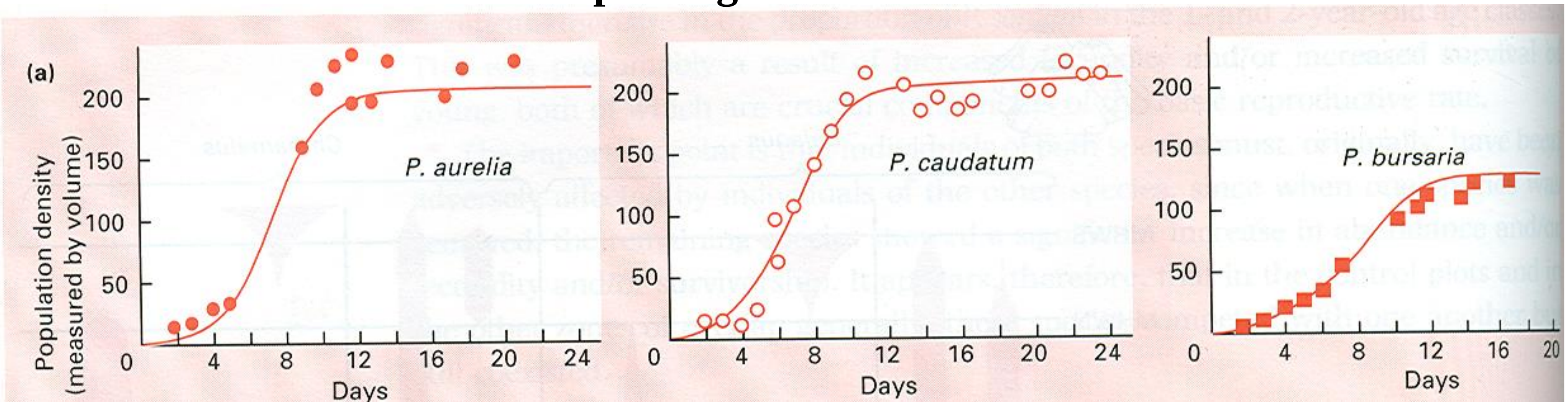
Paramecium bursaria



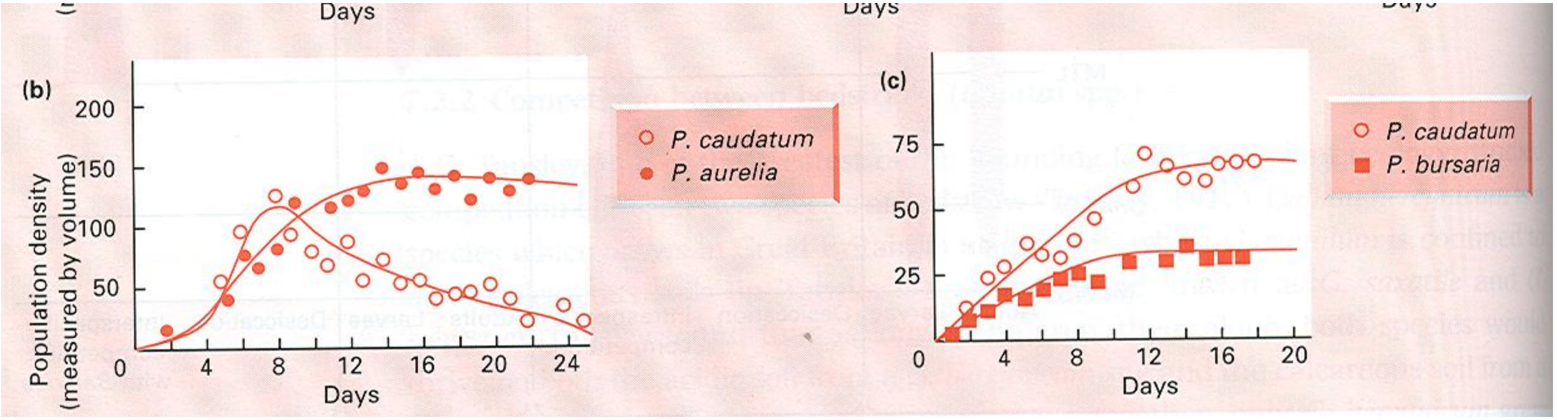
G.F. Gause (1934, 1935)

