History and meaning of the word "Ecology"

A. Definition

1. Oikos, ology - the study of the house - the place we live

B. Etymology - origin and development of the the word

1. Earliest - Haeckel (1869) - comprehensive science of relationship of organism and environment
2. Elton (1927) - scientific natural history
3. Andrewartha (1961) - Scientific study of the distribution and abundance of organisms
4. Krebs (1985) - scientific study of the interactions that determine the distribution and abundance of organisms

C. Note that all talk about "scientific"

Why???

Separation of induction (natural history) and deduction (scientific method)

Definitions

(levels of ecological organization)

A. Individual (can be difficult to define! Generally, a biological organism that…)

1. Lives, reproduces, dies
2. Has a unique genotype
3. Is the unit of selection
4. Is autonomous of other organisms

B. Population (a collection of individuals in an area, of the same species, that…)

1. Interact with one another
2. Interbreed

C. Species (characterized by…)

1. Individuals, naturally capable of interbreeding and producing fertile offspring

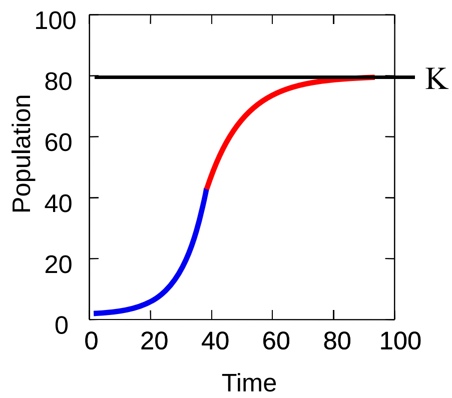
D. Community

1. A group of populations (species) in a given place - usually implies that populations (species) interact

E. Ecosystem

1. A biotic community and its abiotic (physical) environment

Basic Population Biology



Basic Population Biology-

Unlimited Growth = Malthusian Growth or exponential growth

Logic:

Population at time t = N_t

Population at time t + 1= N_t+birthrate (b) + immigration (i)
+ emigration (e)+ death rate (d)

Where t= time t and t+1= sometime after that

Exponential Growth

Assumptions:

1) Emigration = immigration, then

$$N_{t+1} = N_t + \text{births (b)} - \text{deaths (d)}$$

where b and d are instantaneous estimates

2) Generations overlap
3) *Resources are unlimited*

Now let the instantaneous per capita rate of growth (r) equal the birth – death rate:

$$\mathbf{r = b - d}$$

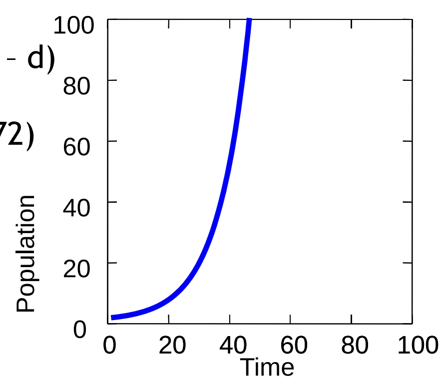
Basic Population Biology - *losses may matter*

Exponential Growth - calculation

$$N_t = N_0 e^{rt}$$

Births > Deaths
r > 0

N_0 = population at time 0
r= per capita rate of growth (b – d)
t= time
e= base of the natural log (~2.72)



Essentially same formula as compounded interest

Exponential Growth - calculation

$N_t = N_0e^{rt}$

Births < Deaths
r < 0

N_0 = population at time 0
r= per capita rate of growth (b – d)
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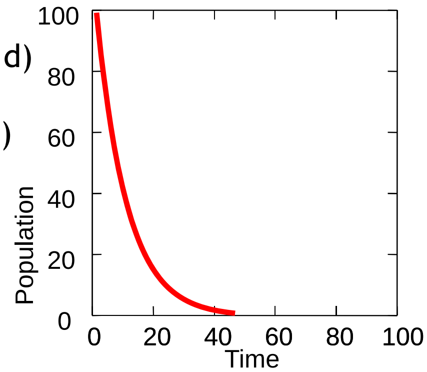


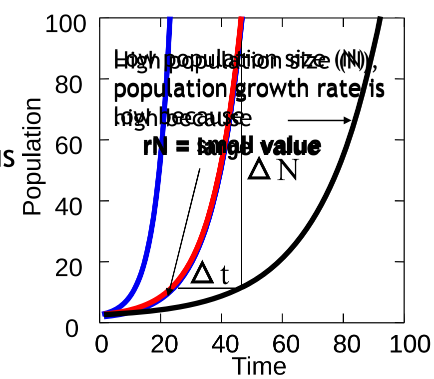
Exponential Growth – an Understanding of Rates

Let r = [illegible]

Rate of growth of population $= \Delta N / \Delta t$

Using calculus we can derive a function for the instantaneous rate of growth of populations. The rate of change of the population is equal to growth rate x the population

dn / dt = rN

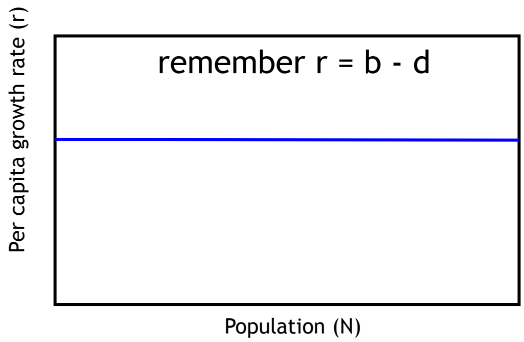


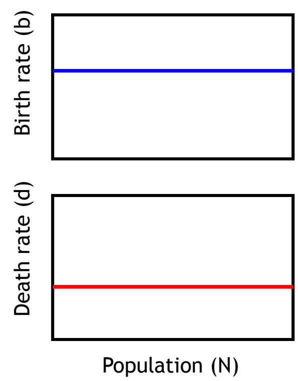
Exponential Growth - why is growth unlimited?

