Interspecific Competition

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Interspecific Competition

- Lotka-Volterra Model of Competition
- Competition exclusion principle
- Spatial variations
- Temporal variations
- Multiple resources
- Realized Niche and Competitive release
- Coexistence and niche differentiation

Six types of interactions possible

- Six types of interactions are sufficient to account for most instances of interspecific competition:
  - (1) consumption
  - (2) preemption
  - (3) overgrowth
  - (4) chemical interaction
  - (5) territorial
  - (6) encounter

Environment limit Population Growth

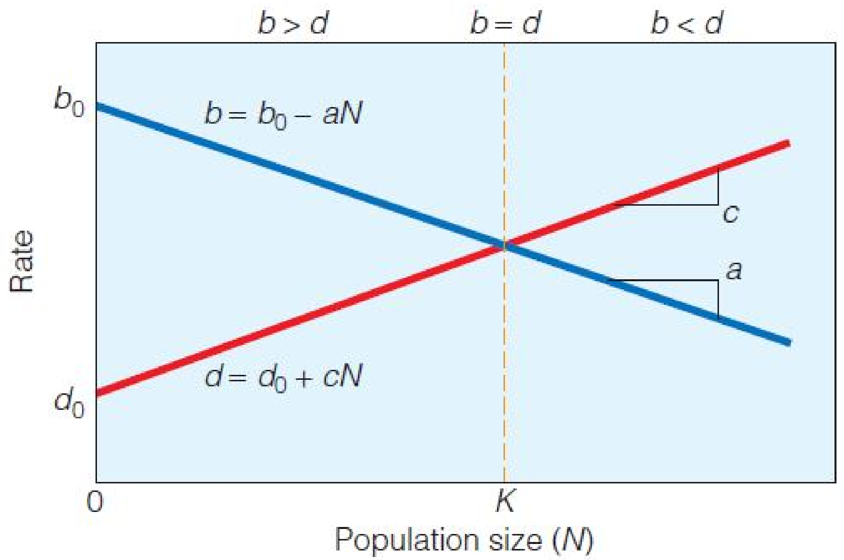


Figure 11.1 Rates of birth (b) and death (d), represented as a linear function of population size N. The values b_0 and d_0 represent the ideal birth and death rates (respectively) under conditions where the population size is near zero and resources are not limiting. The values a and c represent the slopes of the lines describing changes in birth and death rates as a function of N (respectively). The population density where $b = d$ and population growth is zero is defined as K, the carrying capacity. For values of N above K, b is less than d and the population growth rate is negative. For values of N below K, b is greater than d, and the population growth rate is positive.

- Exponential model
  - Unlimited resources
  - Constant environment

$$\frac{dN}{dt} = (b - d)N$$

- Logistic model: **No population continues to grow indefinitely**

$$K = \frac{(b_0 - d_0)}{(a + c)}$$

The constant K is the carrying capacity—the maximum sustainable population size for the prevailing environment (see

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

This is the equation for the logistic model of population growth.

Environment limit Population Growth

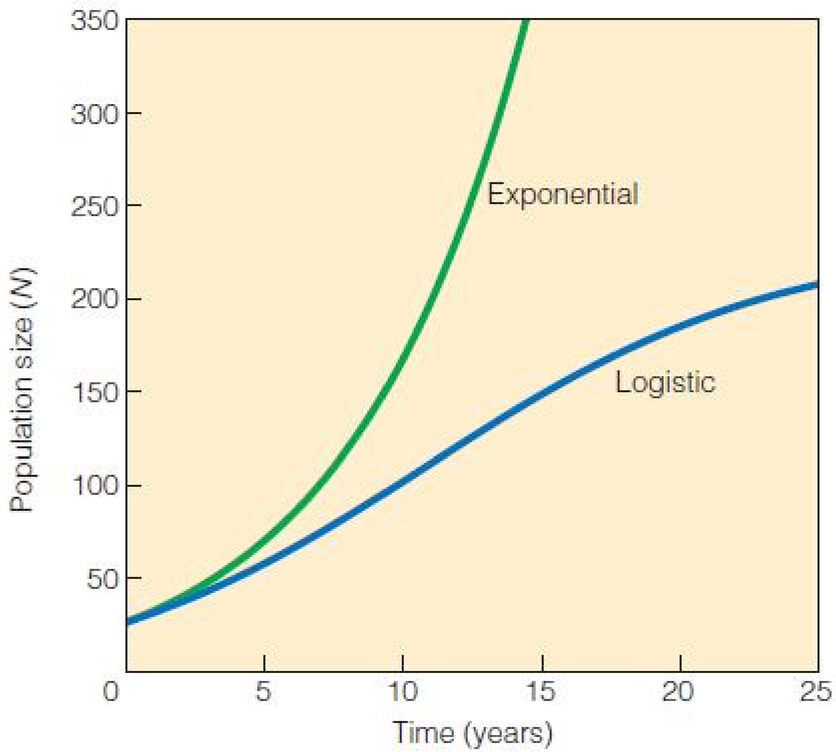


Figure 11.3 Predictions of the exponential and logistic population growth models for the gray squirrel population from Tables 9.1 and 9.6; $r = 0.18$, $K = 200$, and $N(0) = 30$.

Four Possible Outcomes of Interspecific Competition

$$\frac{\mathrm{d}N}{\mathrm{d}t} = rN\frac{(K - N)}{K}$$

$$\text{Species 1: } \frac{\mathrm{d}N_1}{\mathrm{d}t} = r_1N_1\left(\frac{K_1 - N_1 - \alpha N_2}{K_1}\right) \qquad (1)$$

$$\text{Species 2: } \frac{\mathrm{d}N_2}{\mathrm{d}t} = r_2N_2\left(\frac{K_2 - N_2 - \beta N_1}{K_2}\right) \qquad (2)$$

α is the competition coefficient that quantifies the per capita effect of species 2 on species 1

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

Measures interspecific competition *relative to* intraspecific competition (i.e. how many individuals of species 2 are equivalent to one individual of species 1 in terms of their **use of the resource**)

For example, in terms of common resource use:

- one chipmunk is the equivalent of 1/4 of a squirrel
- use the coefficient α = 0.25
- multiply that by the number of chipmunks to get the *overall chipmunk effect* (squirrel equivalents) on the squirrels

Species 1

$dN_1/dt = r_1N_1 \dfrac{(K_1 - N_1 - \alpha N_2)}{K_1}$

α represent the effect species 2 on 1

Species 2

$dN_2/dt = r_2N_2 \dfrac{(K_2 - N_2 - \beta N_1)}{K_2}$

β represent the effect species 1 on 2

Suppose

2*Species 2 = Species 1

$\alpha = 1/2 = 0.5$

Suppose

Species 2 = 2*Species 1

$\alpha = 2$

Species 1:

