Tags

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Mod 18-21 Population Ecology

See also chapter 5 in Withgott:

Evolution, species interaction, communities and species interactions

Lab: Predator prey phase delay

Module 18-abundance and distribution

Start with this:

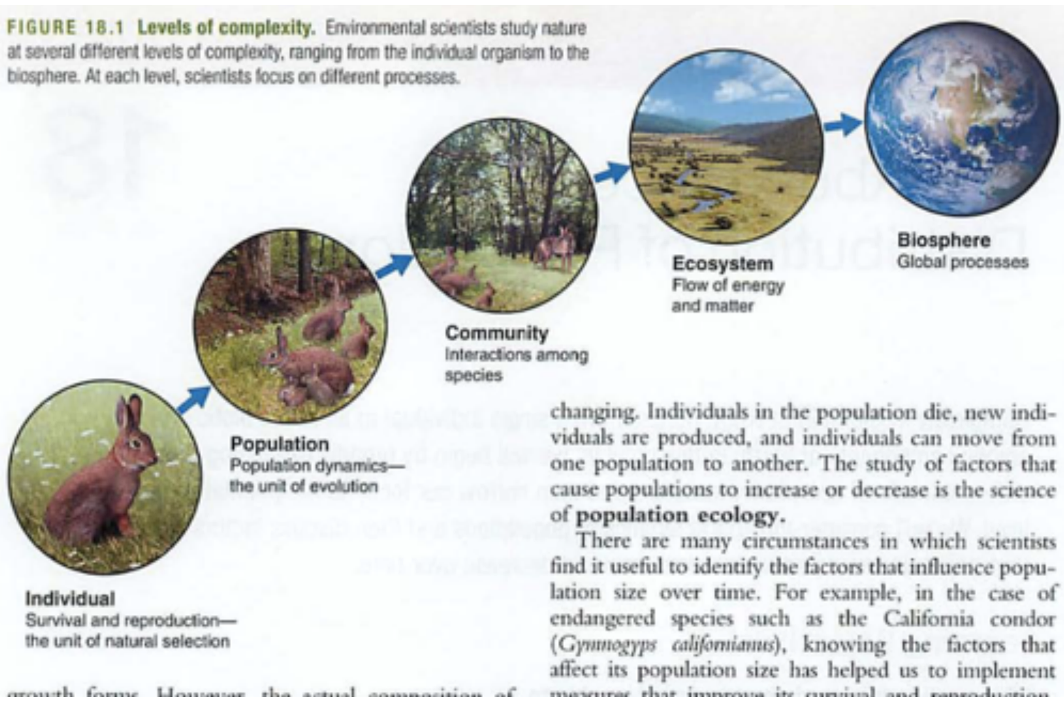

FIGURE 18.1 Levels of complexity. Environmental scientists study nature at several different levels of complexity, ranging from the individual organism to the biosphere. At each level, scientists focus on different processes.

changing. Individuals in the population die, new individuals are produced, and individuals can move from one population to another. The study of factors that cause populations to increase or decrease is the science of **population ecology.**

There are many circumstances in which scientists find it useful to identify the factors that influence population size over time. For example, in the case of endangered species such as the California condor (*Gymnogyps californianus*), knowing the factors that affect its population size has helped us to implement

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A crude example of this might be:

individual-you

population-HPA students

community-HPA

ecosystem-education

biosphere-the world

or:

some rabbit individual

some of the rabbit's friends, a population of rabbits

rabbits and the things they eat and eat them-community

ecosystem-the plants that support both ends of this process biosphere-the planet

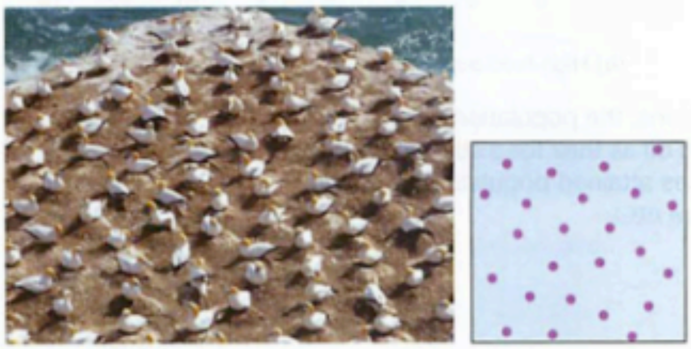
We covered ecosystem energy and matter a few weeks ago, this chapter is about population ecology.