Exploitation competition

Species grown in isolation

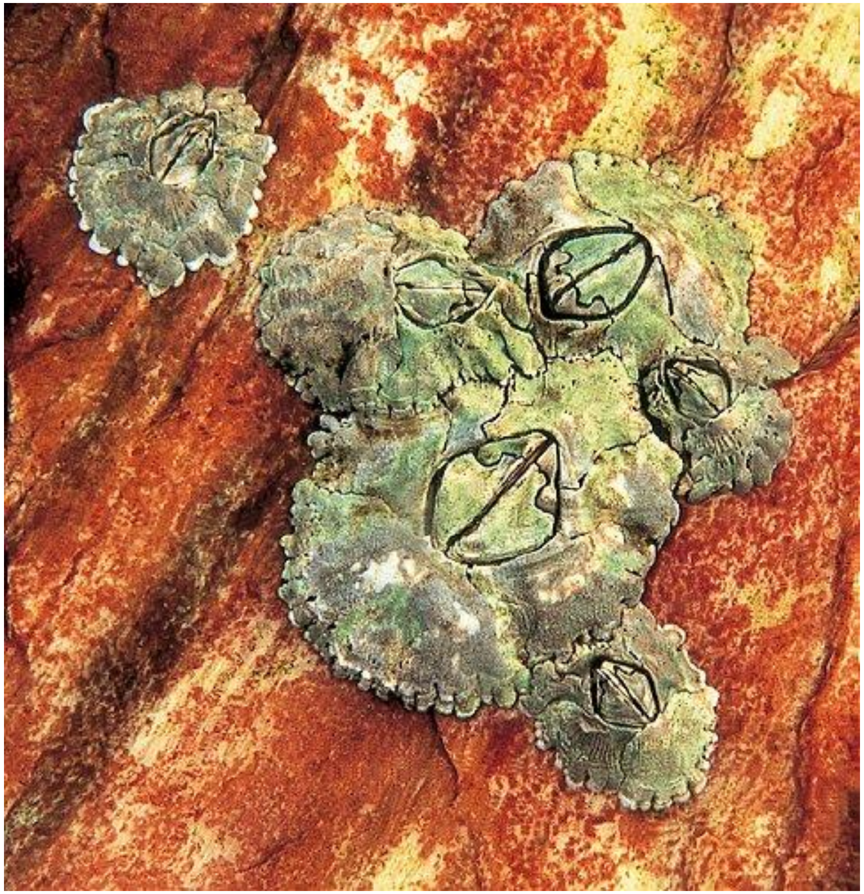


Species grown in competition



Exploitation competition depresses population sizes and can lead to extinction

Interference competition: Scottish barnacles



Balanus balanoides

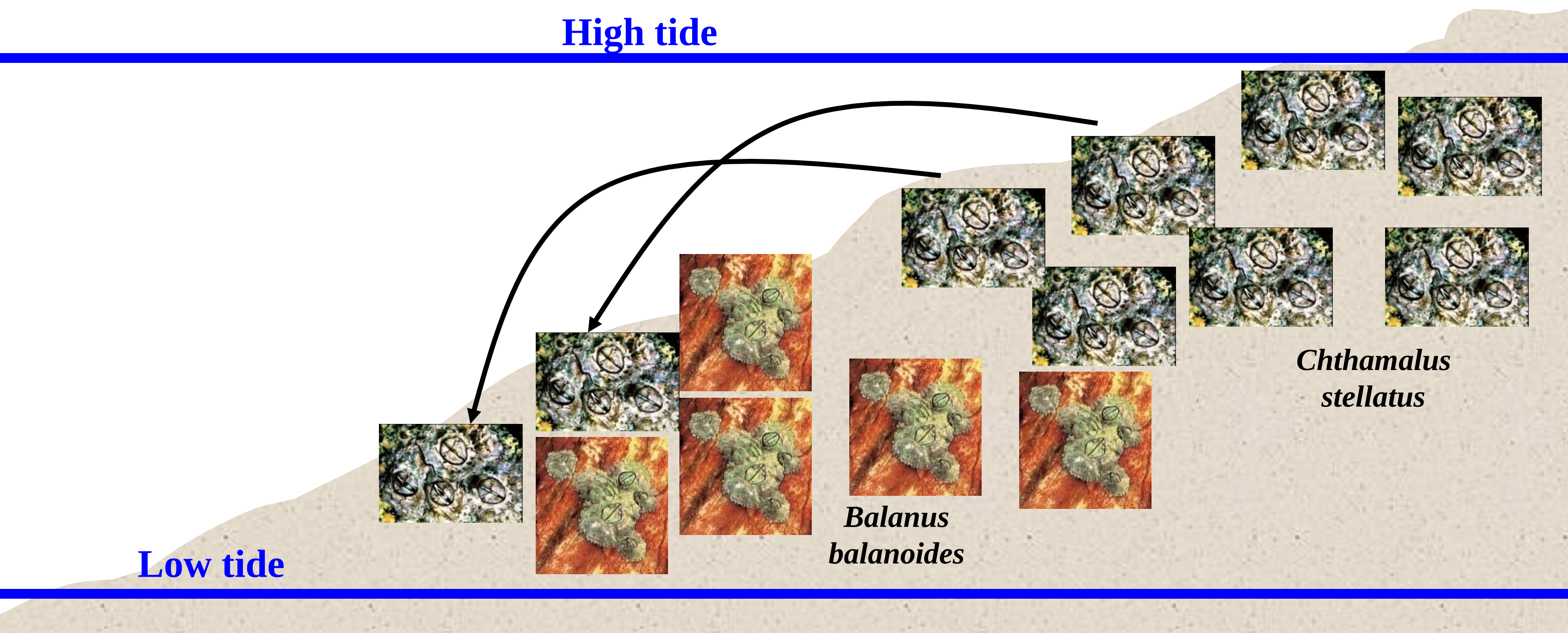
Chthamalus stellatus

Connell (1961)

Interference competition: Scottish barnacles

- *Chthalamus* occur higher up in the intertidal zone

- However, juvenile *Chthalamus* do settle in the lower *Balanus* zone

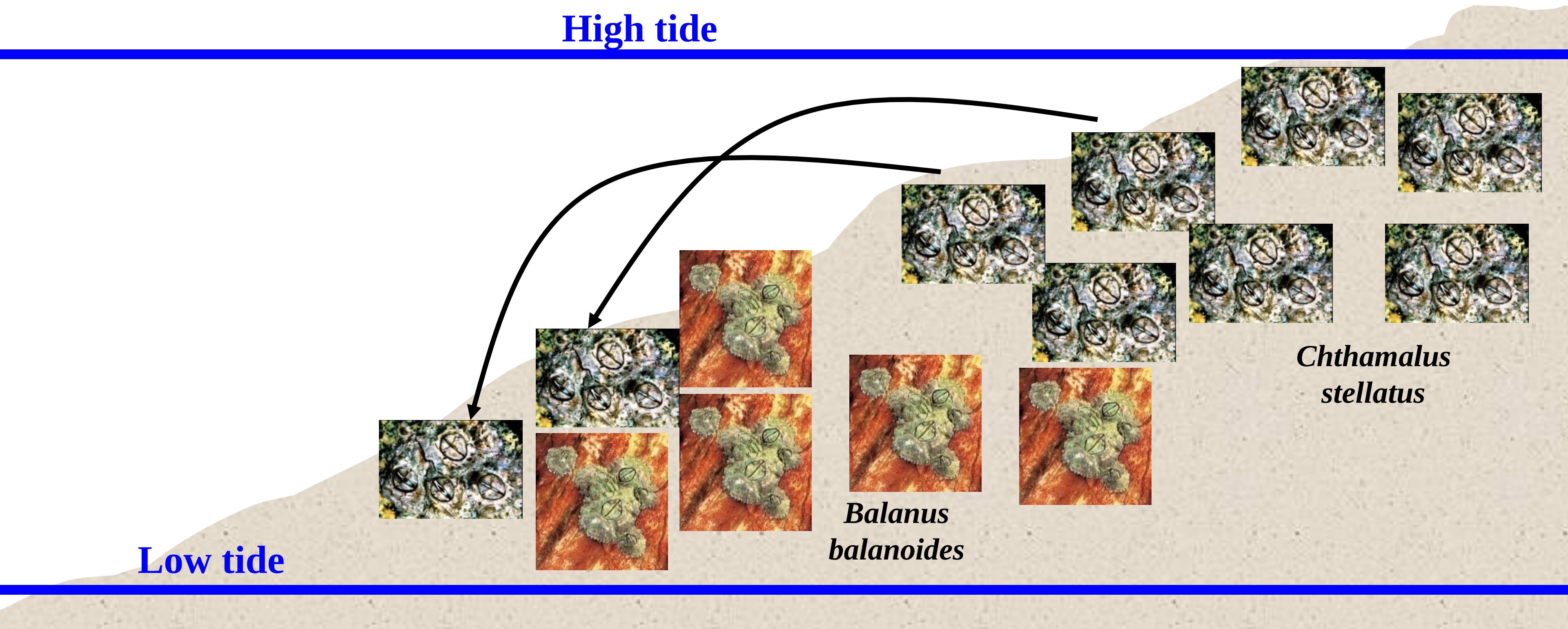


Interference competition: Scottish barnacles

Experiments that monitored the fate of *Chthalamus* juveniles that moved to the lower intertidal (Connell, 1961) showed that:

• *Balanus* crushed or displaced (through its own growth) the *Chthalamus* juveniles, reducing their survival

• If, however, *Balanus* individuals were removed from the immediate area, juvenile *Chthalamus* could survive well in the lower intertidal



The Lotka-Volterra Competition Model

Alfred James Lotka
(1880 - 1949)

Vito Volterra
(1860-1940)

Independently developed a general model of competition between species

Developing the Lotka-Volterra Model

The Lotka-Volterra Competition Model

Imagine we have two species, each growing logistically

Species 1:

$$\frac{dN_1}{dt} = r_1 N_1 \boxed{\left(1 - \frac{N_1}{K_1}\right)}$$

Intraspecific competition

Species 2:

$$\frac{dN_2}{dt} = r_2 N_2 \boxed{\left(1 - \frac{N_2}{K_2}\right)}$$

We need to incorporate *INTERSPECIFIC* competition

The Lotka-Volterra Competition Model

Incorporating *interspecific competition*

Species 1:

$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \frac{\boxed{\alpha_{1\leftarrow 1} N_1} + \boxed{\alpha_{1\leftarrow 2} N_2}}{K_1} \right)$$

Species 2:

$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \frac{\boxed{\alpha_{2\leftarrow 2} N_2} + \boxed{\alpha_{2\leftarrow 1} N_1}}{K_2} \right)$$

Competition coefficients:

$\alpha_{i\leftarrow i}$ **is the effect of species i on its own growth rate (intraspecific competition)**

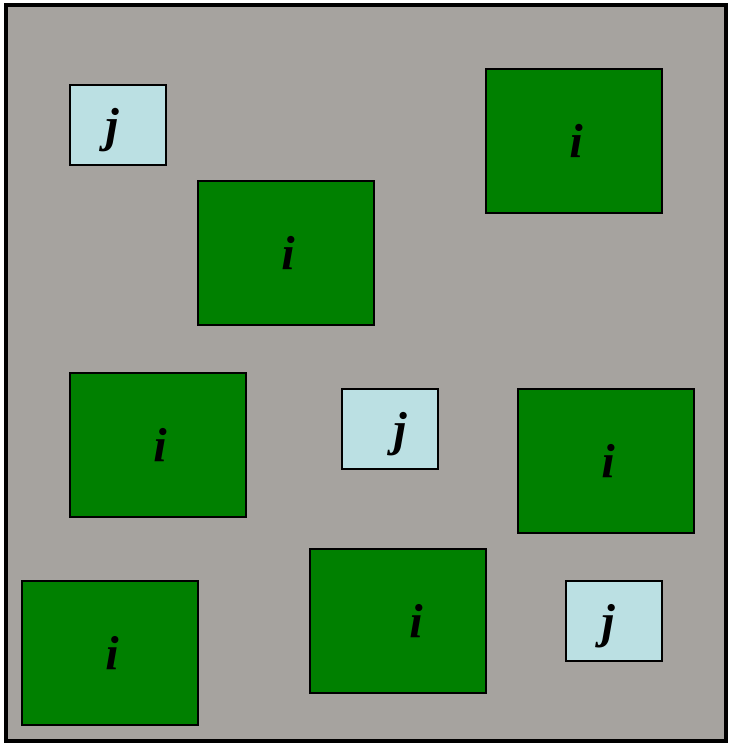
$\alpha_{i\leftarrow j}$ **is the effect of species j on the growth rate of species i (interspecific competition)**