The assumption is that the per capita growth rate (r) is unrelated to population size (N).
This means:

1) Birth rates are unaffected by population size, and
2) Death rates are unaffected by population size

Does this make sense?



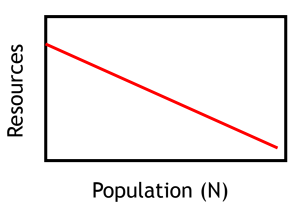


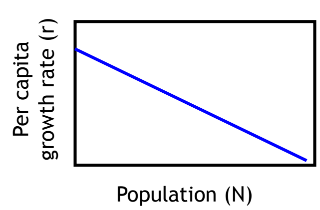
Basic Population Biology - *losses may matter*

Limited Growth

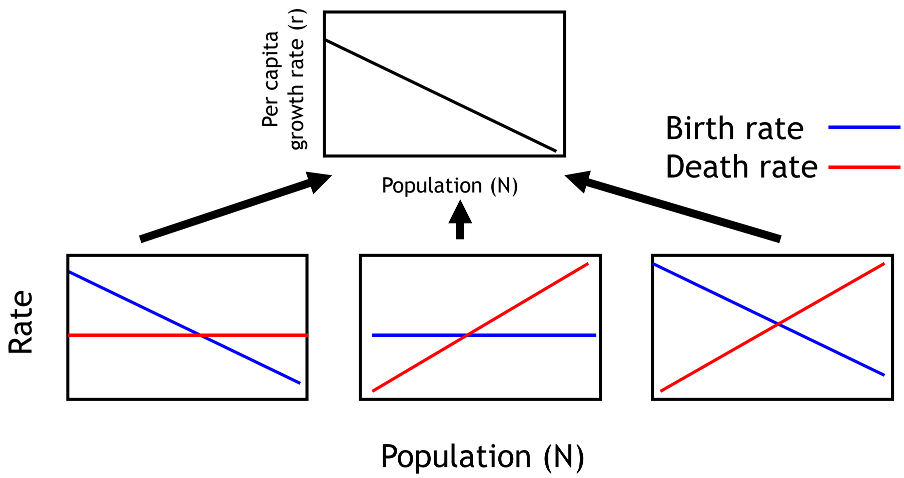
Assumptions:

1) Resources become limited as populations increase
2) Thus, per capita rate of growth must decrease with increasing population





Limited Growth – caused by changes to birth and death rates that are *density dependent*



Limited Growth – density dependence

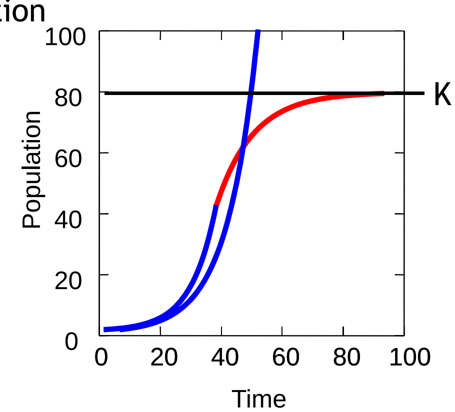
Exponential rate of population growth

$$dn / dt = rN$$

Logistic (limited) rate of population growth

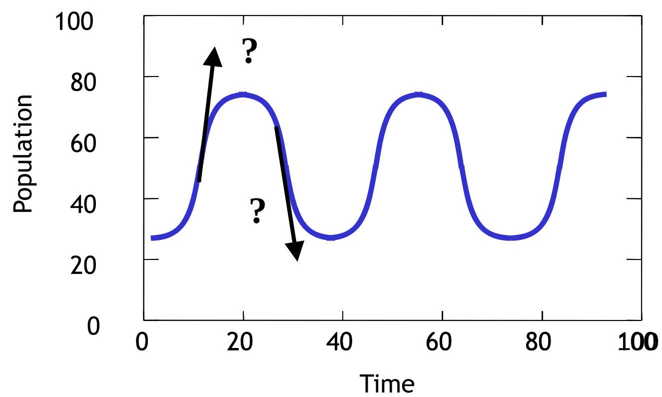
$$dn / dt = rN \frac{(K-N)}{K}$$

K= carrying capacity



Key consequence of density dependence:

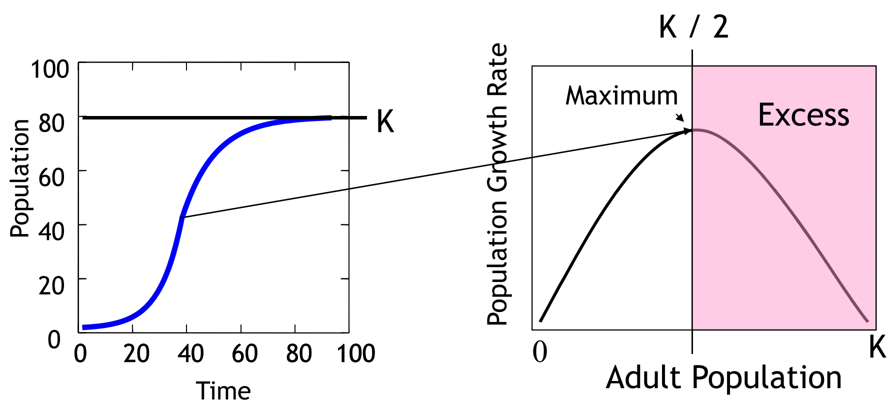
Population regulation: when population fluctuations are bounded so as not to increase indefinitely or decrease to extinction