Population dynamics

Notation: Population size is represented as N (note not "n"): population size within a defined area at a specific time (brings in migration).
So, we could say the student population of HPA would be all students **here** this year, **2020-2021**

Check out the diagrams on population distribution: random, uniform and clumped.
Important vis a vis biodiversity
Structures: age and gender (sex)

(a) Random distribution



(b) Uniform distribution

(c) Clumped distribution

FIGURE 18.3 Population distributions. Populations in nature distribute themselves in three ways. (a) Many of the tree species in this New England forest are randomly distributed, with no apparent pattern in the locations of individuals. (b) Territorial nesting birds, such as these Australasian gannets (*Morus serrator*), exhibit a uniform distribution, in which all individuals maintain a similar distance from one another. (c) Many pairs of eyes are better than one at detecting approaching predators. The clumped distribution of these meerkats (*Suricata suricatta*) provides them with extra protection. *(a: David R. Frazier Photolibrary, Inc./Science Source; b: Michael Thompson/Earth Scenes/Animals Animals; c: Clem Haagner/ARDEA)*

Density dependent factor: e.g. food or reproductive rate in rats (more rats, lower fecundity)
Something that influences reproduction or survival...

Density independent factors: storms, disasters, fires (note density independent: one bambi or 100 bambi all perish in the same fire)

Limiting resource: usually food, but could include space, nutrients, etc.

Carrying capacity: K (note not "k"): how many individuals an environment can support

Module 19: growth models
Imagine you are a happy bacteria, or rabbit, with lots of food, land and no predators. Your population growth curve might look like this:

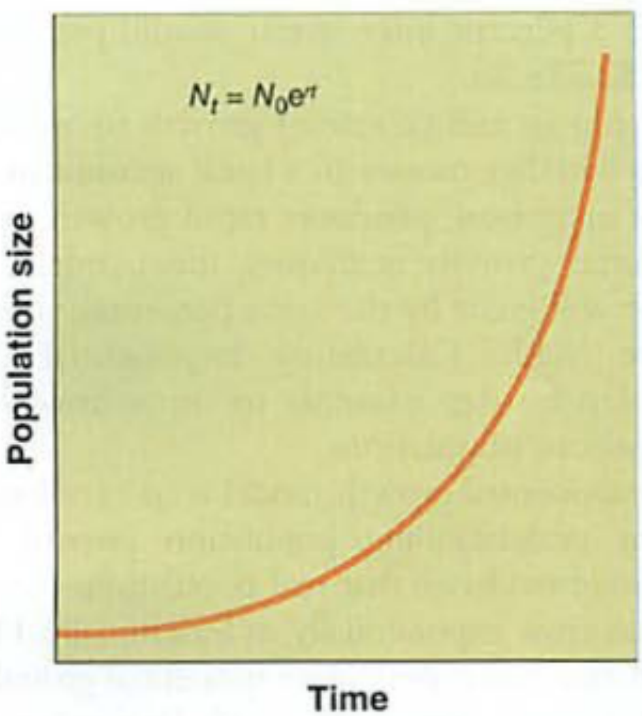
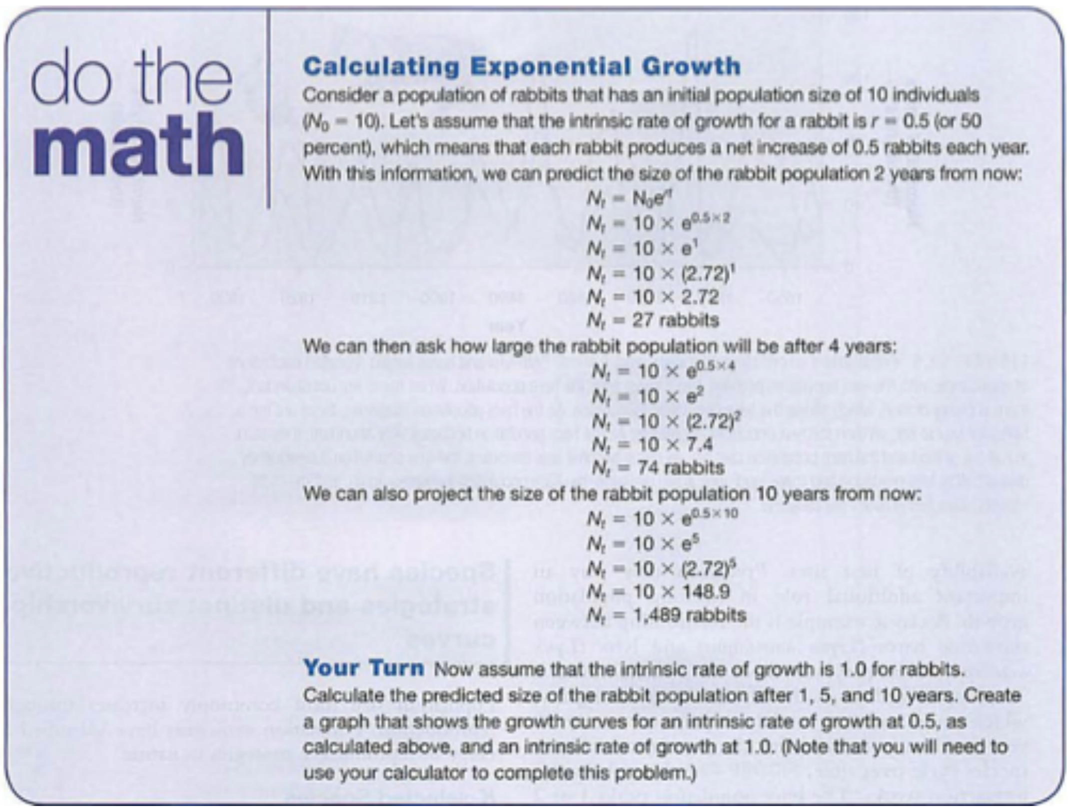