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

i.e. Population 1 size not changing

$$K_1 - N_1 - \alpha N_2 = 0$$

$$N_1 = K_1 - \alpha N_2$$

Isocline of zero population growth for Species 1

Species 2:

$$0 = r_2 N_2 \left(\frac{\boxed{K_2 - N_2 - \beta N_1}}{K_2} \right)$$

$$K_2 - N_2 - \beta N_1 = 0$$

$$N_2 = K_2 - \beta N_1$$

Isocline of zero population growth for Species 2

Zero growth isoclines:

$$N_1 = K_1 - \alpha N_2$$

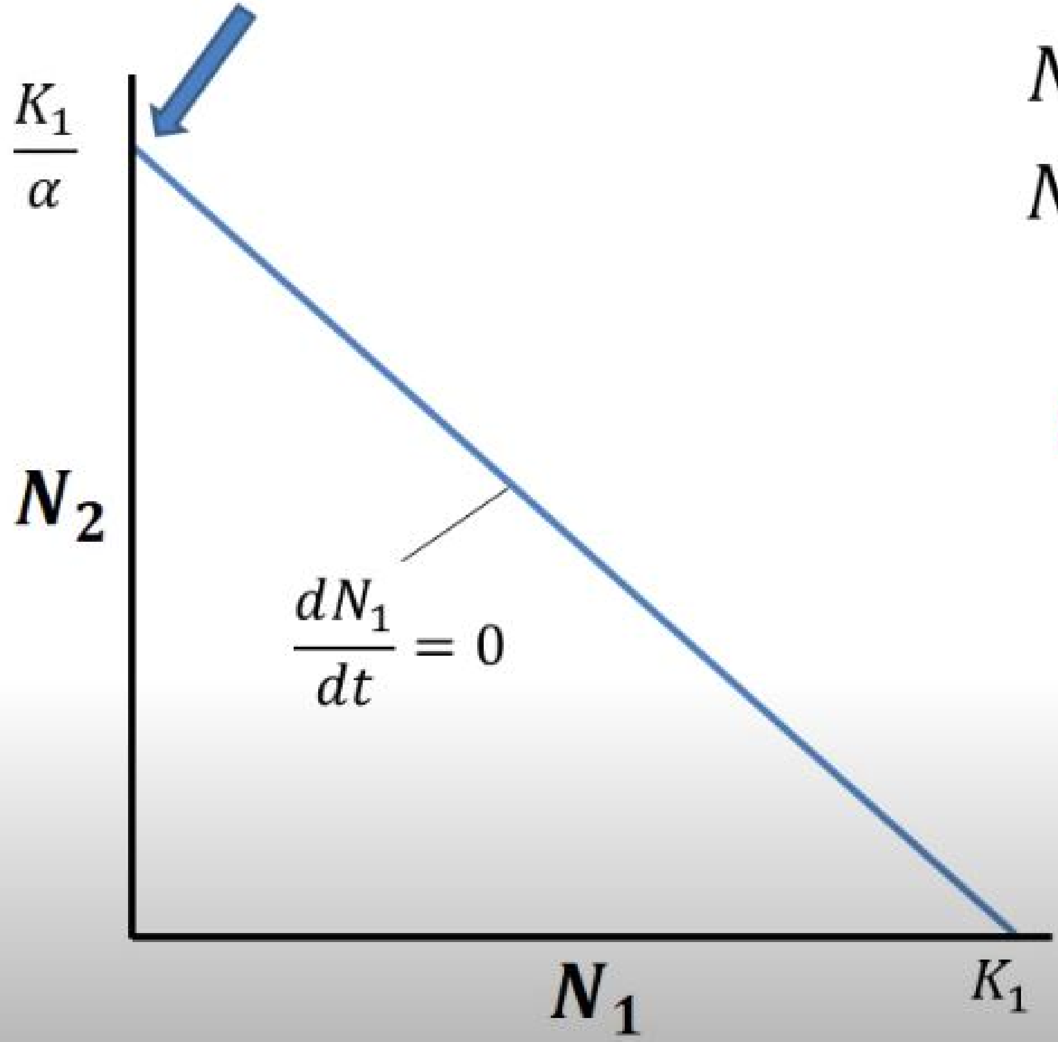
$$N_2 = K_2 - \beta N_1$$

Remember: Under the logistic growth model alone, the population would be stable if:

$$N_1 = K_1$$

Or

$$N_2 = K_2$$



$$N_1 = K_1 - \alpha N_2$$

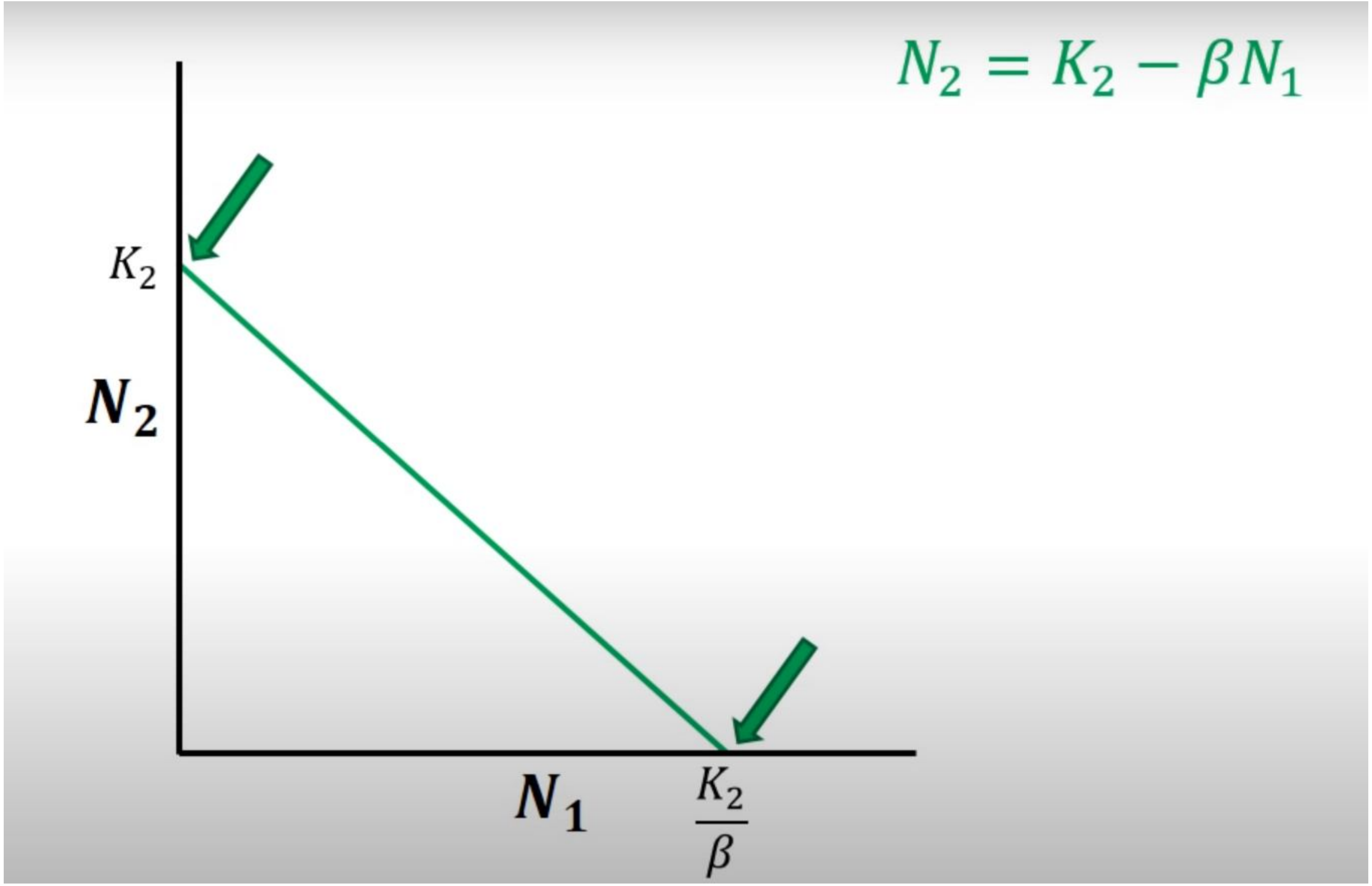
$$N_1 = K_1 - \alpha(0)$$

$$N_1 = K_1$$

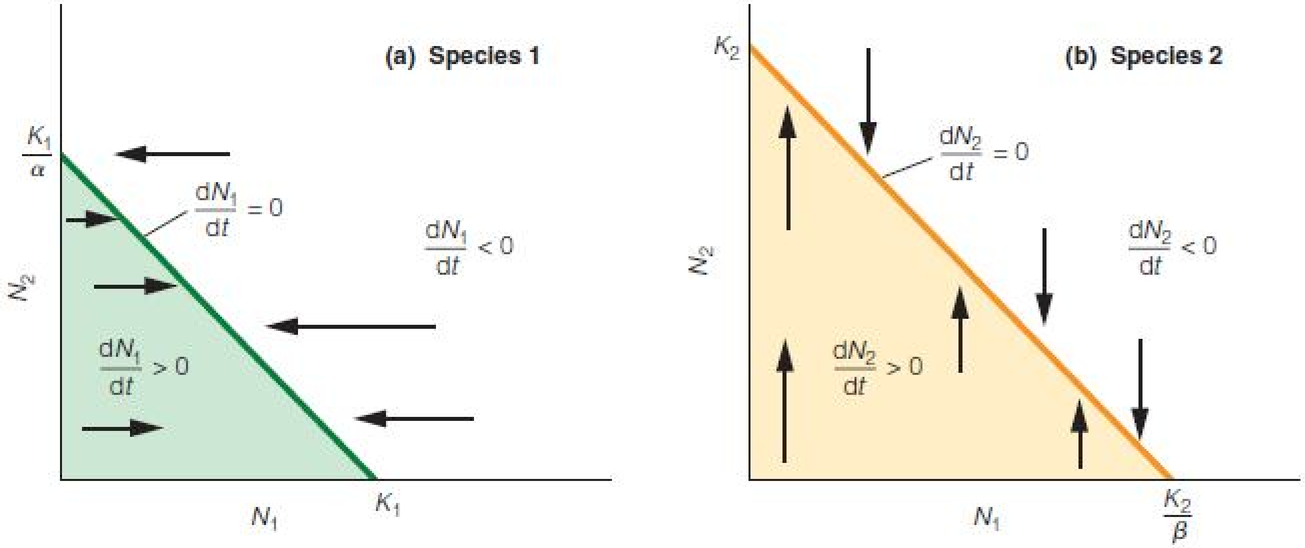
$$0 = K_1 - \alpha N_2$$

$$\alpha N_2 = K_1$$

$$N_2 = \frac{K_1}{\alpha}$$


$N_2 = K_2 - \beta N_1$
K_2
N_2
N_1
$\frac{K_2}{\beta}$

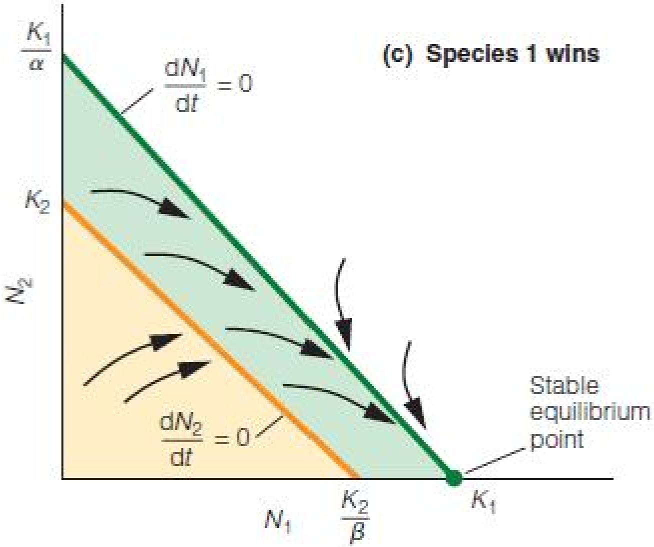
Lotka-Volterra Model of Competition

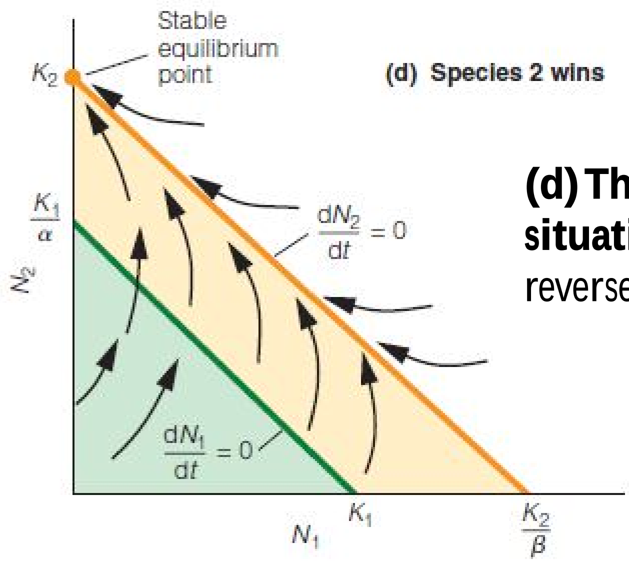


The Lotka–Volterra model of competition between two species. **(a, b) The zero** isocline for each species is defi ned as the combinations of (N_1 , N_2) *for which* dN/dt *0 (zero* population growth). In the shaded area (combined values of (N_1 , N_2)) *below the line, population* growth is positive and the population increases (as indicated by the arrows); for combined values of (N_1 , N_2) *above the line, the population decreases.*