Basic Population Biology - *losses may matter*

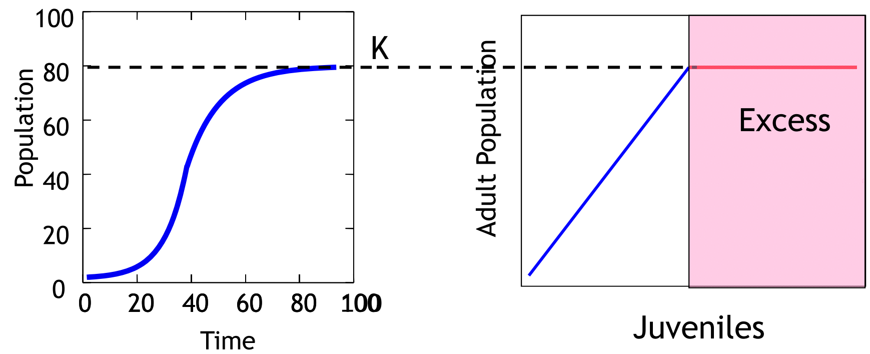
Logistic (limited) growth – implications for conservation I

Excess Adults



Logistic (limited) growth – implications for conservation II

Excess Juveniles - Compensation



Population Structure:

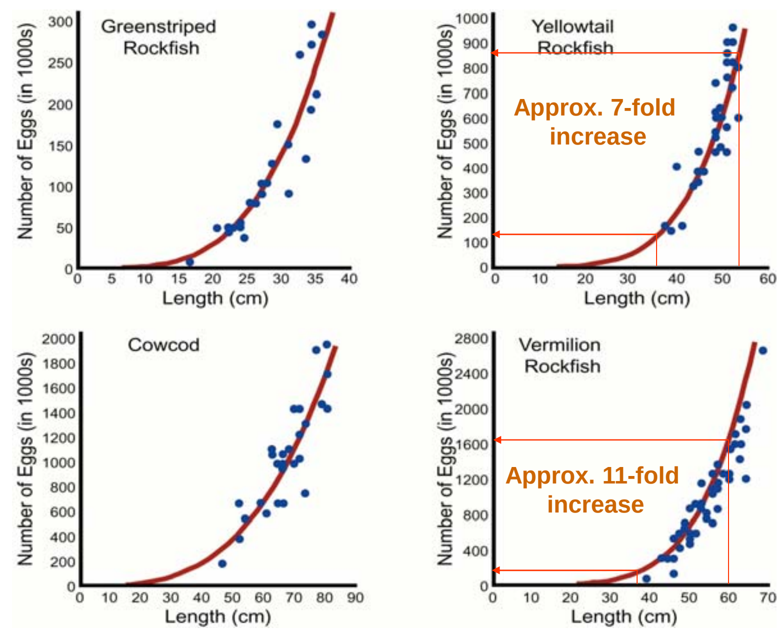
Contrary to assumptions of Logistic Growth, not all individuals in a population are the same!

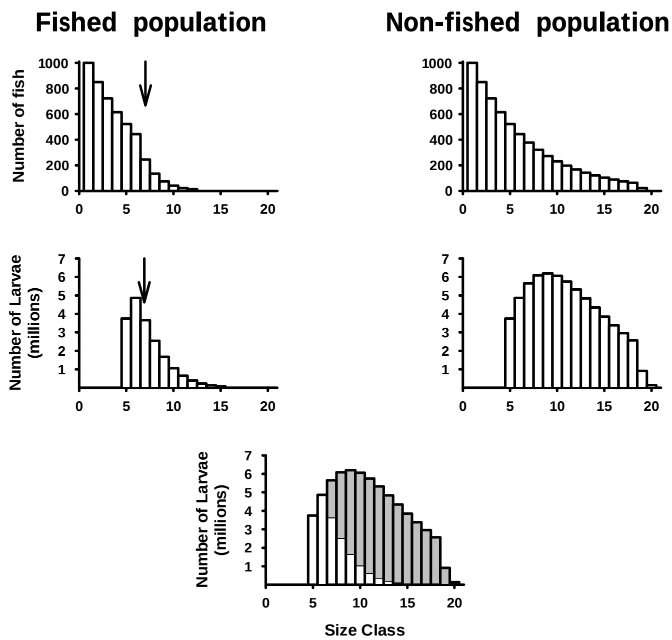
Structure: relative abundance of individual traits among individuals in a population:

- i) age
- ii) size
- iii) stage (e.g., larvae, juveniles, adults)
- iv) sex
- v) genetic (distribution of genotypes throughout population)
- vi) spatial (distribution and interaction of individuals within and among populations)

All of these influence per-capita rate of mortality (D) and reproduction (B)

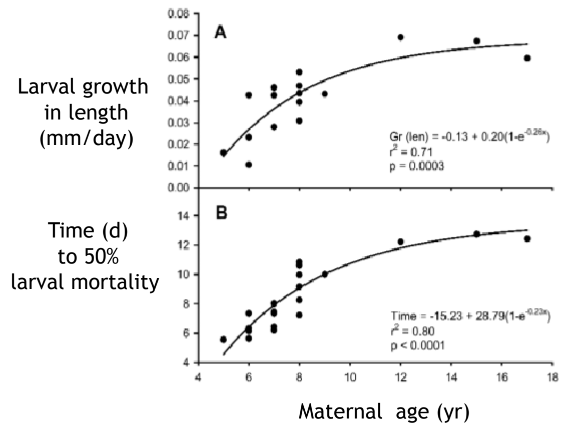
Size Matters: Bigger Fish Produce Far More Larvae





Age matters: older females produce higher quality larvae with a higher likelihood to survive

black rockfish (*Sebastes melanops*).



Berkeley et al. 2004. Fisheries 29: 23-32.