FIGURE 19.1 The exponential growth model. When populations are not limited by resources, their growth can be very rapid. More births occur with each step in time, creating a J-shaped growth curve.

This is called exponential growth, or "J shaped growth"
Note that it has no end, or limiting factor.

Small r is the growth rate. If you have had physics (yay!) this is usually "k" in some examples, or related to RC decay/growth.
Learning this equation is VERY useful.
Note that it depends on two things:
the starting amount in the population (No)
and the growth rate (r)
Here is an example:



do the **math**

Calculating Exponential Growth

Consider a population of rabbits that has an initial population size of 10 individuals ($N_0 = 10$). Let's assume that the intrinsic rate of growth for a rabbit is $r = 0.5$ (or 50 percent), which means that each rabbit produces a net increase of 0.5 rabbits each year. With this information, we can predict the size of the rabbit population 2 years from now:

$$N_t = N_0e^{rt}$$
$$N_t = 10 \times e^{0.5 \times 2}$$
$$N_t = 10 \times e^1$$
$$N_t = 10 \times (2.72)^1$$
$$N_t = 10 \times 2.72$$
$$N_t = 27 \text{ rabbits}$$

We can then ask how large the rabbit population will be after 4 years:

$$N_t = 10 \times e^{0.5 \times 4}$$
$$N_t = 10 \times e^2$$
$$N_t = 10 \times (2.72)^2$$
$$N_t = 10 \times 7.4$$
$$N_t = 74 \text{ rabbits}$$

We can also project the size of the rabbit population 10 years from now:

$$N_t = 10 \times e^{0.5 \times 10}$$
$$N_t = 10 \times e^5$$
$$N_t = 10 \times (2.72)^5$$
$$N_t = 10 \times 148.9$$
$$N_t = 1{,}489 \text{ rabbits}$$

Your Turn Now assume that the intrinsic rate of growth is 1.0 for rabbits. Calculate the predicted size of the rabbit population after 1, 5, and 10 years. Create a graph that shows the growth curves for an intrinsic rate of growth at 0.5, as calculated above, and an intrinsic rate of growth at 1.0. (Note that you will need to use your calculator to complete this problem.)