Four Possible outcomes

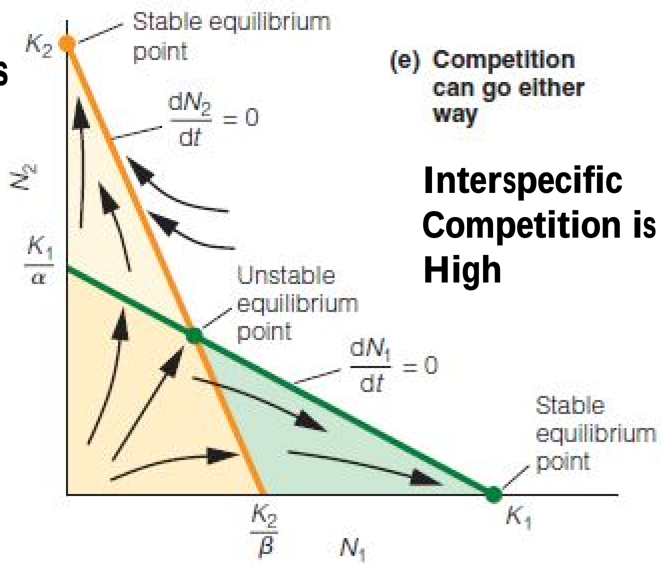
(c) The isocline of species 1 falls outside the isocline of species 2. Species 1 always wins, leading to the extinction of species 2.



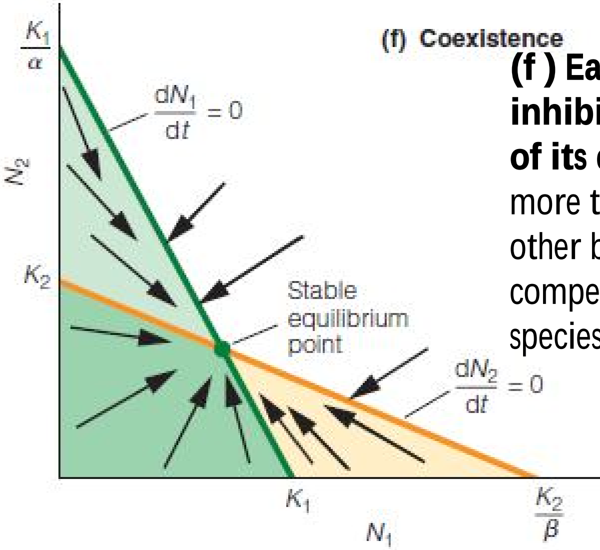


(d) The situation is the reverse of (c)

(e) The isoclines cross. Each species inhibits the growth of the other more than its own growth. The more abundant species often wins



Interspecific Competition is High



(f) Each species inhibits the growth of its own population more than that of the other by intraspecifi c competition. The species coexist

Intraspecific Competition is High

The Lotka–Volterra equations describe four possible outcomes of interspecific competition.

- Species 1 may succeed over species 2;
- species 2 may succeed over species 1.

(Both of these outcomes represent competitive exclusion.)

(The other two outcomes involve coexistence.)

- One is unstable equilibrium, in which the species that was most abundant at the outset usually succeeds.
- A final possible outcome is stable equilibrium, in which two species coexist but at a lower population level than if each existed without the other.

Laboratory Experiments Support the Lotka–Volterra Equations

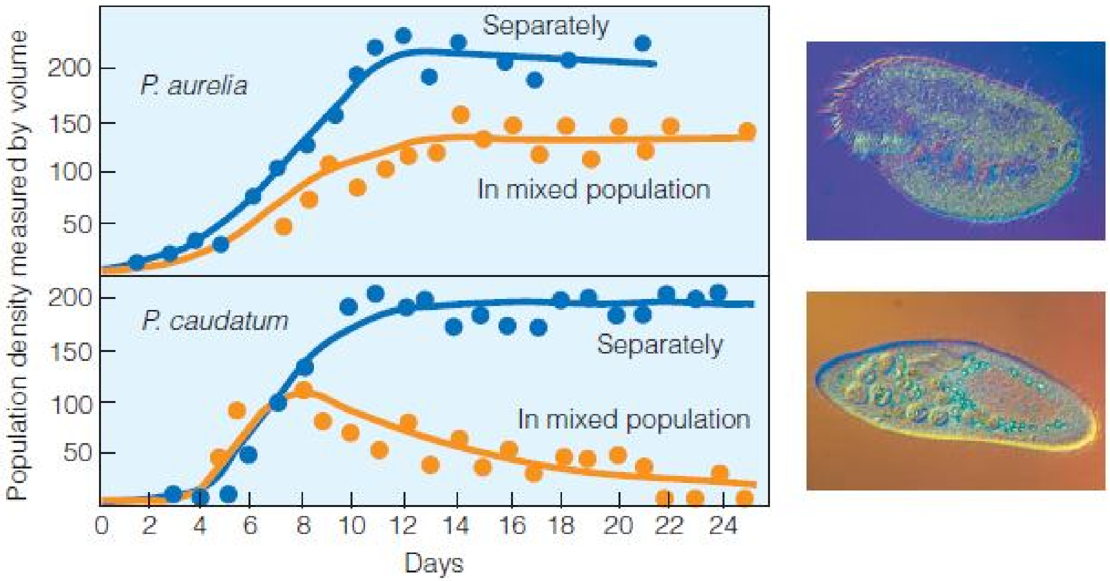


Figure 14.2 Competition experiments with two ciliated protozoans, *Paramecium aurelia* and *P. caudatum,* grown separately and in a mixed culture. In a mixed culture, *P. aurelia* outcompetes *P. caudatum,* and the result is competitive exclusion.
(Adapted from Gause 1934.)

Competitive Exclusion Principle

- "Complete competitors" cannot coexist
- Assumptions
  - First, this principle assumes that the competitors have **exactly the same resource** requirements.
  - Second, it assumes that environmental conditions remain **constant**