The Lotka-Volterra Competition Model

Understanding α

Interspecific < Intraspecific

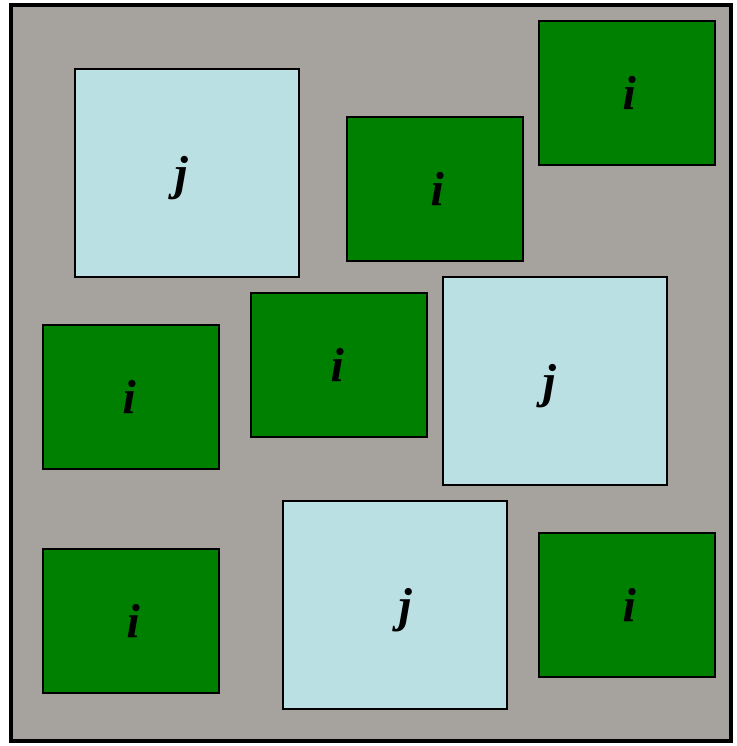
$\alpha_{i\leftarrow j} < \alpha_{i\leftarrow i}$



Here the effect of Species j on species i is less than the effect of Species i on itself. Species i uses more resource (grey box) per capita than does Species j

Interspecific > Intraspecific

$\alpha_{i\leftarrow j} > \alpha_{i\leftarrow i}$

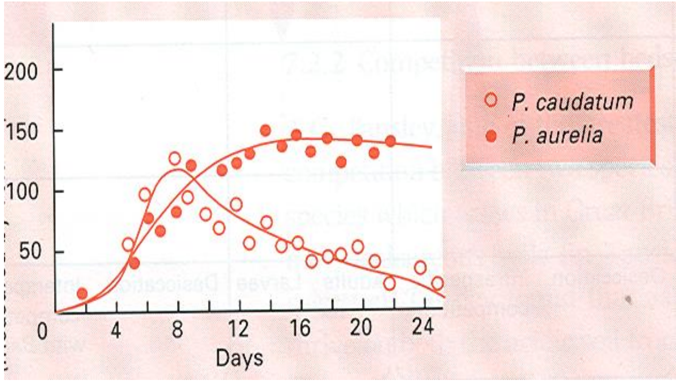


Here the effect of Species j on species i is greater than the effect of Species i on itself. Species j uses more resource (grey box) per capita than does Species i

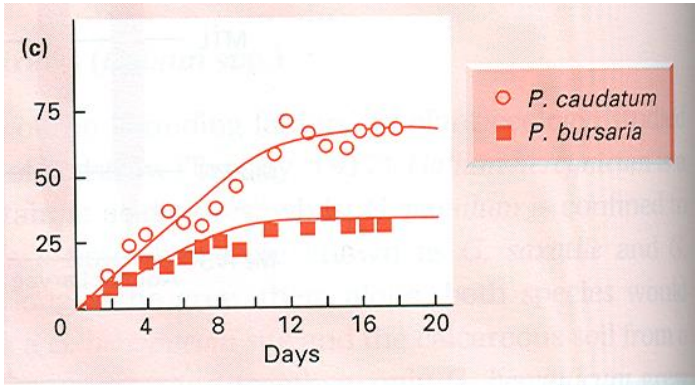
Applying the Lotka-Volterra model to Gause's data

Remember, Gause found two possible outcomes of competition:

<u>Outcome 1: One species goes extinct</u>



<u>Outcome 2: Both species coexist</u>



Are these outcomes of competition predicted by the model?

The Lotka-Volterra model predicts:

<u>Three possible equilibria:</u>

Equilibrium #1: $\hat{N}_1 = \dfrac{K_1}{\alpha_{1\leftarrow 1}}; \hat{N}_2 = 0$

Equilibrium #2: $\hat{N}_1 = 0; \hat{N}_2 = \dfrac{K_2}{\alpha_{2\leftarrow 2}}$

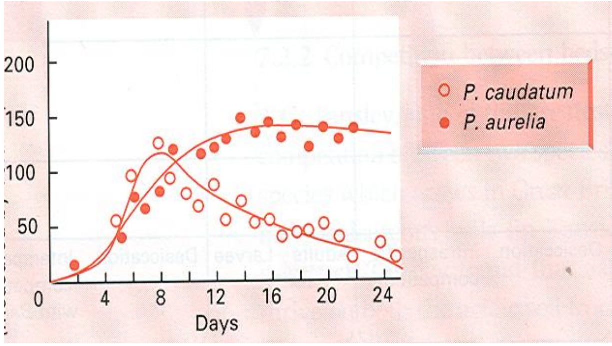
Equilibrium #3: $\hat{N}_1 = \dfrac{\alpha_{1\leftarrow 1}K_1 - \alpha_{1\leftarrow 2}K_2}{1-\alpha_{1\leftarrow 2}\alpha_{2\leftarrow 1}}$, $\hat{N}_2 = \dfrac{\alpha_{2\leftarrow 2}K_2 - \alpha_{2\leftarrow 1}K_1}{1-\alpha_{2\leftarrow 1}\alpha_{1\leftarrow 2}}$

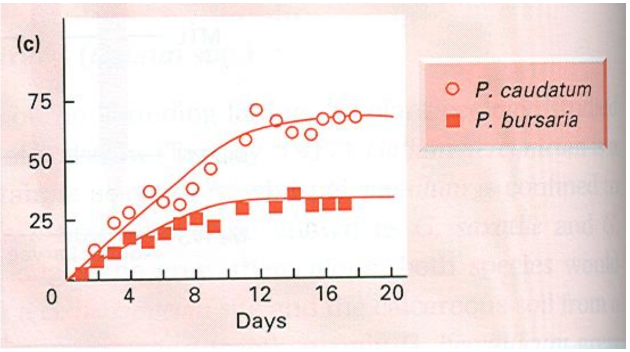
What do each of these mean biologically?

Which correspond to Gause's experimental findings?