Click for full-size image

You might also find this link useful:
https://www.khanacademy.org/science/ap-biology/ecology-ap/population-ecology-ap/a/exponential-logistic-growth

Many systems follow J shaped exponential growth until they run out of food or space, then there is overshoot and die-off:

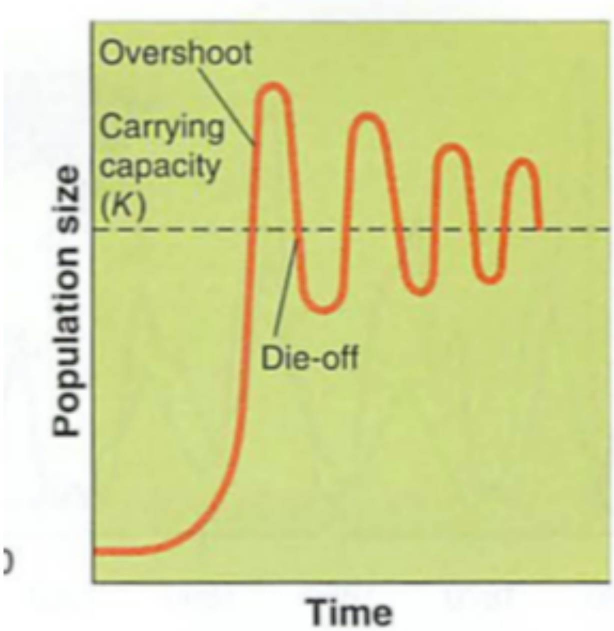


FIGURE 19.4 Population oscillations. Some populations experience recurring cycles of overshoots and die-offs that lead to a pattern of oscillations around the carrying capacity of their environment.

A more ideal version of this is the S shaped curve, called logistic growth:

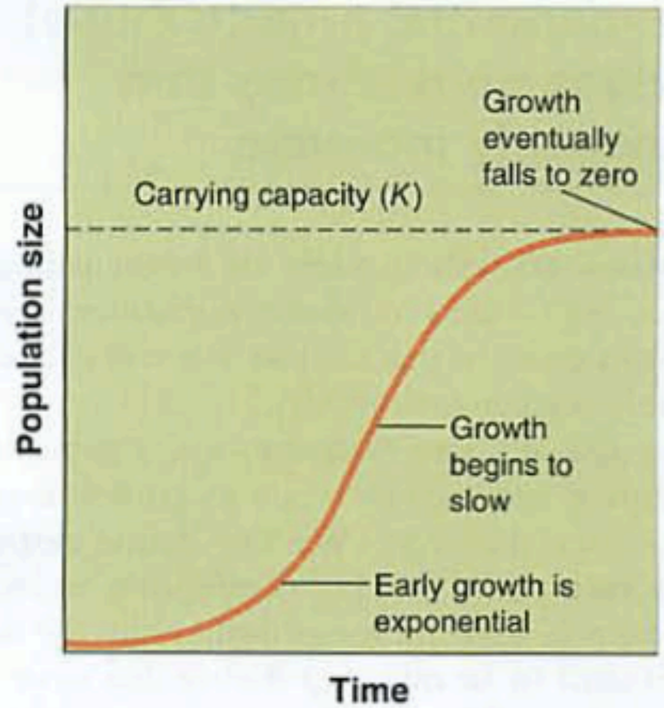


FIGURE 19.2 The logistic growth model. A small population initially experiences exponential growth. As the population becomes larger, however, resources become scarcer, and the growth rate slows. When the population size reaches the carrying capacity of the environment, growth stops. As a result, the pattern of population growth follows an S-shaped curve.

Here is a formula for logistic growth that we'll discuss:

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

dN/dt: change in numbers over time
r: exponential growth rate
N: population size
K: carrying capacity

Click for full-size image

Don't be intimidated by this formula...

dN/dt is just delta N over delta t, or the Δ in number over the Δ in time,
or the rate of population growth (some of you may see this as the slope of the S curve)
Note that when the ratio N/K is very small or close to zero, the stuff in the parentheses becomes 1, so the formula is rate = rN, or J curved exponential growth.
As N/K nears one (number of critters equals carrying capacity) the term in the parentheses becomes zero, so no growth.
Note also that if N/K is GREATER than one, the growth rate (slope of the curve) become negative. This is overshoot and die off.