Spatial Variations

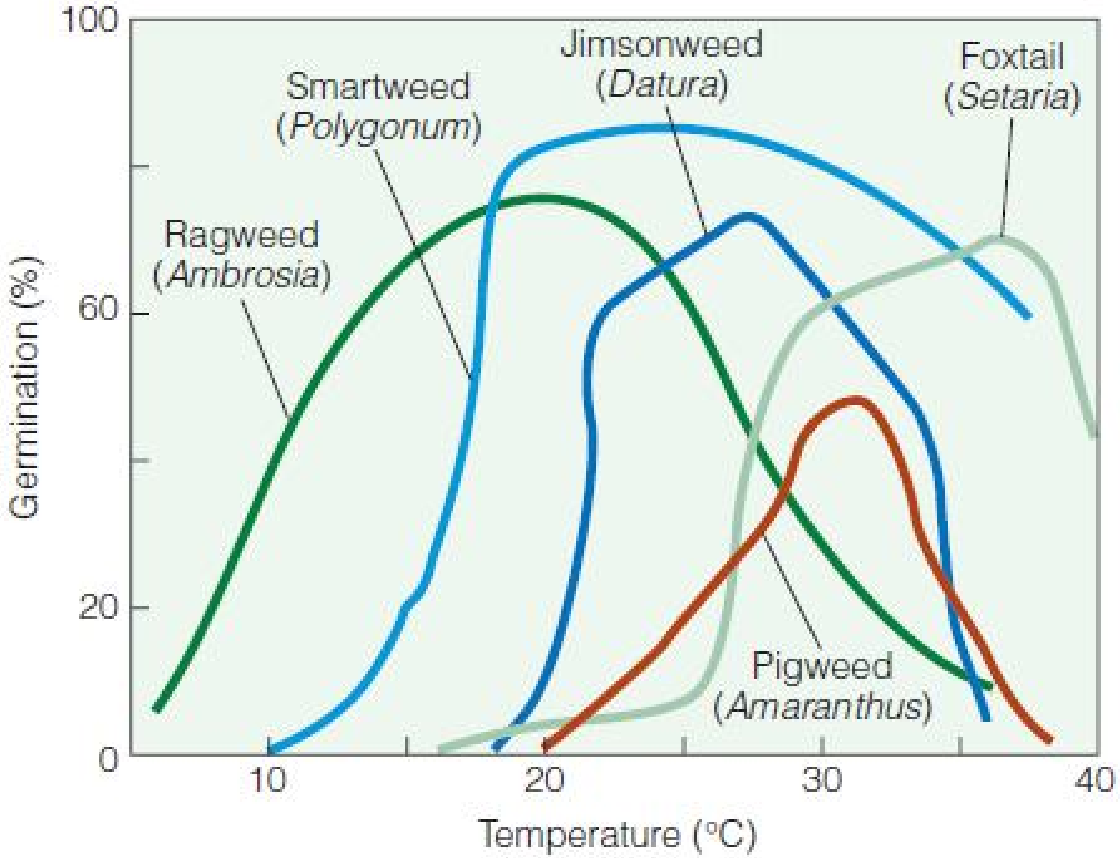
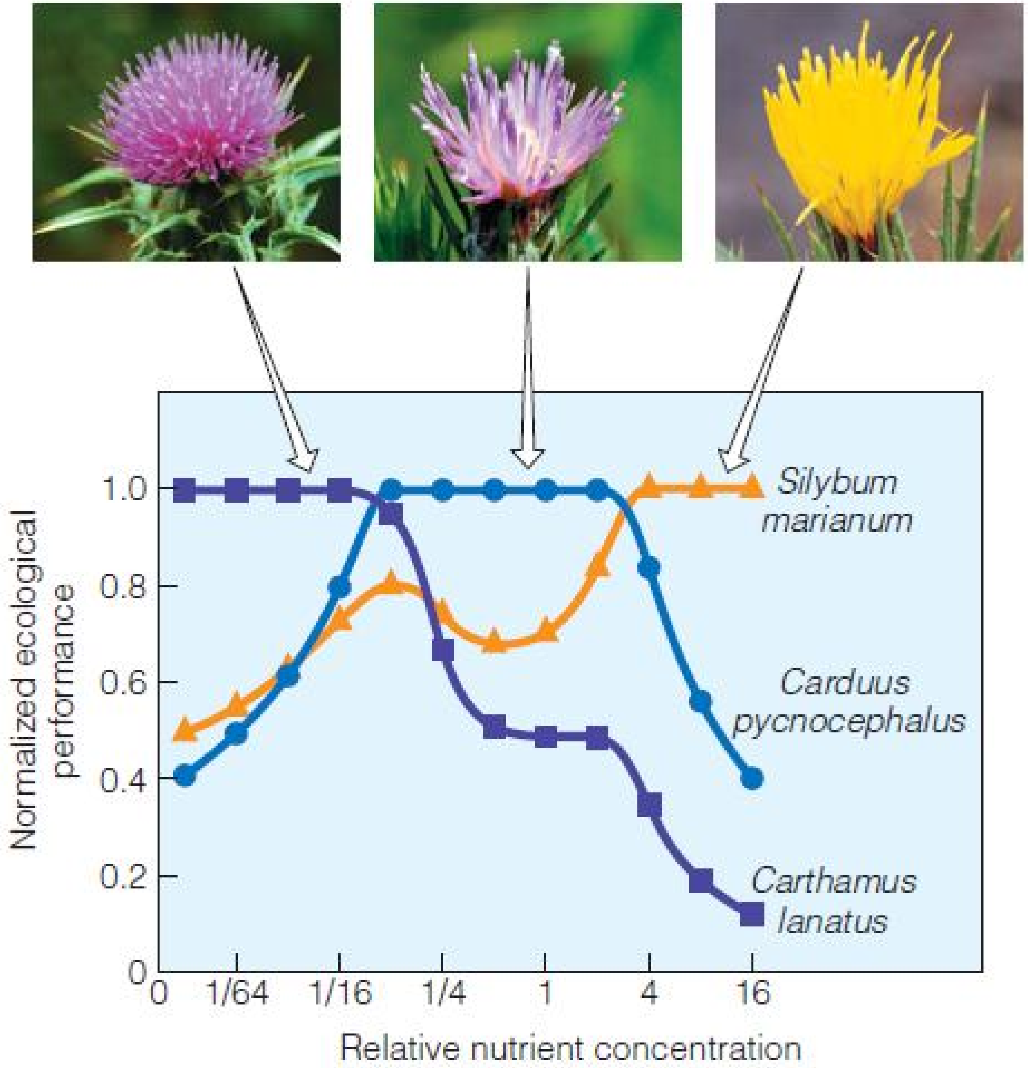


Figure 14.4 Patterns of seed germination of five annual plant species along a gradient of temperature. These species dominate the early stages of secondary succession in field communities of the midwestern United States.

(Adapted from Bazzaz 1996.)

Competitive abilities changes along environmental gradient



When grown in **mixture**, the response of each species along the resource gradient differed from the pattern observed when grown in **isolation.** The relative **competitive abilities** of the species changed along the nutrient **gradient**