Matching model to data

Data





Model

$$\hat{N}_1 = \frac{K_1}{\alpha_{1\leftarrow 1}}; \hat{N}_2 = 0$$

Or

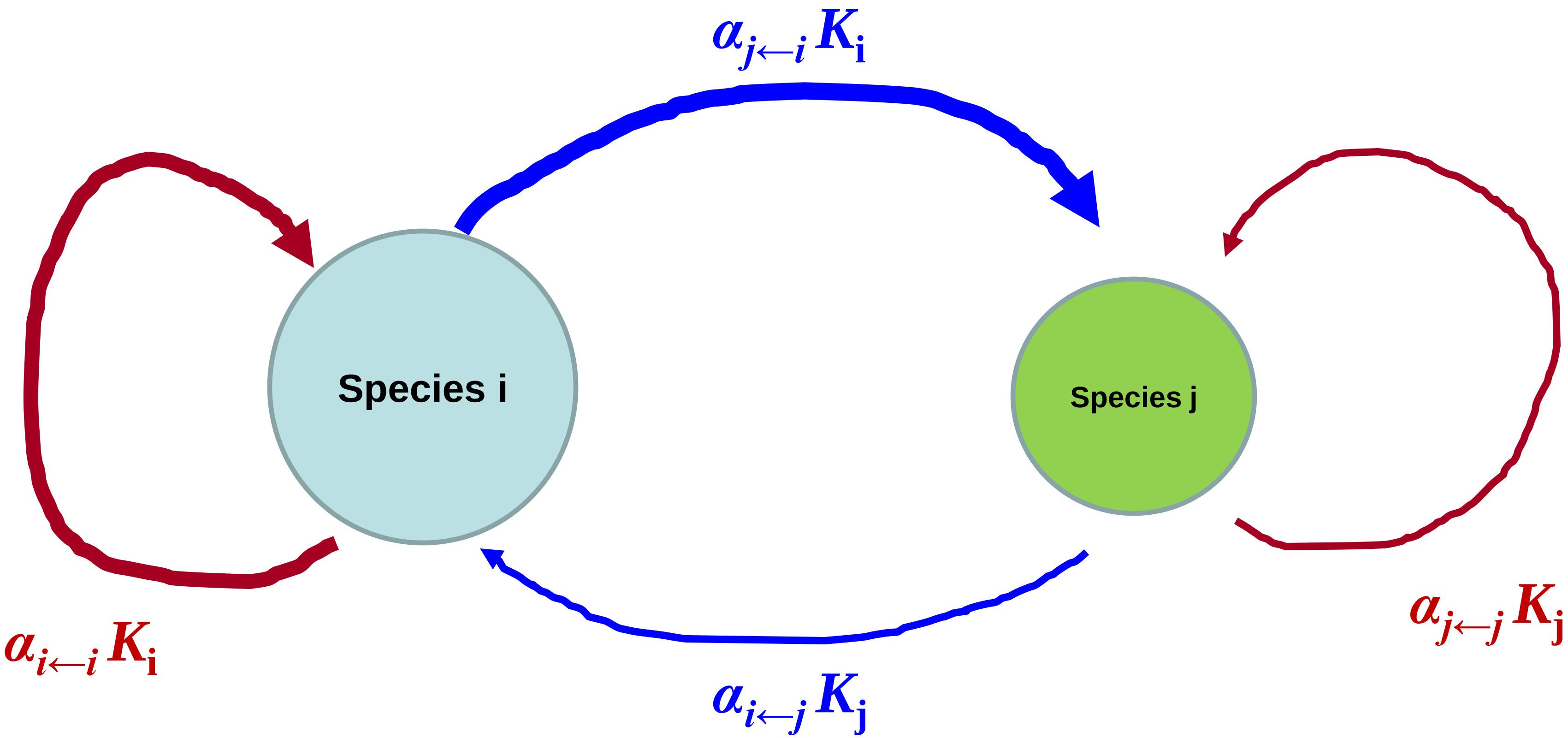
$$\hat{N}_1 = 0; \hat{N}_2 = \frac{K_2}{\alpha_{2\leftarrow 2}}$$

$$\hat{N}_1 = \frac{\alpha_{1\leftarrow 1}K_1 - \alpha_{1\leftarrow 2}K_2}{1-\alpha_{1\leftarrow 2}\alpha_{2\leftarrow 1}}$$

$$\hat{N}_2 = \frac{\alpha_{2\leftarrow 2}K_2 - \alpha_{2\leftarrow 1}K_1}{1-\alpha_{2\leftarrow 1}\alpha_{1\leftarrow 2}}$$

When does each outcome occur?
What conditions favor coexistence vs. extinction?

When is one species driven to extinction?

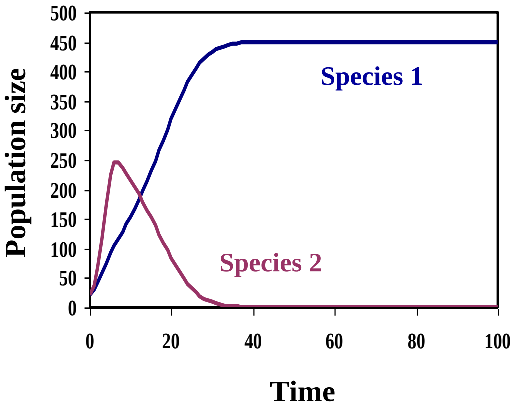


Anytime:

$\alpha_{i\leftarrow i} K_i > \alpha_{i\leftarrow j} K_j$ **and** $\alpha_{j\leftarrow j} K_j < \alpha_{j\leftarrow i} K_i$

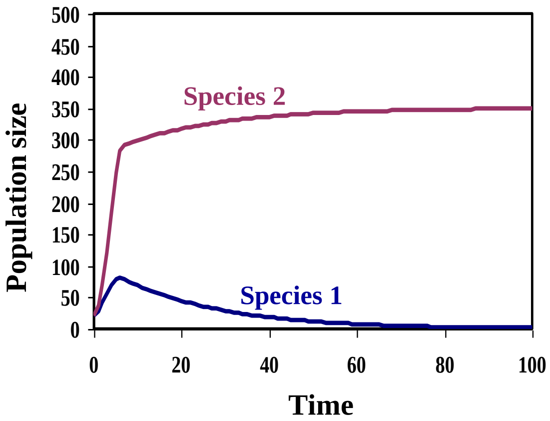
This can happen in two ways:

Species 1 is the superior competitor



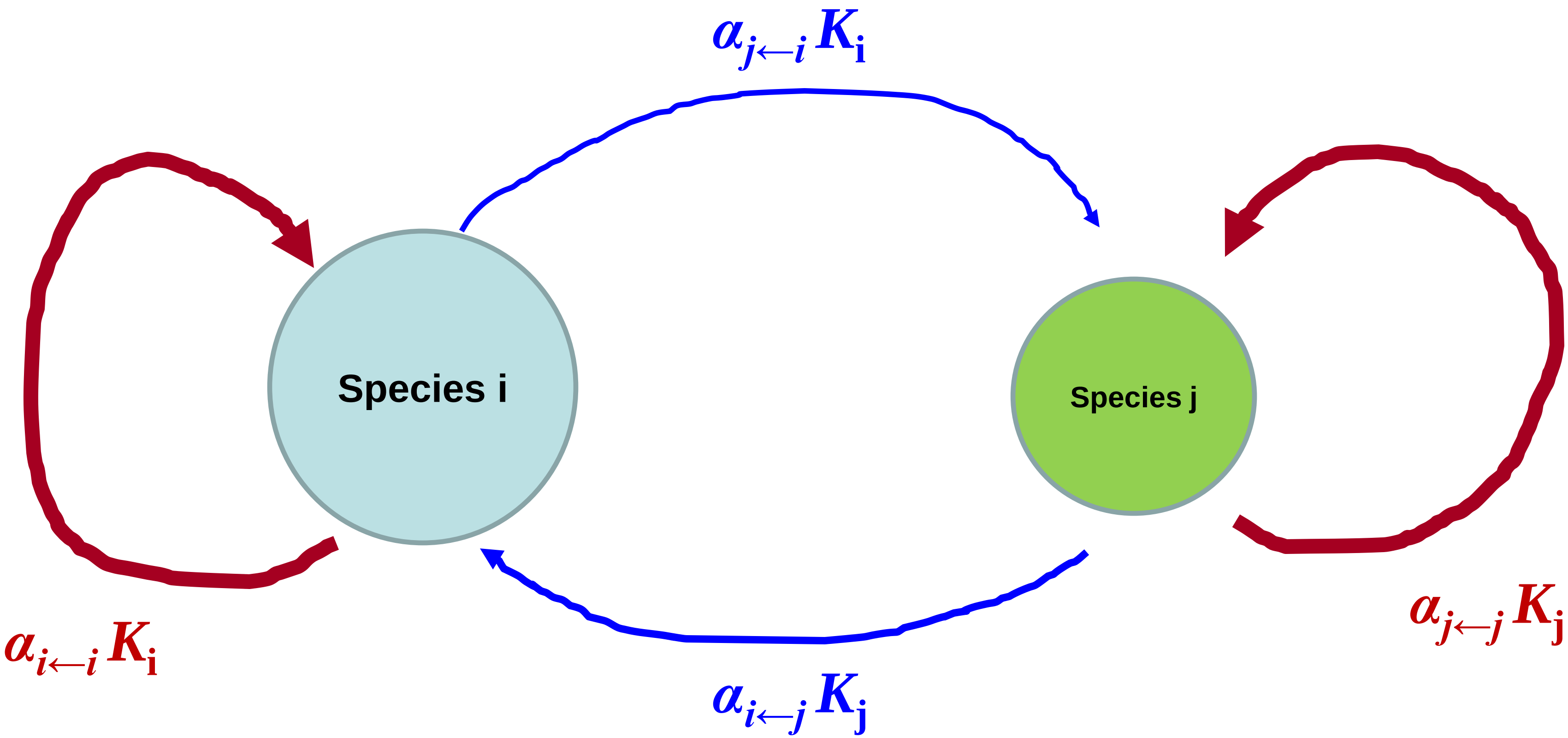
Species 2 goes extinct and Species 1 reaches its carrying capacity