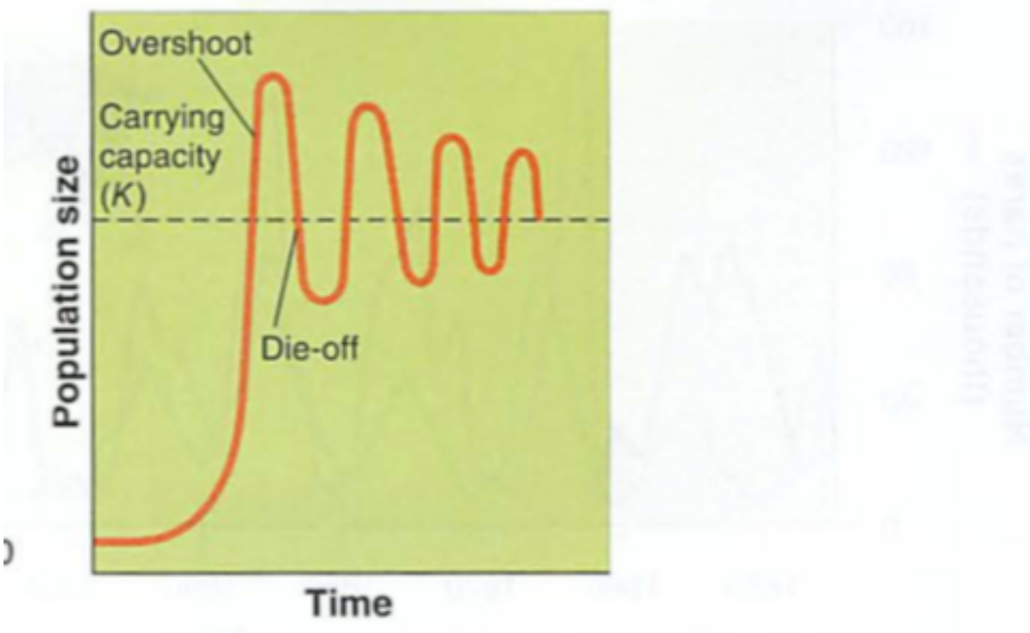


FIGURE 19.4 Population oscillations. Some populations experience recurring cycles of overshoots and die-offs that lead to a pattern of oscillations around the carrying capacity of their environment.

Logistic growth worksheet

First: exponential growth:

Imagine 10 imaginary rabbits (No=10)

Assume r = 0.5 (50 percent growth rate, or each rabbit makes 0.5 rabbits per year)

Find the population 2 years later:

Nt = Noe^rt

Nt = 10e^0.5*2

Nt = 27 rabbits

After 4 years:

After 10 years:

———

Next, use the logistic growth formula, same data, with a carrying capacity (K) of 100:

Small population: 10 rabbits

$\Delta N/\Delta t = rN(1-N/K)$

$= 0.5*10(1-10/100)$

$= 5(1-0.1)$

$= 5(0.9)$

= 4.5 rabbits per year

Find the rabbits per year for these populations:

Medium population: 27 rabbits

Near K: 74 rabbits

Above K: 1489 rabbits

quiz (you may use **your** worksheet only)

1. 30 rabbits live on an island with carrying capacity 200. They reproduce at a rate of 0.5 per year. How many rabbits will be on the island after 3 years? (hint: you would do the calculation three times-this is only an estimate though, the true formula would be a bit more complex)
2. What will be the slope of the growth curve at this point?

Next: predator/prey phase diagrams

Check this out:

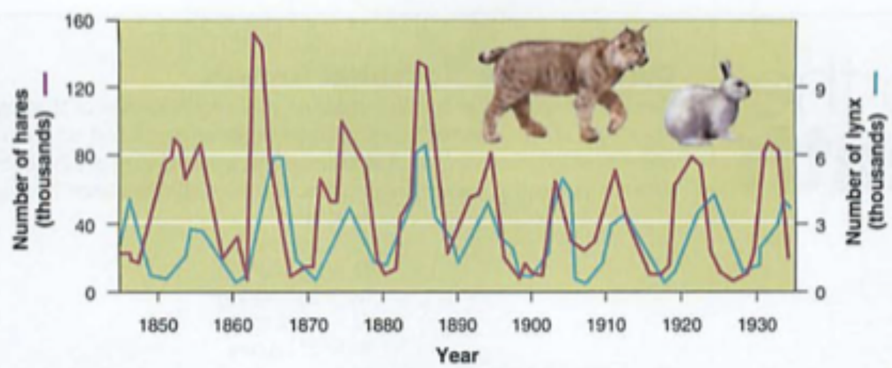


FIGURE 19.5 Population oscillations in lynx and hares. Both lynx and hares exhibit repeated oscillations of abundance, with the lynx population peaking 1 to 2 years after the hare population. When hares are not abundant, there is plenty of food, which allows the hare population to increase. As the hare population increases, there are more hares for lynx to eat, so then the lynx population increases. As the hare population becomes very abundant, they start to run out of food and the hare population dies off. As hares become less abundant, the lynx population subsequently dies off. With less predation and more food once again available, the hare population increases again, and the cycle repeats. *(Data from Hudson's Bay Company)*

Click for full-size image

Note the phase (timing) relationship between the abundance of the food and the population of the prey, then the predator.