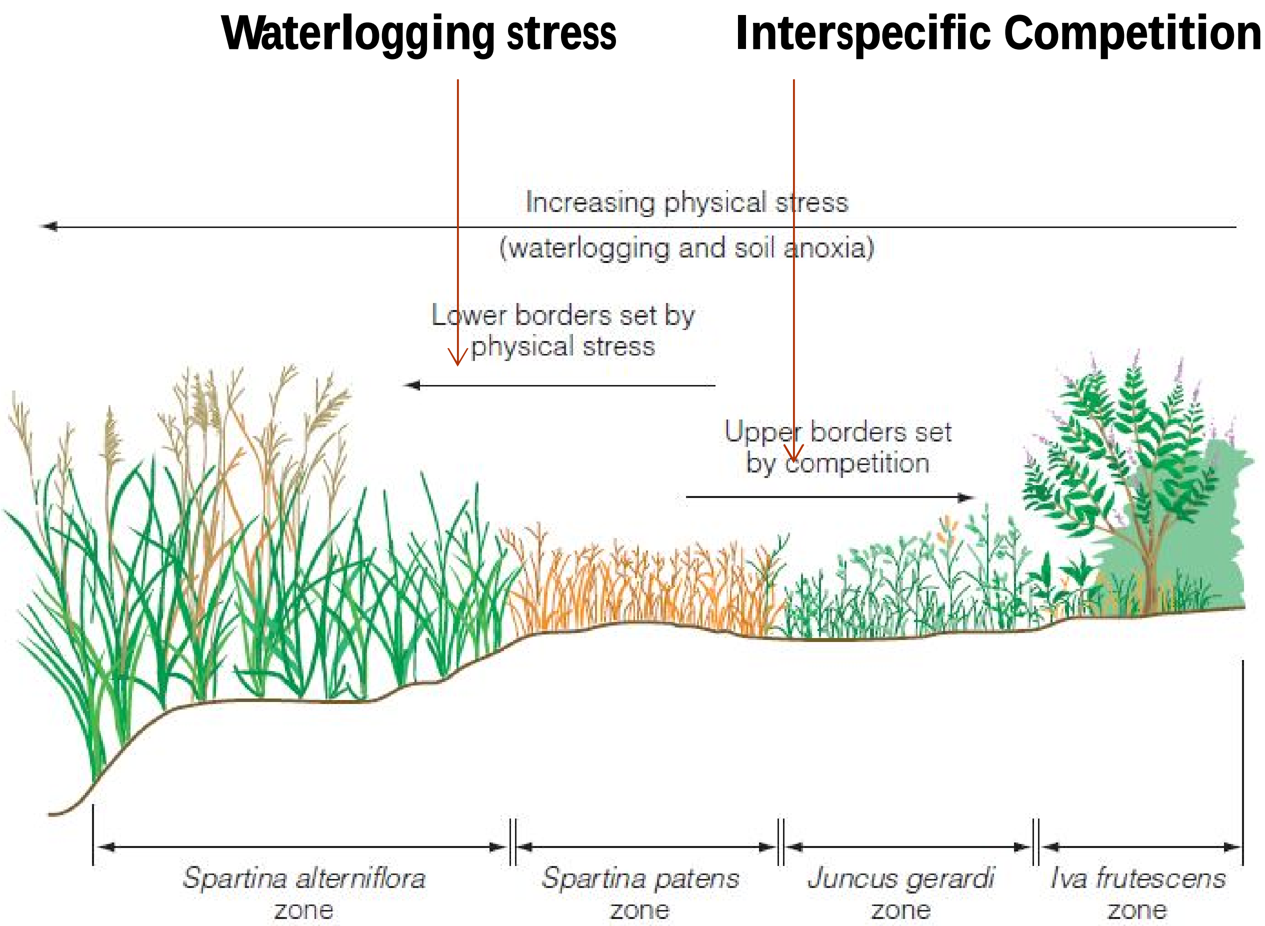


Figure 14.10 Zonation of the dominant perennial plant species in a New England salt-marsh community. Upper borders of species distribution are a function of competition, whereas lower borders are a function of the species' ability to tolerate the physical stress associated with salinity, waterlogging, and low oxygen concentrations in the sediments.

(Adapted from Emery et al. 2001.)

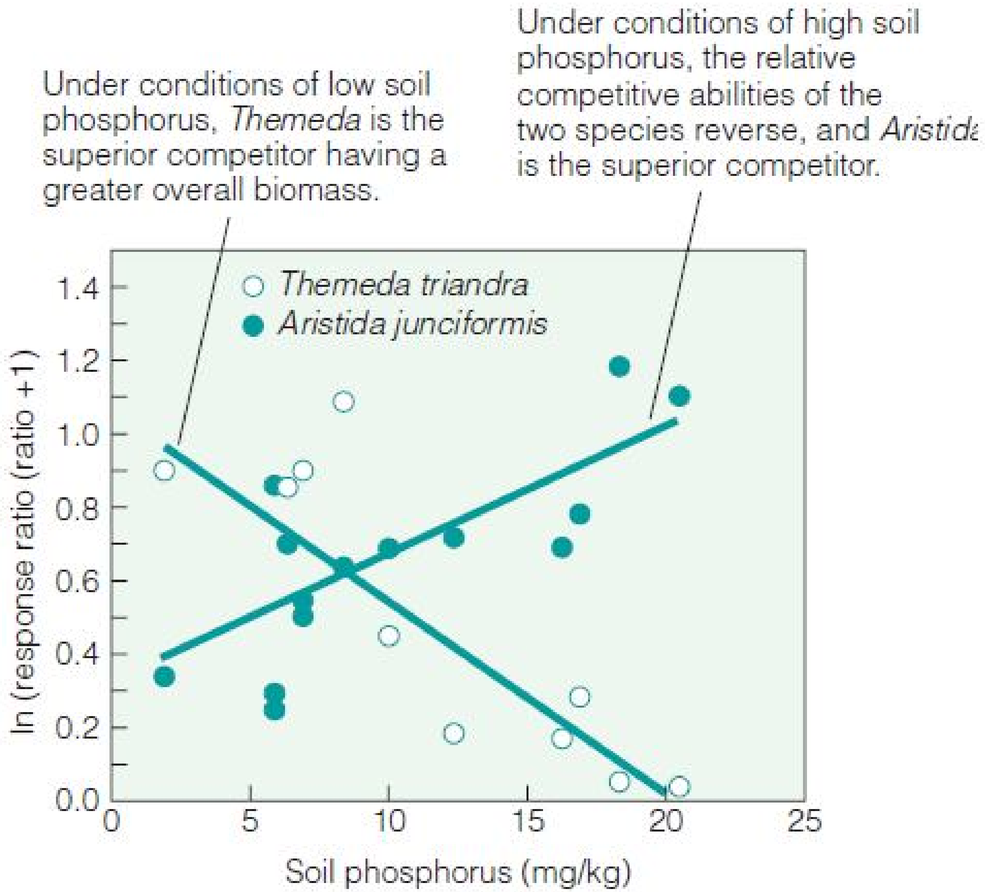


Figure 14.9 Patterns of response ratio (mixture biomass/monoculture biomass) for two grass species (*Themeda triandra* and *Aristida junciformis*) grown along a gradient of soil phosphorus. Plants were grown both in monoculture and mixtures (both species present) along the gradient, and the response ratio reflects the relative competitive abilities of the two species at the varying levels of soil phosphorus.
(Fynn et al. 2005).