Species 2 is the superior competitor



Species 1 goes extinct and Species 2 reaches its carrying capacity

When do the species coexist?

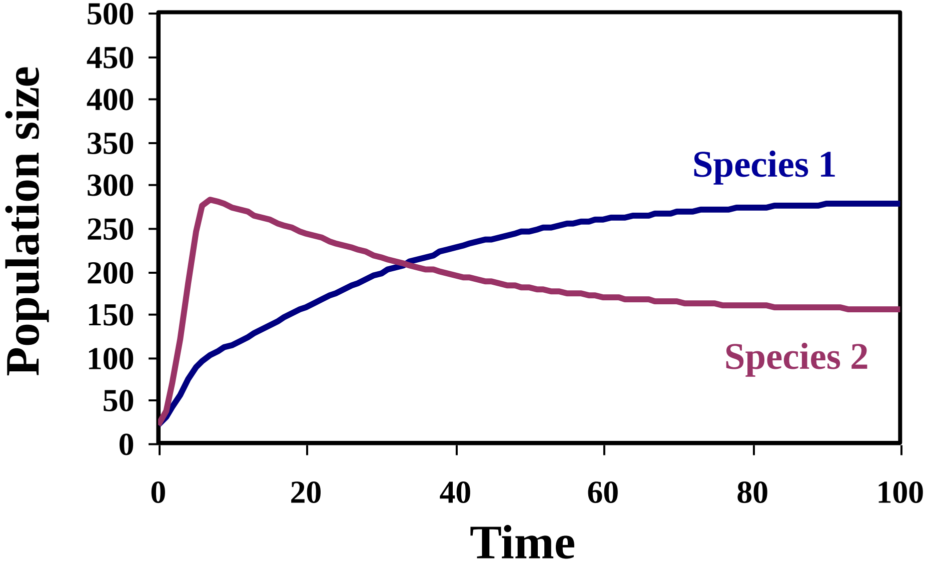


Anytime:

$\alpha_{i\leftarrow i} K_{\mathrm{i}} > \alpha_{i\leftarrow j} K_{\mathrm{j}}$ **and** $\alpha_{j\leftarrow j} K_{\mathrm{j}} > \alpha_{j\leftarrow i} K_{\mathrm{i}}$

When this occurs:

→ **intraspecific competition exceeds interspecific competition**

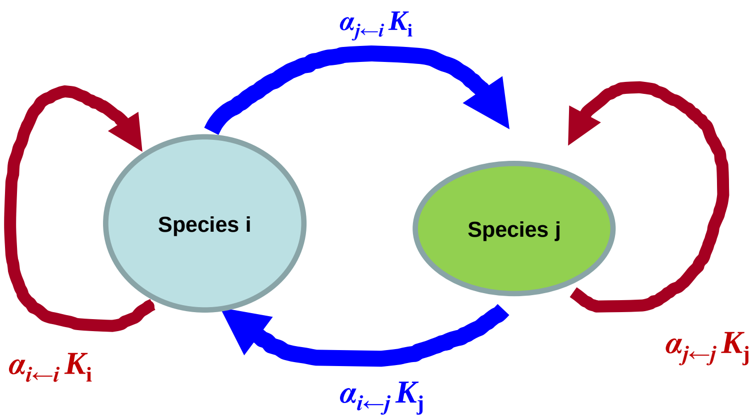


Species 1 and Species 2 coexist with equilibrium densities:

$$\hat{N}_1 = \frac{\alpha_{1\leftarrow 1}K_1 - \alpha_{1\leftarrow 2}K_2}{1-\alpha_{1\leftarrow 2}\alpha_{2\leftarrow 1}} \qquad \hat{N}_2 = \frac{\alpha_{2\leftarrow 2}K_2 - \alpha_{2\leftarrow 1}K_1}{1-\alpha_{2\leftarrow 1}\alpha_{1\leftarrow 2}}$$

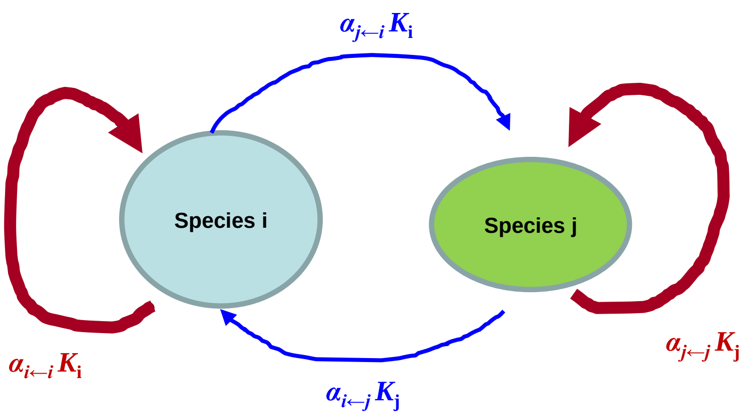
What favors coexistence?

Ecologically similar species



Coexistence unlikely

Ecologically dissimilar species



Coexistence likely

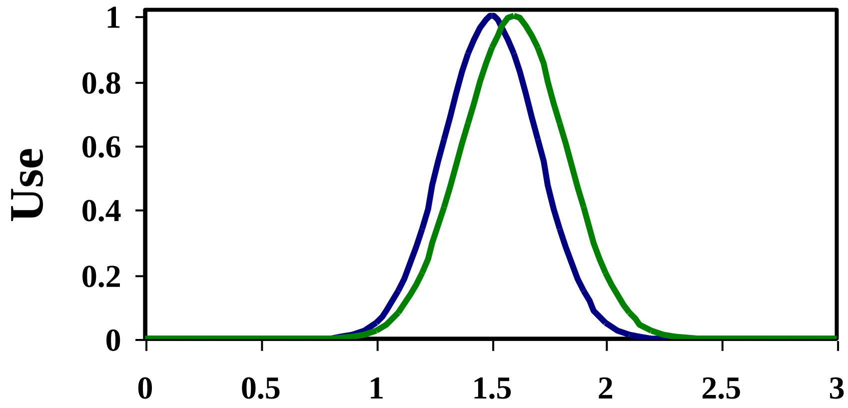
The more similar two species are ecologically, the more they impact one another and the less likely is coexistence