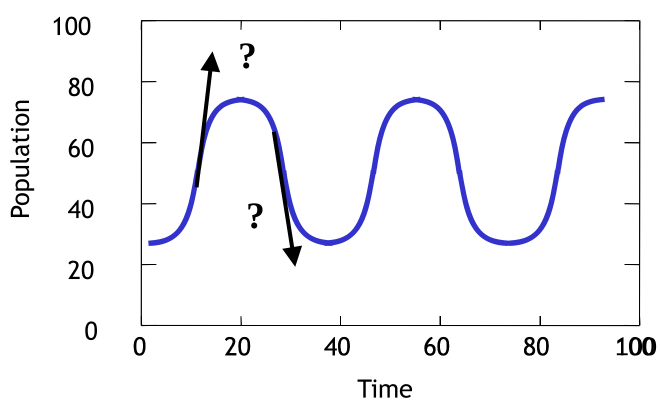
Berkeley et al. 2004. Ecology 85:1258-1264.

Moreover: Different aged fish spawn at different times

Bobko, S. J. and S. A. Berkeley. 2004. Fishery Bulletin 102:418-429.

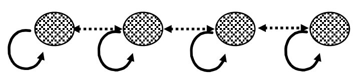
Key consequence of density dependence:

Population regulation: when population fluctuations are bounded so as not to increase indefinitely or decrease to extinction

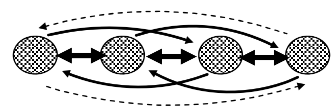


Spatial structure of populations implications for gene flow, genetic diversity and population persistence

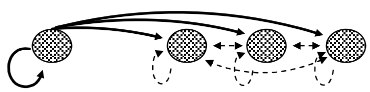
"Closed" populations: self-replenishing



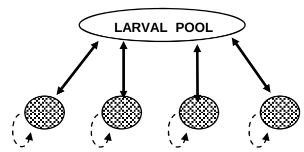
Limited dispersal: stepping-stone



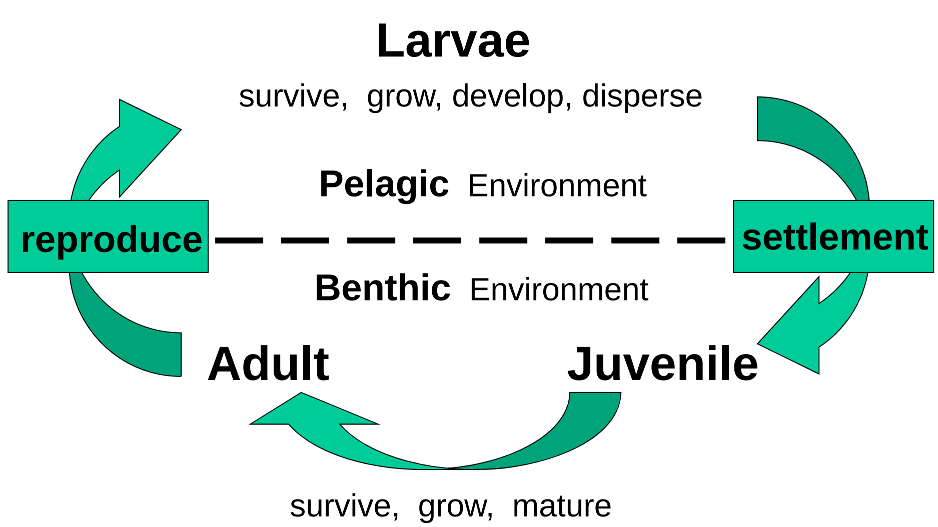
Single source: mainland - island



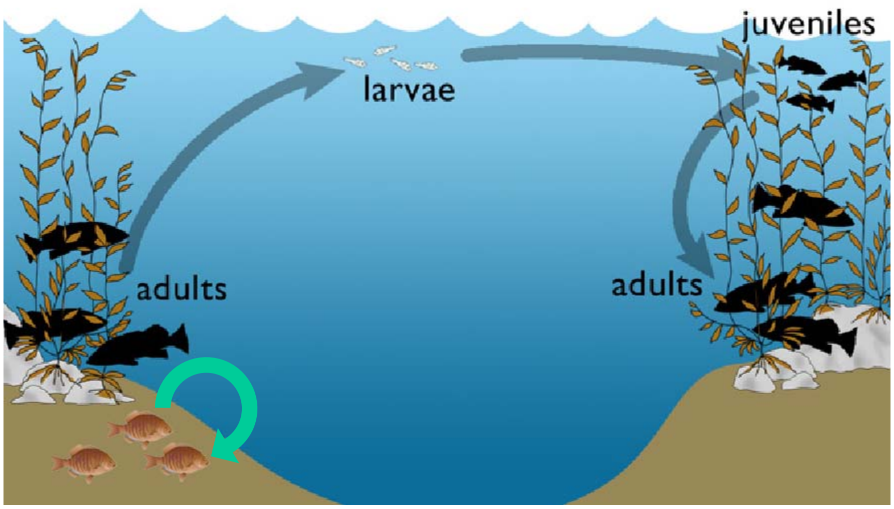
Multiple sources: larval pool



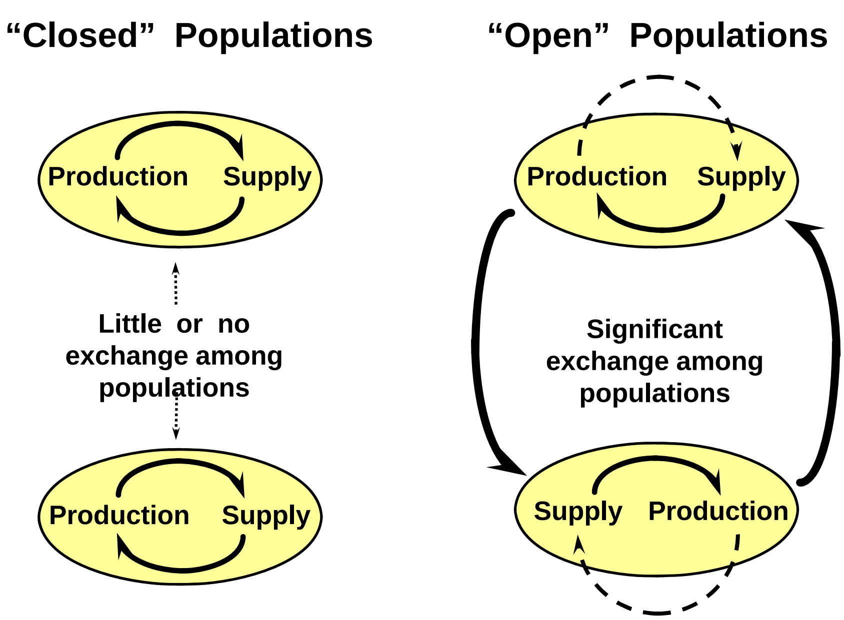
"Bipartite" life cycle of benthic marine organisms with pelagic larvae