Temporal Variation: Rainfall variation influence Competitive interactions

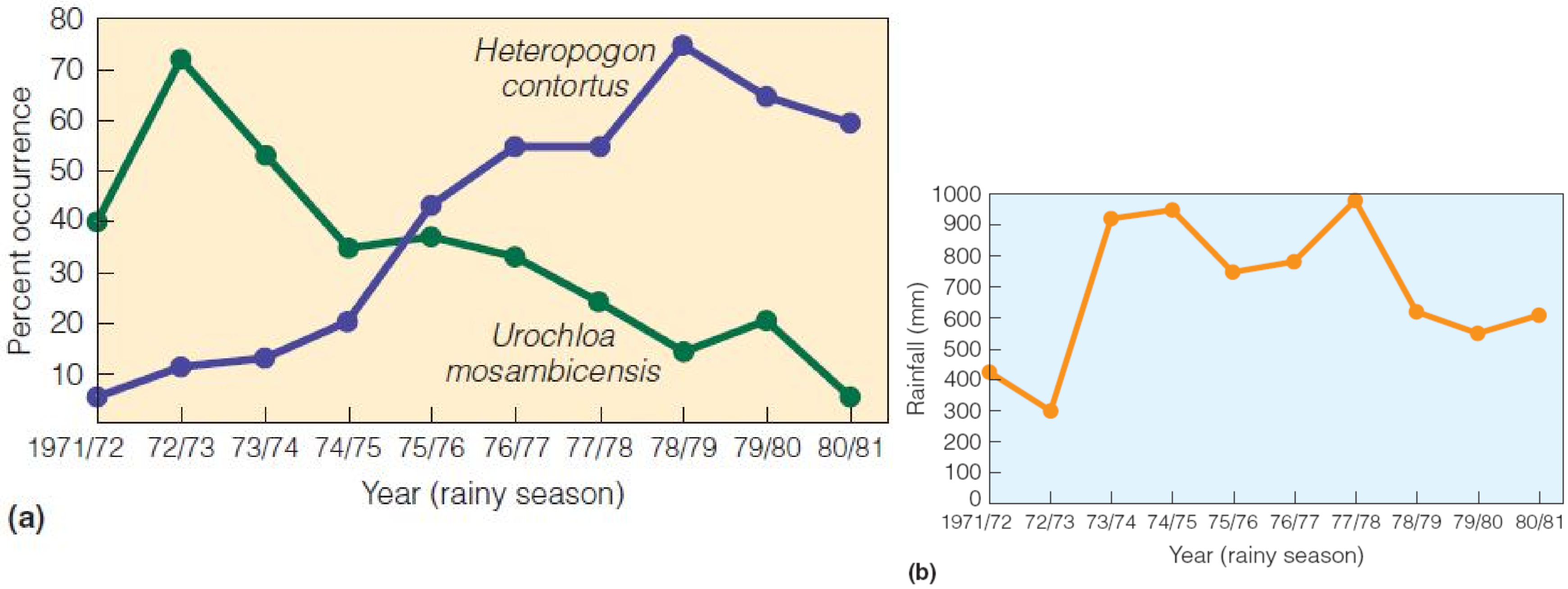
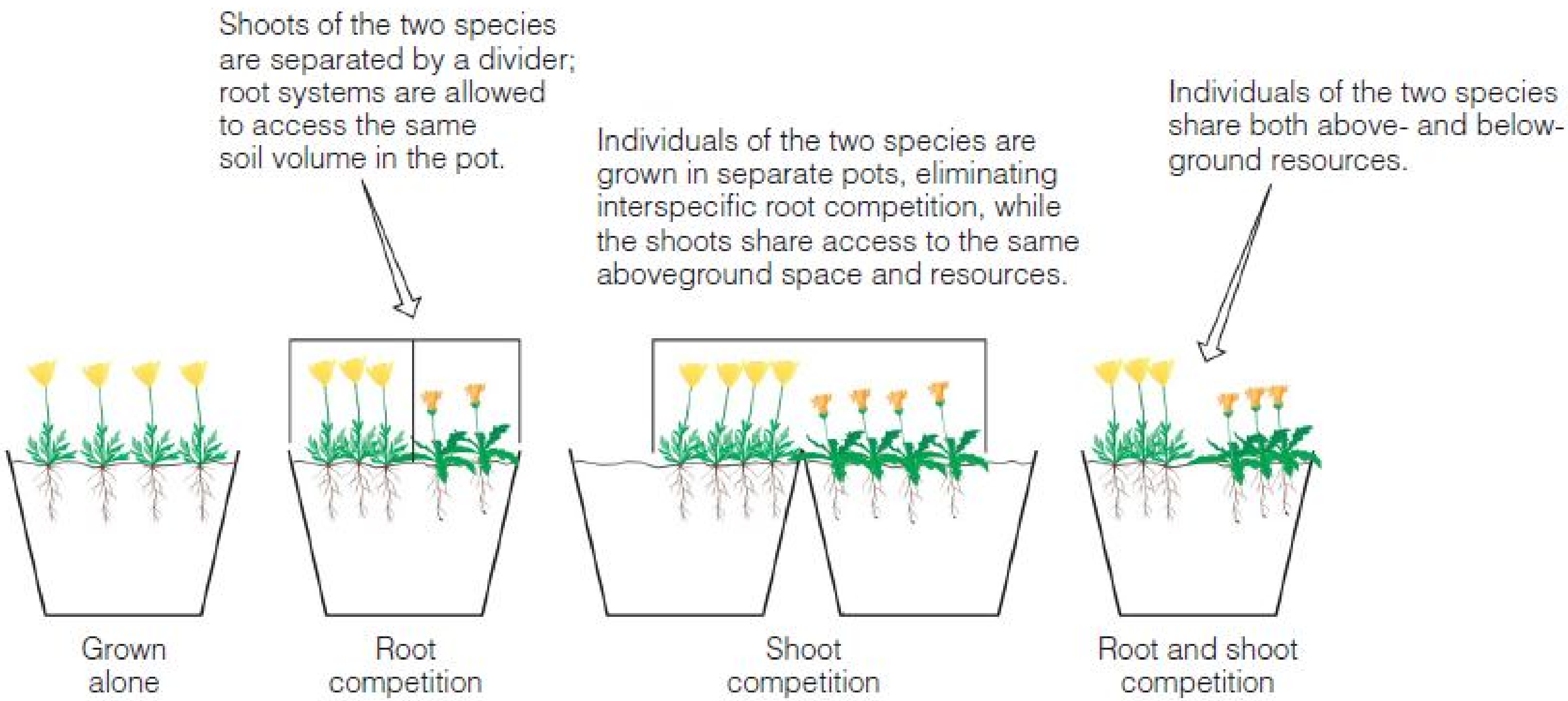


Figure 14.5 (a) Shift in the dominant grass species in a savanna community in southwest Zimbabwe during the period 1971–81. The shift is in response to changing patterns of precipitation during the same period (**b**). *Urochloa mosambicensis* was able to compete successfully under the drier conditions during the 1971–72 and 1972–73 rainy seasons. With the increase in rainfall beginning in the 1973–74 season, *Heteropogon contortus* came to dominate the site.

(Adapted from Dye and Spear 1982.)