The competitive exclusion principle

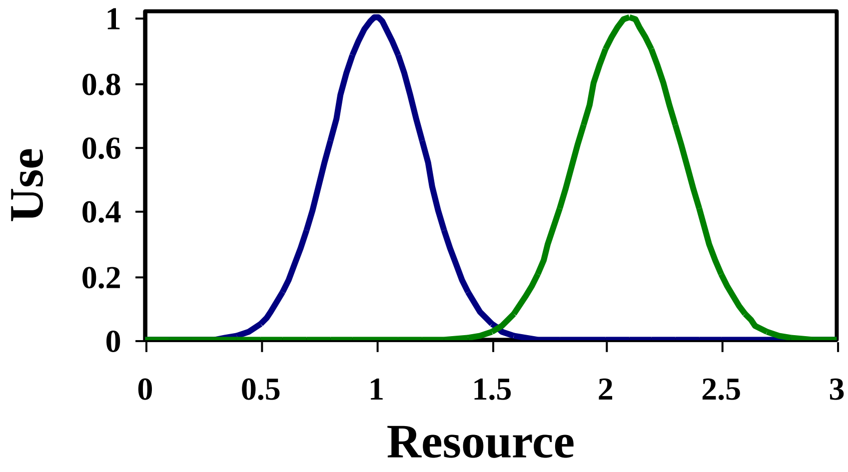
If two competing species coexist in a stable environment, then they do so as a result of niche differentiation. If, however, there is no such differentiation, then one competing species will eliminate or exclude the other.

– Begon et. al. 1996

The competitive exclusion principle



Competitive exclusion occurs



Competitive coexistence occurs

Evidence for the importance of competition

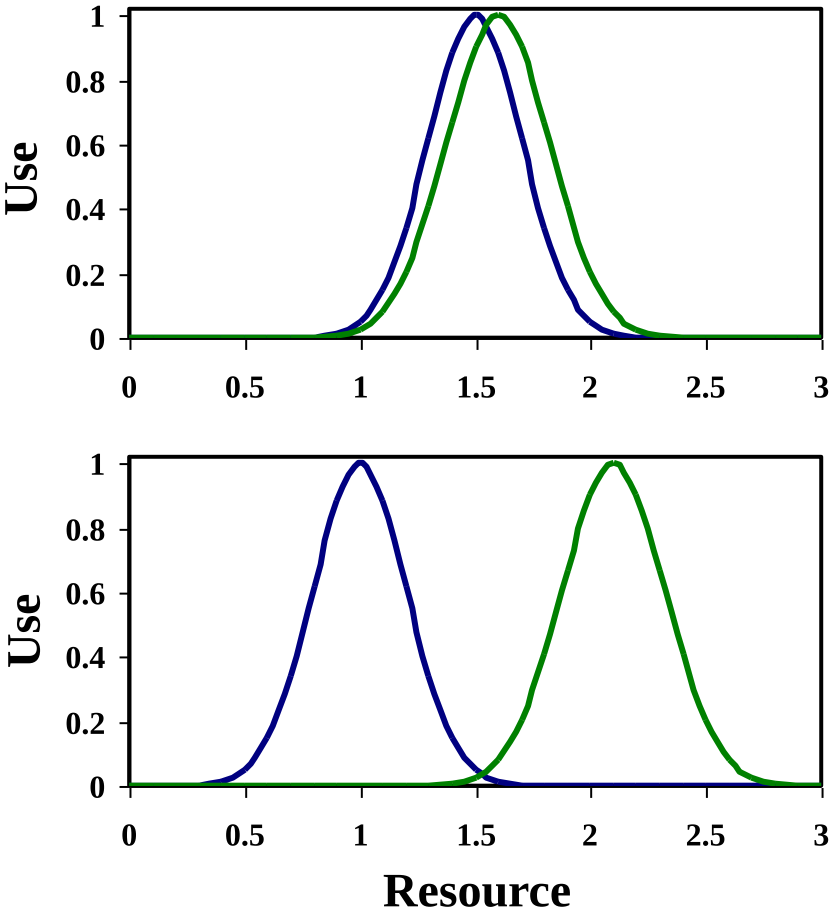
1. Character displacement – Increased ecological differences between species in regions where they occur together

2. Ecological release – The expansion of a species niche under conditions where the other species is absent

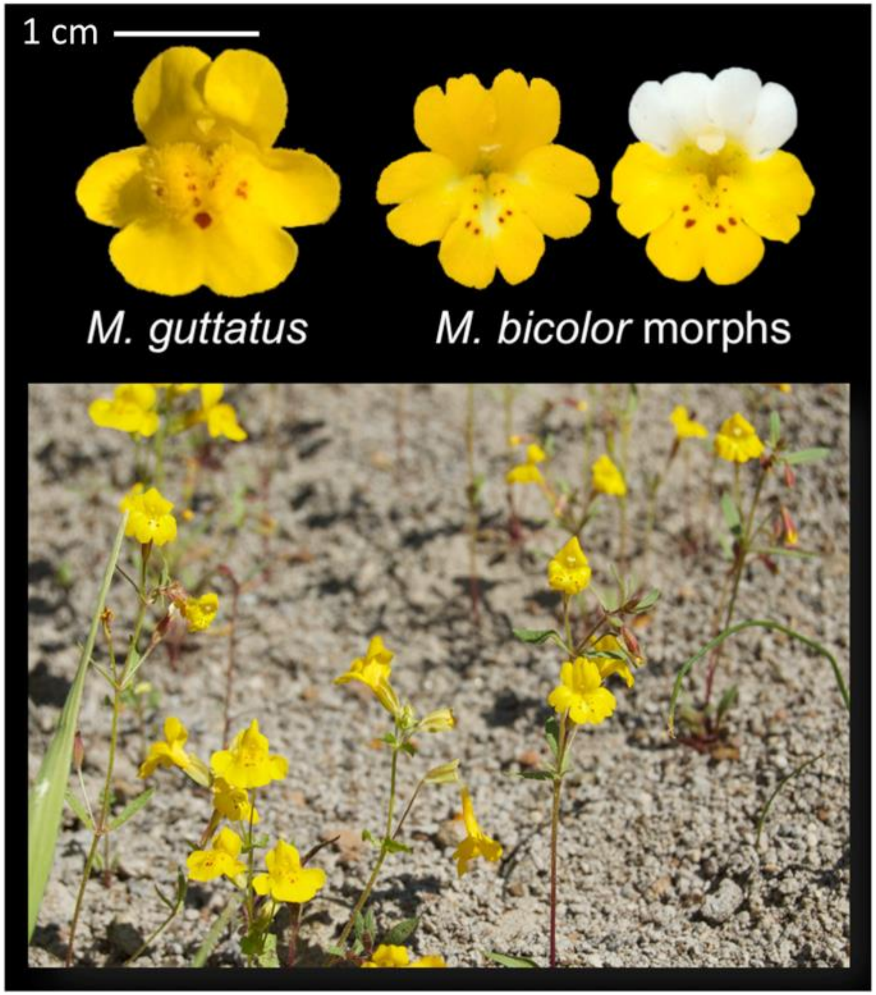
Character displacement

• When two species occur in sympatry natural selection should favor the evolution of mechanisms that reduce competition

• This often takes the form of *character displacement*, where the two competing species diverge in a trait that reduces the strength of interspecific competition