Predator Prey Lab:

predator-prey-simulation12.pdf

Worksheet: (uses Numbers application)

Population Growth Model.numbers

Worksheet: excel version:

Population Growth Model.xls

Questions:

ESI-24-modeling_population_growth.pdf

Now we can discuss generalizations of r and K strategists:

Note: r comes from small r (growth rate) in the growth formula, while K comes from large K in the same formula (carrying capacity):

TABLE 19.1 Traits of *K*-selected and *r*-selected species

Trait	*K*-selected species	*r*-selected species
Life span	Long	Short
Time to reproductive maturity	Long	Short
Number of reproductive events	Few	Many
Number of offspring	Few	Many
Size of offspring	Large	Small
Parental care	Present	Absent
Population growth rate	Slow	Fast
Population regulation	Density dependent	Density independent
Population dynamics	Stable, near carrying capacity	Highly variable

Where do you fit in? How about Nemo?

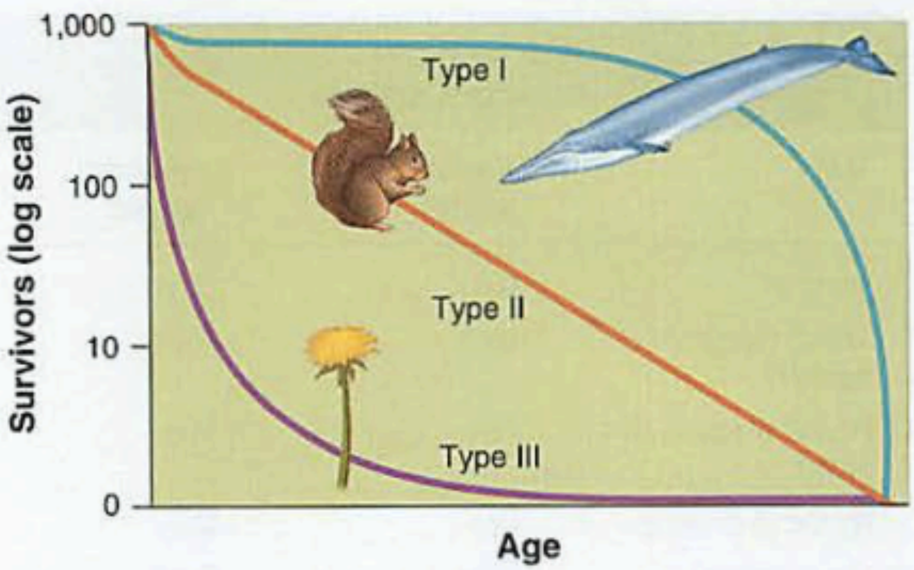


FIGURE 19.7 Survivorship curves. Different species have distinct patterns of survivorship over the life span. Species range from exhibiting excellent survivorship until old age (type I curve) to exhibiting a relatively constant decline in survivorship over time (type II curve) to having very low rates of survivorship early in life (type III curve). *K*-selected species tend to exhibit type I curves, whereas *r*-selected species tend to exhibit type III curves.

Birds also fall into type II (no pun intended), as they randomly crash into stuff...
There is a fourth type: deer. How would you imagine this curve?
Related:
Another reason why genocides are so damaging to cultures: If an oral tradition (e.g. Hawaiians) are decimated by smallpox for example, it is the very old (the holders of the legends and history) and the very young (those who have time to listen, not work, and will then grow up and tell their kids) that are gone. This is a sort of cultural bottleneck...