“Bipartite” life cycle of benthic marine fishes with pelagic larvae



“Closed” Populations / “Open” Populations



Life History Traits (individual, heritable, species-wide)

- longevity, fecundity
- reproductive modes
- life cycle

Population Attributes

- distribution
- structure (size, age, genetic, spatial)
- dynamics

Community Attributes

- structure (composition, abundance)
- diversity
- biogeography
- dynamics

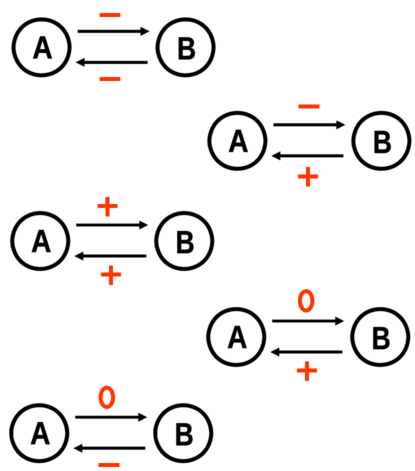
But populations and species do not exist in a vacuum…

Species interactions…

Community Ecology

A) Five fundamental types of species interactions:

	Effect on species A	Effect on species B
Competition	–	–
Predation	+	–
Mutualism	+	+
Commensalism	+	0
Amensalism	–	0



B) Concept of the Niche

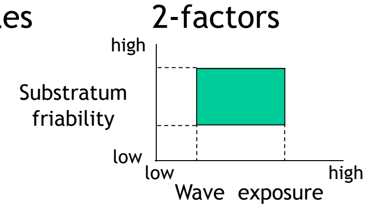
1) Best known definition of <u>niche</u> is Hutchinson (e.g., 1957)

   a) role organism plays in environment

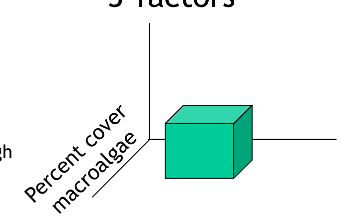
   b) role can be determined by measuring all of an organism's activities and requirements

2) Examples

2-factors



3-factors



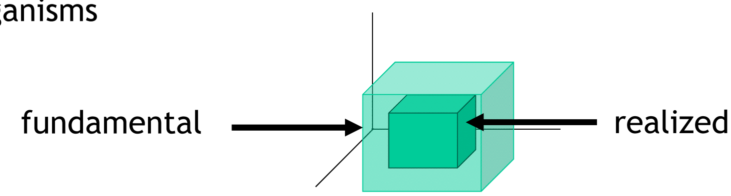
3) By extension… niche defined as an <u>N-dimensional hyperspace</u> (encompasses all effects and requirements of a species)

B) Concept of the Niche

3) Two types of niche

a) fundamental: niche space determined by physical factors and resource requirements. Manifest in the absence of other organisms.

b) realized: niche space determined by combined physical and biological factors. Realized in presence of other organisms



fundamental niche always bigger (or at least as large) - biological interactions can (usually do) limit realized niche

C) Competition

Defined:
The common use of a resource that is in limited supply.

1) Within and between species

a) Intraspecific - among individuals of the same species source of density dependence discussed last time

b) Interspecific - among individuals of two or more species

2) Two types of competition

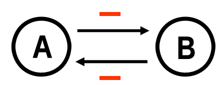
a) Interference

b) Exploitative

C) Competition

2) Two types of competition

a) **Interference - <u>direct</u> competition**



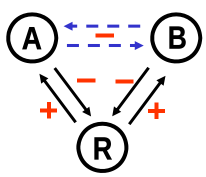
i) e.g., aggression

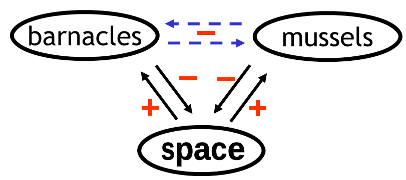
ii) e.g., territoriality (fishes, birds, limpets)

b) **Exploitation - <u>indirect</u> competition**

i) Compete through a resource (R)

ii) e.g., sessile spp. -- space, filter feeders -- plankton





C) Competition

3) Competitive exclusion principle

The more similar organisms are, the more likely they are to compete.

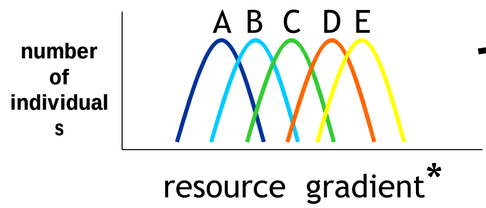
a) Species occupying the same niche cannot coexist.