Character displacement in *Mimulus*



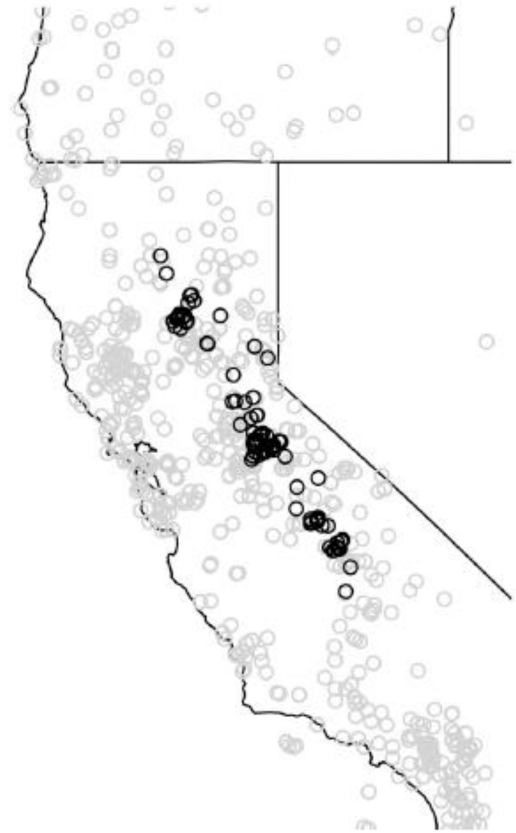


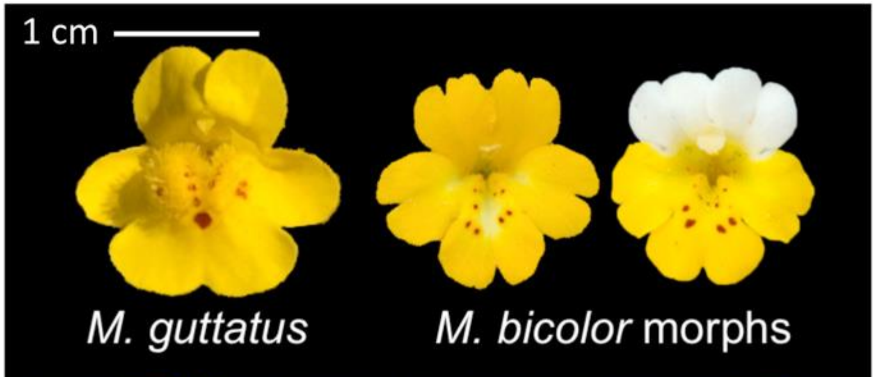
Fig. 1. The geographic distribution of *Mimulus bicolor* (open black circles) is restricted to the Sierra Nevada of California, whereas *M. guttatus* (open gray circles) occurs across western North America. Data were obtained from the global biodiversity information facility (http://www.gbif.org).

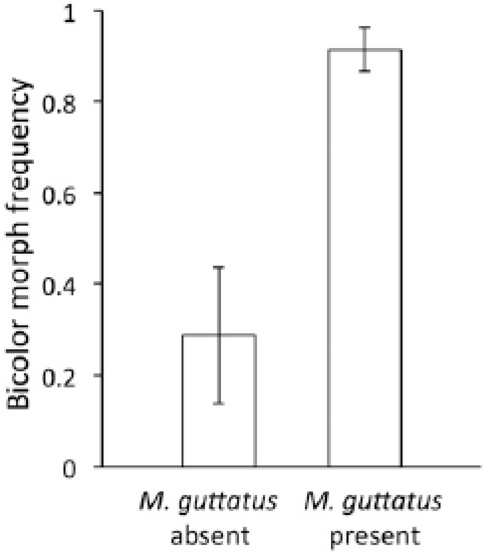
American Journal of Botany 101(11): 1915–1924, 2014.

POLLINATOR-MEDIATED COMPETITION INFLUENCES SELECTION FOR FLOWER-COLOR DISPLACEMENT IN SYMPATRIC MONKEYFLOWERS[1]

DENA L. GROSSENBACHER[2,4] AND MAUREEN L. STANTON[3]

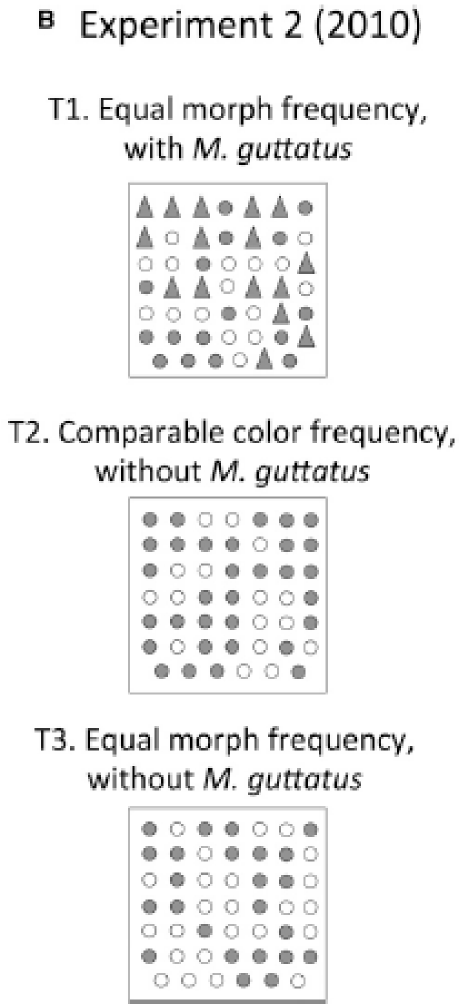
Character displacement in *Mimulus bicolor*

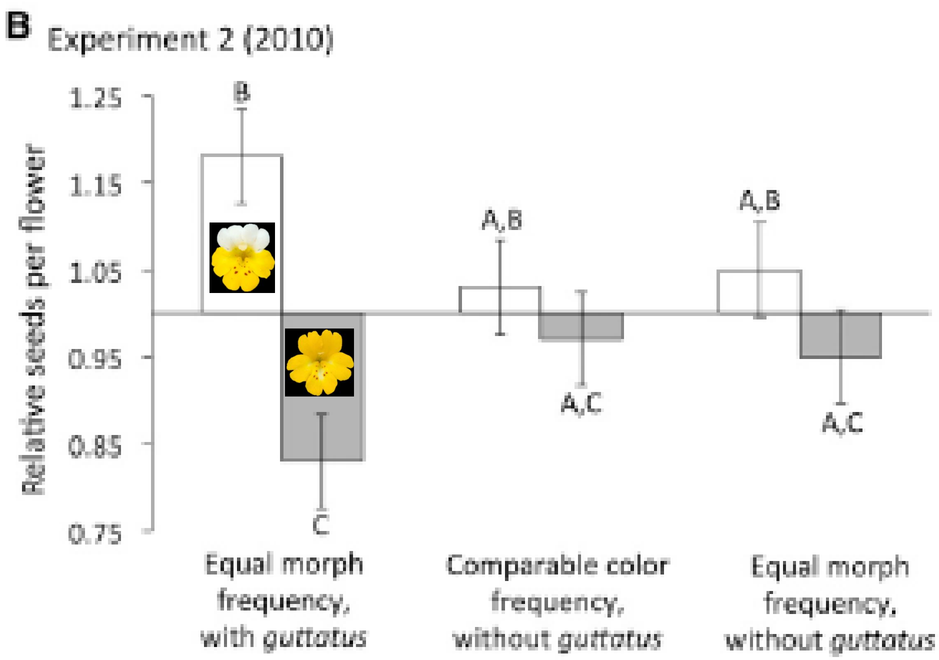




The frequency of the white/divergent morph is greater when *M. bicolor* occurs in sympatry with *M. guttatus*

