Competition

• Terminology

  – Interference Competition – direct aggression between individuals
  – Resource Limitation – when there is limited supply of resources
  – Intraspecific Competition – between individuals of the same species
  – Interspecific Competition – between individuals of different species
Intraspecific Competition Among Herbaceous Plants – Tilman and Cowan grew *Sorghastrum* at low and high densities – found that at low densities plant size and growth rate varied directly.

**Population density, soil nitrogen, and the size attained by the grass *Sorghastrum nutans***.

- *S. natans* was grown at high and low densities on a gradient of nitrogen availability.
- At low densities *S. natans* grew to a large size.
- *S. natans* remained small at high densities.
Competition

- Self Thinning in Plant Populations – as a stand of trees goes from seedlings to saplings to trees the number gradually decreases – usually the consequence of intraspecific competition for limited resources.

**Self-thinning in plant populations.**

The self-thinning rule predicts that plants will decrease in population density (self-thin) as the total biomass of the population increases.

Typically the slope of this line is $-1/2$.

*M. sativa* population at end of the experiment consisted of larger plants growing at lower density.

Here dry weight is compared to density and demonstrates a $-3/2$ slope.
Competition

- Intraspecific Competition Among Planthoppers

**Population density and planthopper performance.**

As the population density of the planthopper *Prokelesea marginata* was increased, the following was observed:

- **Lower survivorship**
- **Increased developmental time**
- **Reduced body size**
Competition

- Interference Competition Among Terrestrial Isopods
  - Grosholz, studied an isopod that lives in areas where farming takes place – Densities of more than 2000 m$^2$ were observed – using flashing, plots were divided up and he controlled density and food supply, it was found that food had no effect, rather the decreases in density was the result of cannibalism.

![Graph showing population density and survival in populations of a terrestrial isopod, Porcellio scaber.](image)
Competition

- More Terminology

- Niche – all factors necessary for a species to exist, that is when, where, and how a species makes its living

- Competitive Exclusion Principle – developed by Gause (1934) – if two competing organisms try to occupy the same niche one will eventually “win” out

- Fundamental Niche – idea developed by Hutchinson (1957) – defined the physical conditions under which a species might live, in the absence of interactions with other species (in reality for any given niche we will not know all of the conditions)

- Realized Niche – the physical conditions under which a species lives when competition exists
Feeding Niches of Galapagos Finches – food is very important to Galapagos finches - Grant measured beak morphology to ascertain differences in diet.

Body size and seed size in Galápagos finch species.
Competition

Within the same species variation exists in beak depth, causing different foods within the species to be eaten.
Competition

This relates to the previously discussed affect of the drought of 1977 on the population of *G. fortis*

Seed depletion by the medium ground finch, *Geospiza fortis*, and average seed hardness.

As *G. fortis* depleted the seed supply, the average hardness of the remaining seeds increased. Then average seed hardness declined as new supplies were produced in 1978.

Selection for larger size among medium ground finches, *Geospiza fortis*, during a drought on the island of Daphne Major.

During the drought of 1977 larger birds capable of cracking hard seeds survived at a higher rate. Consequently the population was dominated by larger birds at the end of the drought.
Competition

- Habitat Niche of Salt Marsh Grass – it was discovered that a species of *Spartina* was produced via allopolyploidy (in some hybrids a doubling of chromosomes occurs which permits sexual reproduction) – frequently these allopolyploids demonstrate increased fitness (21 plants introduced into China in 1963 grew to cover 36,000 ha by 1980)

\[ S. \textit{anglica} = S. \textit{maritima} \times S. \textit{alterniflora} \]

This allopolyploid demonstrated increased tolerance to periodic inundation, which in turn is reflected in its distribution
Competition

- *S. anglica* is found in area of well defined environmental factors:
  - Grows mainly in the intertidal zone between levels of mean high tide and mean low tide

The niche of *Spartina anglica* is related to tidal fluctuations.
Competition

– Influenced by frequency of inundation by tides and waves

• In Britain occupies the intertidal between mean high-water spring tides and mean-high water neap tides

• Distribution also affected by *fetch* (the longest distance that wind can blow over water producing waves) - greater fetch produces larger waves, which moves the *S. anglica* higher up shore

• Latitude also plays a role – *S. anglica* is a C₄ plant – what affect could this possibly have on plants living at higher latitudes?