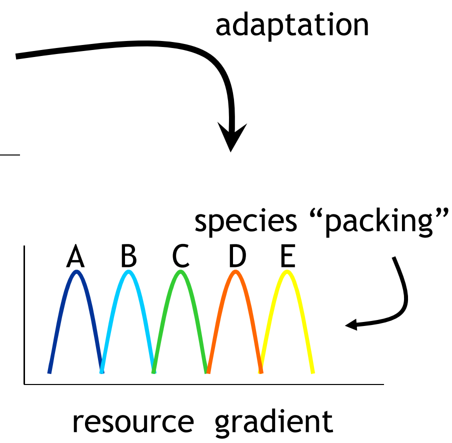
b) The greater the niche overlap, the greater the likelihood of competitive exclusion, leading to local extinction of one species.

c) Leads to “resource partitioning”

C) Competition

4) Resource partitioning





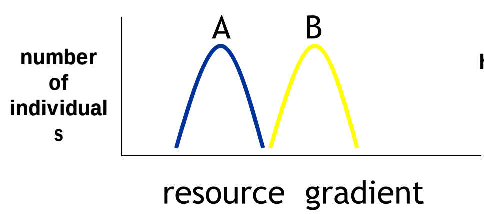
* e.g.,

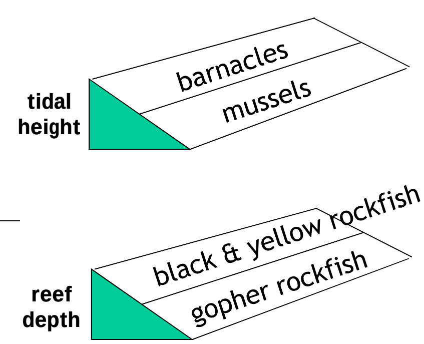
- seed / plankton size
- elevation
- height on tree / alga

C) Competition

5) Manifested in patterns

a) non-overlapping spatial (or temporal) distribution

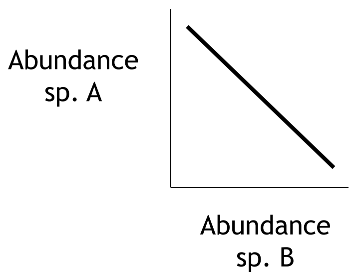




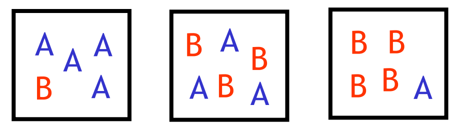
C) Competition

5) Manifested in patterns

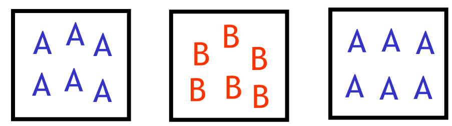
a) negative (inverse) relationship in abundance



i) gradient in density



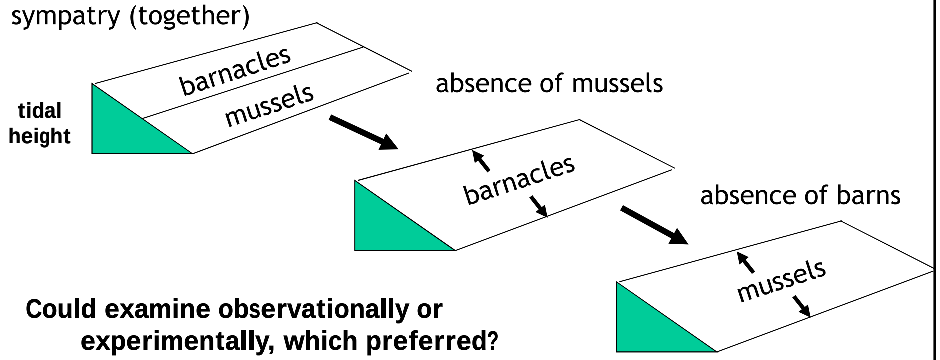
ii) patchy / clumped



C) Competition

6) Competitive release

a) Change in distribution (or some other response such as growth) when separate and together



Could examine observationally or experimentally, which preferred?

C) Competition

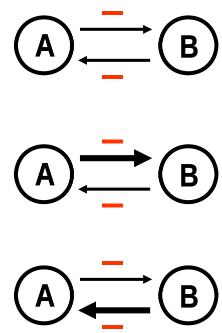
7) Competitive symmetry

a) Relative competitive strength

b) superior, inferior (or) dominant, subordinate

Symmetrical — A = B

Asymmetrical:
- A > B
- A < B



How would you assess this??

C) Competition

7) Effects on measured variables

a) Individual responses:

- Behavioral (feeding rates, foraging distribution)
- Physiological (growth rate, reproductive rate)
- Morphological (body size, biomass)

b) Population responses:

- Abundance (density)
- Distribution (zonation)
- Demographic rates (population growth)

D) Predation

Consumption of one organism (prey) by another (predator), which by definition, occurs between organisms on different trophic levels (vs. competition: within same trophic level)

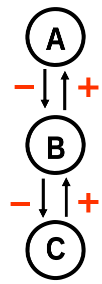
1) diagrammatically:

Predator

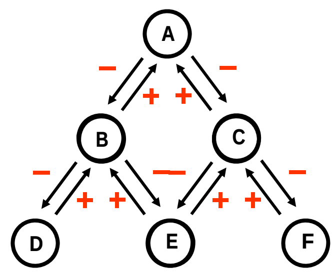
Herbivore

Primary producer (plant / alga)

food chain



food web



D) Predation

2) Effects on prey (direct and indirect):

"Direct effects": direct losses (removal of individuals)
- **death of individuals**
- **mortality rate of population**

"Indirect effects": influence of predator on variable other than death or mortality

- **behavioral (feeding rates, foraging distribution)**
- **physiological (growth rate, reproductive rate)**
- **morphological (body size, biomass)**

D) Predation

3) Effects on prey (individual and population):

Individual responses:

- **behavioral (feeding rates, foraging distribution)**
- **physiological (growth rate, reproductive rate)**
- **morphological (body size, biomass)**

Population responses:

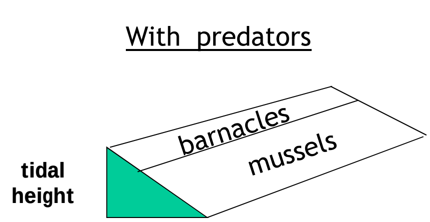
- **abundance, density**
- **distribution (habitat use)**
- **structure (e.g., size, age, sex ratio, genetic, spatial)**
- **dynamics and persistence (regulation)**

D) Predation

4) Complex interactions (with other processes)

E.g., competition:

e.g., predator that specializes on barnacles and is restricted to the mid and lower intertidal



In absence of predator, barnacle out-competes mussels and expands distribution down into the mid intertidal

*

D) Predation

4) More complex predation interactions:

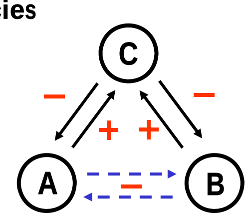
Apparent competition

Where, A and B are prey
and C is a common predator.