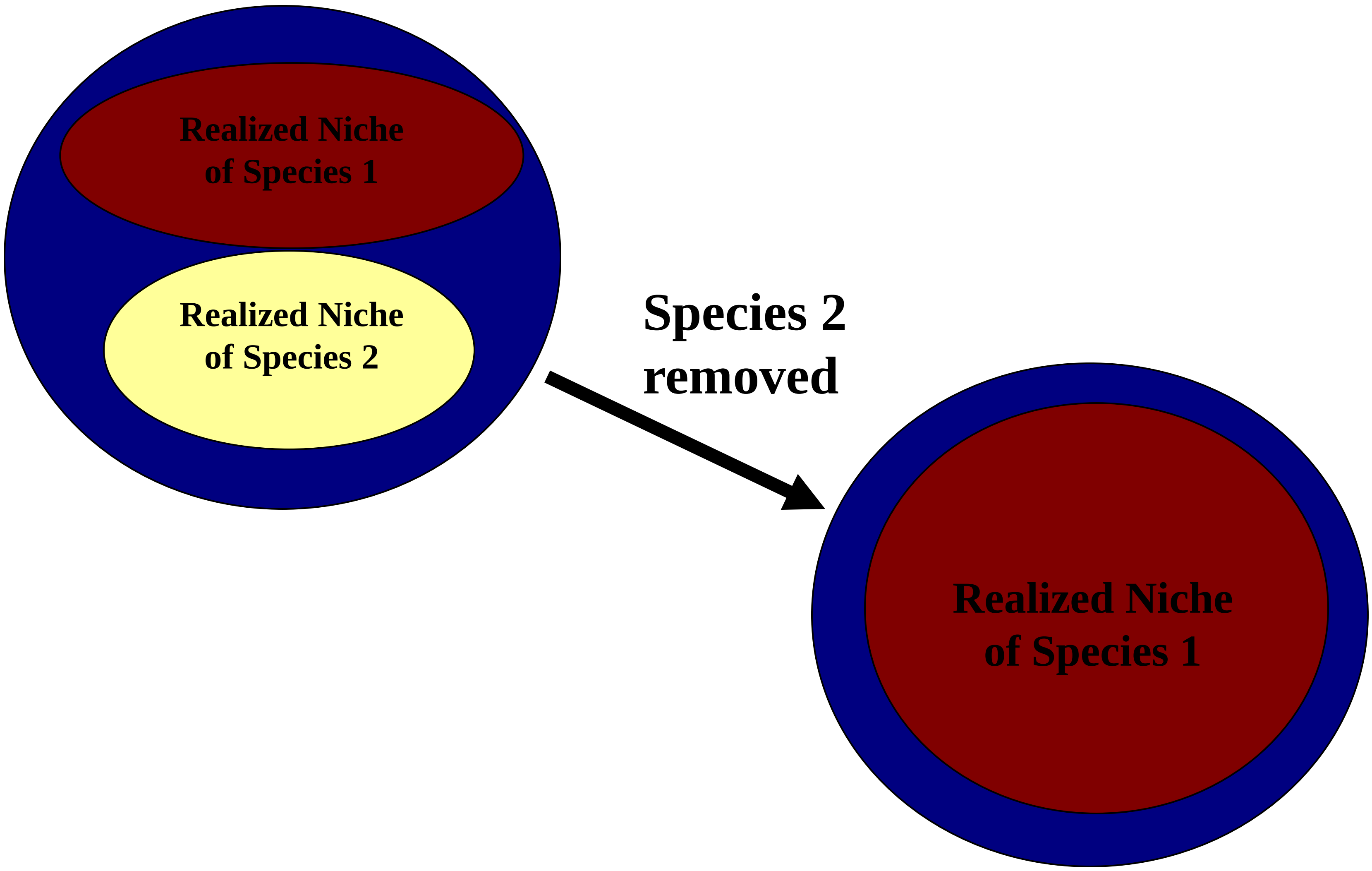
Character displacement in *Mimulus bicolor*





Suggests that competition for pollinators drives character displacement

Ecological release



Ecological release:
Interactions between wolves and coyotes

Canis lupus
≈ 95lbs

Canis latrins
≈ 35lbs

Journal of Animal Ecology 2007
76, 1075–1085

Does interference competition with wolves limit the distribution and abundance of coyotes?

KIM MURRAY BERGER and ERIC M. GESE

Ecological release:
Interactions between wolves and coyotes

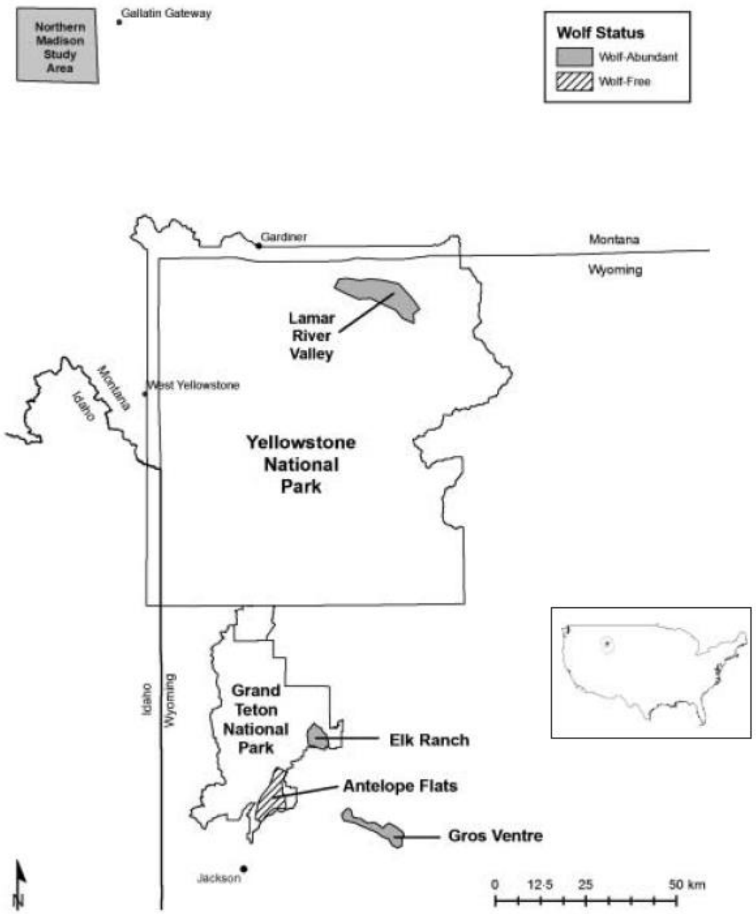


Fig. 1. Map showing the location of the Greater Yellowstone Ecosystem (GYE) in the western United States (inset), the locations of study areas, and place names referred to in the text. 'Wolf status' refers to the distribution of wolves within the GYE during the 1997–2005 period.

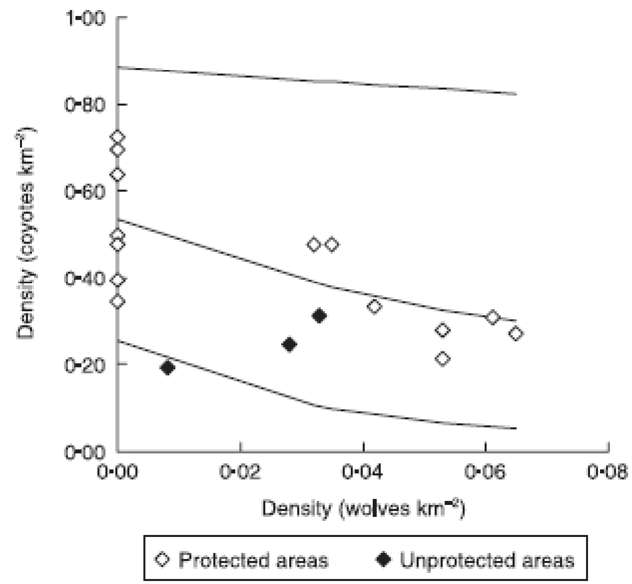


Fig. 4. Negative exponential model of the relationship between coyote and wolf densities within protected areas for three study areas (GTNP, LRV and NMSA) in the Greater Yellowstone Ecosystem 1991–2005. For reference, actual coyote and wolf densities in both protected (◇) and unprotected (◆) areas are shown.

- **Suggests wolves competitively exclude coyotes**
- **Absence of wolves results in ecological release**

Practice problem

Site	Wolves Present	Coyotes/km^2
Lamar River	0	0.499
Lamar River	0	0.636
Lamar River	0	0.694
Lamar River	0	0.726
Antelope Flats	0	0.345
Antelope Flats	0	0.479
Antelope Flats	0	0.394
Lamar River	1	0.477
Lamar River	1	0.332
Lamar River	1	0.477
Lamar River	1	0.270
Elk Ranch	1	0.279
Elk Ranch	1	0.308
Elk Ranch	1	0.215
Gros Ventre	1	0.312
Gros Ventre	1	0.247
Northern Madison	1	0.194

Does this data support the hypothesis of ecological release in Coyotes?

Interspecific competition: summary

- **Interspecific competition occurs when multiple species overlap in resource use**

- **The ecological outcome of competition can be stable coexistence or competitive exclusion**

- **Competitive exclusion becomes increasingly likely as niche overlap increases**

- **The evolutionary outcome of competition is often ecological character displacement**

Exam 2 Results