Competition Occurs for Multiple Resources



35%

53%

69% reduction
in Skeleton weed

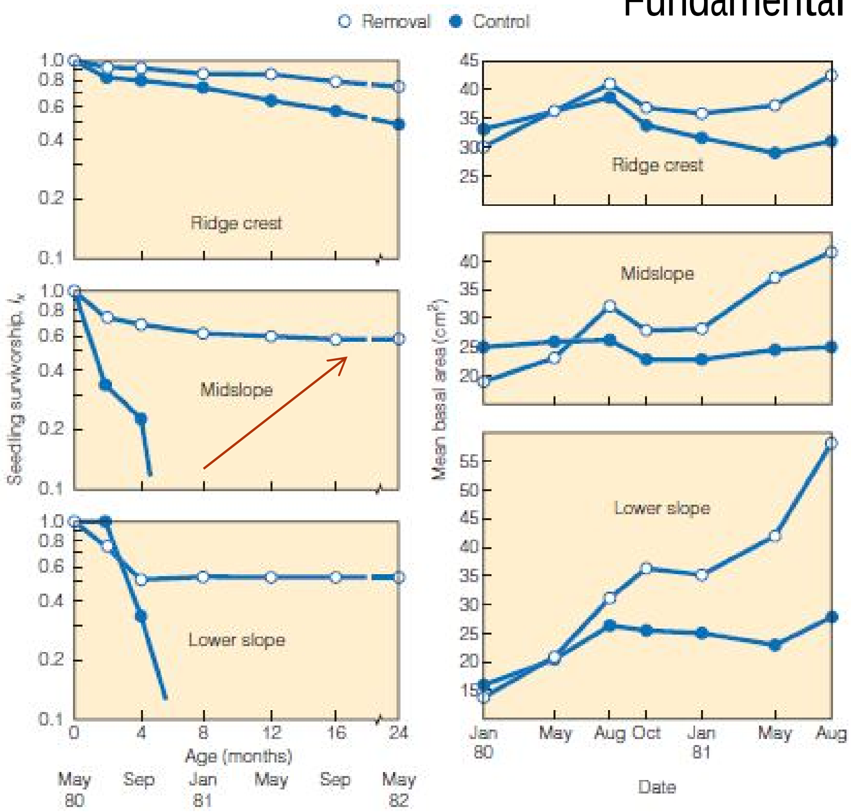
Figure 14.6 Experimental design used to examine aboveground and belowground competition between subterranean clover and skeleton weed.
(Adapted from Groves and Williams 1975.)

Competition influence Niche of a species

Interspecific Competition

Fundamental Niche → Realized Niche

Competitive Release (red arrow)



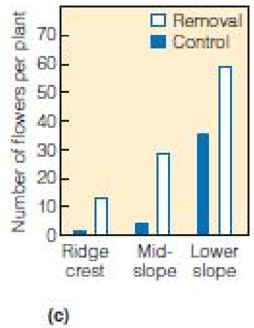


Figure 14.12 Response of *Stipa neomexicana* plants in three different habitats (ridge crest, midslope, and lower slope). Results of both treatment (neighboring plants removed) and control (neighbors *not* removed) plants are shown for (**a**) seedling survival, (**b**) mean growth rate, and (**c**) flowers produced per plant. Under natural conditions, distribution of *Stipa* is restricted to the ridge-crest habitats due to competition from other grass species.

(Adapted from Gurevitch 1986.)

Niche differentiation for co-existence

Spatial Niche

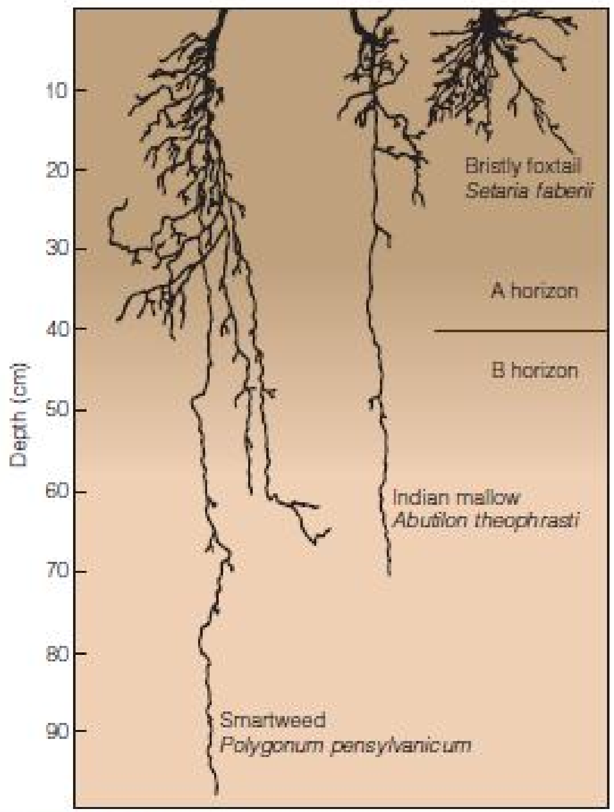


Figure 14.14 Vertical partitioning of the prairie soil resource at different levels by three species of annual plants, one year after disturbance.

Tropic Niche

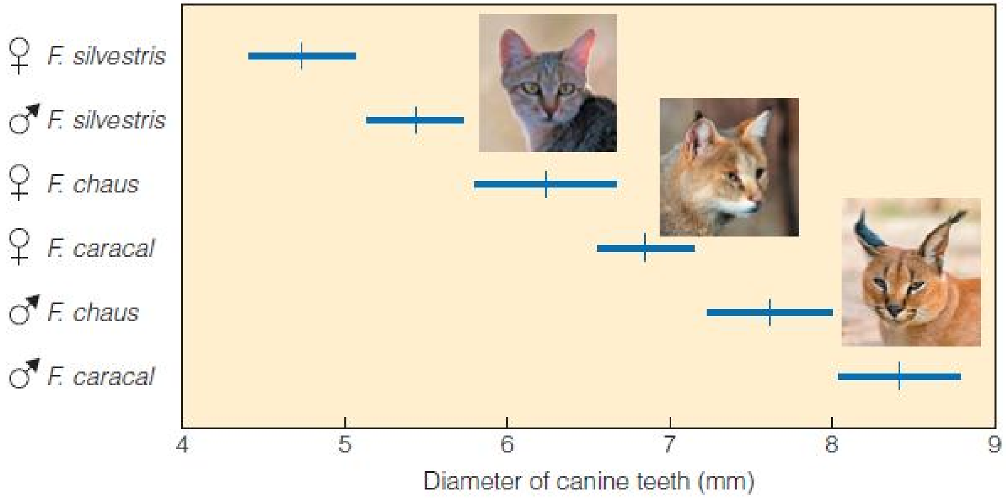


Figure 14.15 Size (diameter) of canine teeth for small cat species that co-occur in Israel. Note the regular pattern of differences in size between species. Size is correlated with the size of prey selected by the different species.

(Adapted from Dayan et al. 1990.)

- Competition is a complex interaction that seldom involves the interaction between two species for a single limiting resource. Competition involves a variety of environmental factors that directly influence survival, growth, and reproduction—factors that vary in both time and space

- Competition is only one of many interactions occurring between species—interactions that ultimately influence population dynamics and community structure

Thank you