Effect on species

A	B	C
–	–	+

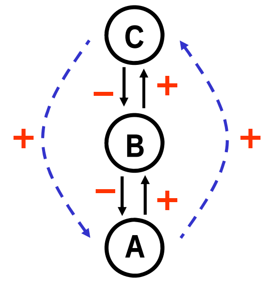
Presence of both prey increases overall predation rates, leading to negative indirect effect on one another.



Trophic cascade

Where, A is primary producer,
B is an herbivore, and C is a predator.

Effect of species on adjacent trophic level has net positive indirect effect on next trophic level.



Trophic cascades

Strong **"top-down"** effects that produce downward rippling effects through a food chain.

Higher tropic level predators *indirectly* affect plant biomass via their impacts on herbivore populations.

Strong **"bottom-up"** effects that produce upward rippling effects through a food chain.

Lower tropic level producers *indirectly* affect predator biomass via their impacts on herbivore populations.

A linear food chain

Predator

↓

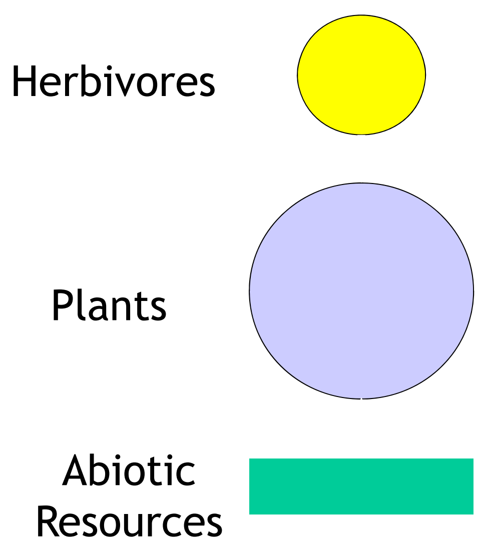
Herbivore

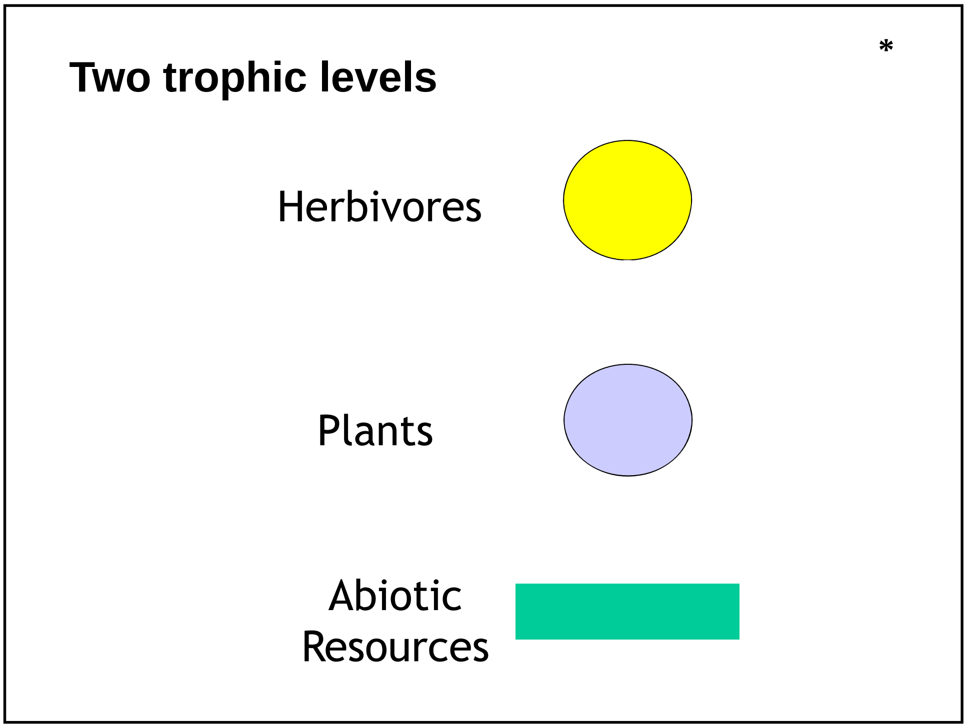
↓

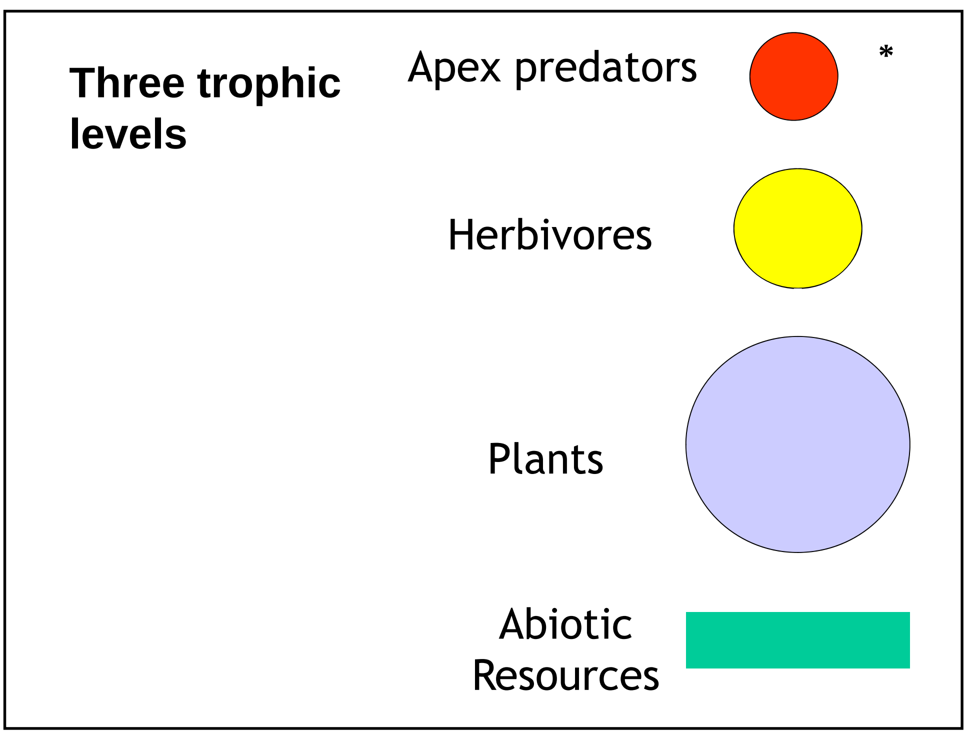
Plants

Two trophic levels

*



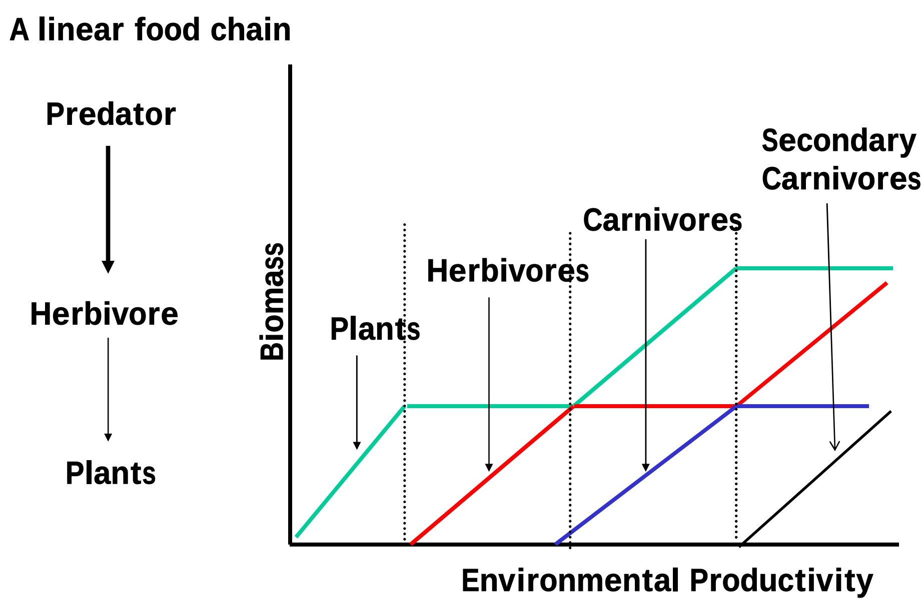

Two trophic levels
*
Herbivores
Plants
Abiotic
Resources


Three trophic
levels
Apex predators
*
Herbivores
Plants
Abiotic
Resources

Oksanen/Fretwell Model: Productivity and Food Chain Length

- Depending on productivity of community, food chains can have fewer or more than three trophic levels.
- As primary productivity increases, trophic levels will be sequentially added.