  – In northerly locations *S. anglica* is replaced by C₃ plants

• Could this be the result of competition? More later
Competition

- Modeling Interspecific Competition – Volterra (1926) and Lotka (1932)

\[
dN/dt = r_m \cdot N(K-N/K)
\]

If two competitors are introduced then:

\[
dN_1/dt = r_{m1}N_1(K_1-N_1/K_1)
\]

\[
dN_2/dt = r_{m2}N_2(K_2-N_2/K_2)
\]
Competition

When interspecific competition exists

\[ \frac{dN_1}{dt} = r_{m1}N_1(K_1 - N_1 - \alpha_{12}N_2/K_1) \]

\[ \frac{dN_2}{dt} = r_{m2}N_2(K_2 - N_2 - \alpha_{21}N_1/K_2) \]

Population growth for both species stops when

\[ N_1 = K_1 - \alpha_{12}N_2 \text{ or } N_2 = K_2 - \alpha_{21}N_2 \]

\[ \frac{dN_1}{dt} = 0 \text{ and } \frac{dN_2}{dt} = 0 \]
The orientation of isoclines for zero population growth and the outcome of competition according to the Lotka-Volterra competition model.

Arrows show trajectories of population change in population of species 1 and 2.

Species 1 wins; population size equals \( K_1 \).

Species 2 wins; population size equals \( K_2 \).

Eventually species 1 or 2 wins.

Species 1 and 2 coexist at the crossover point of the isoclines.
Population growth and population sizes attained by *Paramecium aurelia* and *P. caudatum* grown separately.

*P. aurelia* attained greater population size than *P. caudatum* both...  

...when grown in half-strength growth medium...  

Half-strength growth medium  

K=105  

K=54  

...and when grown in full-strength growth medium.

Full-strength growth medium  

K=195  

K=137  

When grown together *P. aurelia* replaced *P. caudatum*
Competition

Populations of *Tribolium confusum* and *T. castaneum* grown separately (a) and together (b) at 34°C and 70% relative humidity.

Populations of *Tribolium confusum* and *T. castaneum* grown separately (a) and together (b) at 24°C and 30% relative humidity.
Niches and Competition Among Plants – Tansley (1917)

When grown together *G. sylvestre* excluded *G. saxatile* on basic soils; on acid soils *G. saxatile* out competed *G. sylvestre* but did not exclude it through the course of the experiment.
Niche Overlap and Competition Between Barnacles

A competition experiment with barnacles: removal of *Balanus* and survival by *Chthamalus* in the upper and middle intertidal zones.

Environmental factors restricting the distribution of *Chthamalus* to the upper intertidal zone.
Competition

• Competition and the Niches of Small Rodents – Munger and Brown (1981)
  – Set up plots in Chihuahuan Desert
  – Large scale
    • 20 ha
    • 24 plots, 50m x 50m
  – Experiment has been well replicated
  – Long term – 1977 to present
Competition

- Rodents can be separated into groups based upon size and feeding habits
  
  • Most are grainivores – seeds
  
  • Large grainivores three species of kangaroo rats
  
  • Small grainivores – four species pocket mouse
  
  • Small insectivores – two species
Competition

- Looked at

  - Whether large rodents limit small rodents

  - See if there was competition for food

  - Plots were created using fencing with opening too small to let rodents through

  - Cut holes of varying sizes to either permit or limit rodents moving between plots
Competition

- Responses of small grainivores and insectivores upon removal of large grainivores (1st three years)

![Graph showing population trends of Dipodomys spp., Small granivores, and Onychomys spp. over the years 1978 to 1990.](image)

- Dipodomys numbers remained high on control plots throughout the study.

- Removal kept Dipodomys numbers at or near zero on the Dipodomys removal plots.

- In response, numbers of small granivorous rodents increased on the removal plots relative to the control plots.

- Meanwhile, numbers of insectivorous rodents did not differ on control and removal plots.
Competition

- Replication experiment

- Dipodomys numbers were immediately reduced by the removal procedures on the removal plots.

- Small granivore numbers increased very quickly on the Dipodomys removal plots.

- Meanwhile, numbers of insectivorous rodents again did not change in response to Dipodomys removal.
Competition

- Character Displacement – the process of evolution in the face of competition

![Map of Galapagos Islands with beak depth distributions](image)

- Beak size distributions for *G. fortis* on Daphne Major:
  - Compared to the population on Daphne Major, the beaks of *G. fortis* are significantly larger on the island of Santa Cruz, where it is sympatric with *G. fuliginosa*.

- Beak size distributions for sympatric populations of *G. fortis* and *G. fuliginosa* on Santa Cruz Island:

- Similarly, compared to the population on Los Hermanos, the beaks of *G. fuliginosa* are significantly smaller on Santa Cruz, where it is sympatric with *G. fortis*.

- Beak size distribution for *G. fuliginosa* on Los Hermanos:
Competition

- Six criteria necessary to support observations being the result of character displacement
  - Morphological differences between a pair of sympatric species are statistically greater than the differences between allopatric populations of the same species
  - The observed differences between sympatric and allopatric populations are genetically based
  - Differences between sympatric and allopatric populations must have evolved in place and they must not be due to the sympatric and allopatric populations having been derived from different founder populations already differing in the character under study
Competition

- Variation in the character must have a know effect on the use of resources

- There must be demonstrated competition for the resource under question and competition must be directly correlated with the similarity in the character

- Differences in the character cannot be explained by differences in the resources available to sympatric and allopatric populations