- Food chains that have an odd number of trophic levels should be filled with lush vegetation, because herbivores are kept in check by predators.
- Food chains that have an even number of trophic levels should have low plant abundance because plants are herbivore limited.

Oksanen/Fretwell Model



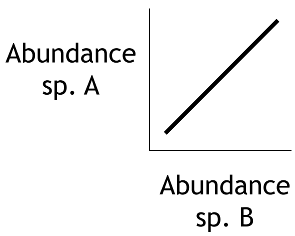
E) Mutualism / commensalism

1) Occurs within or between trophic levels, more often between trophic levels

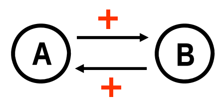
a) mutualisms: e.g., pollinators

obligate - required for each others existence - pollinators
facultative - not required - cleaner fish and parasitized hosts

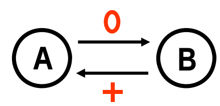
b) commensalisms: e.g., facilitation



mutualism (symmetrical) A = B



commensalism (asymmetrical) A < B



How would you assess this??

E) Community metrics

1) Species richness: number of species in a community

2) Species composition: identity of species that constitute a community

3) Species diversity: species richness and relative abundance

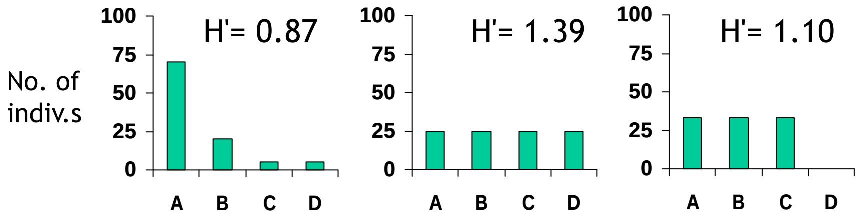
Shannon-Weiner index of diversity:

$$H' = -\Sigma p_i (\ln p_i)$$

Where p_i is the proportion of individuals in the community that are species i

E) Community metrics

4) Illustration of diversity



Evenness: measure of the relative similarity of species abundance in a community

$$E = H'/(\ln S)$$ where, S is species richness

F) Scales of species diversity

1) Alpha (α): within habitat diversity

2) Beta (β): between habitat diversity