Module 20: Community ecology
Competitive exclusion principle: two species competing for the same resources cannot co-exist, leads to...
Resource partitioning: time, space, type of food (one species picks one, the other survives)
Relationships:
Predation: predator and prey, one lives, the other dies

Symbiotic:

Mutualism: both benefit

Commensalism: one benefits, no harm to the other

Non-symbiotic:

Parasitism: one benefits, harm to other

TABLE 20.1 Interactions between species and their effects

Type of interaction	Species 1	Species 2
Competition	–	–
Predation	+	–
Parasitism	+	–
Herbivory	+	–
Mutualism	+	+
Commensalism	+	0

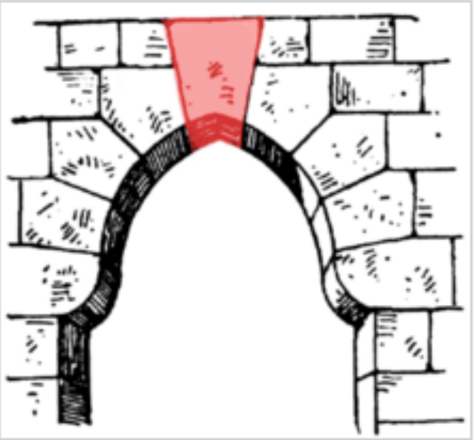
quizlet review

keystone species vs. indicator species

Keystone species-many others depend on it, removal has an impact much greater than their relative population

e.g. beavers: create habitat for others (dams), so they are also "keystone engineers", only they don't wear funny hats.

Here's what a keystone looks like:



The keystone (shown in red) of an arch

In architecture, if you remove the **keystone**, the arch collapses. Cool term, right?

This is different from a **capstone** (seniors might like this): a capstone is what you put on top of a finished structure

Another example: "**keystone predators**" e.g. sea stars, which eat mussels, clearing space on rocks for other species

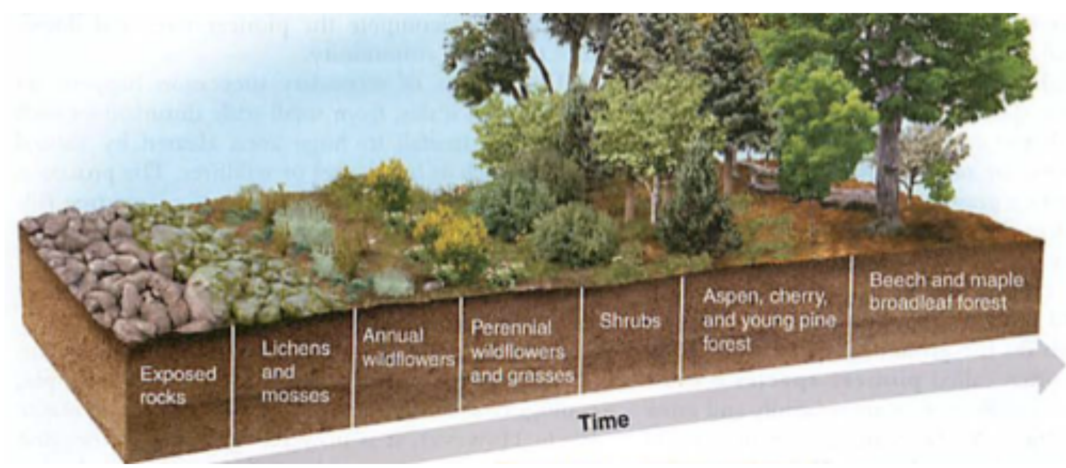
Indicator species-signal health of a system, like some fish or worms signify water quality, also known as "bioindicators"

Succession: one species takes over another in time

Module 21: Community Succession

Primary succession: From bare rock, no soil: (e.g. lichen)

These hold moisture and some sort of matrix (e.g. soil) so that others can then grow



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You might imagine driving from the Kohala coast up to Waimea, seeing bare lava along the coast, then fountain grass, then small bushes, then trees along the stream, then larger trees away from the stream.
Water is the key to life, so anything that can trap and hold water (e.g. soil) can support life.

Secondary succession: from disturbed area with soil (e.g. after a fire)-there is soil, but no plants, growth here might be quicker than primary sucession.

Pioneer species: arrives first, sets up reliable system of water and matrix

Climax community: stable, well evolved ecosystem, e.g. old growth forest, able to survive disasters (e.g. fire)

Aquatic succession: from stream (flowing water) to pond (less flow) to shallow pond (even less flow) to marsh (mostly mud)

Island biogeography (like here in Waimea): habitat size AND distance from others influences diversity (e.g. birds)

This was Darwin's whole gig, also some folks off the coast of Chile, often with birds involved.

Check out an alternate presentation of these in the Withgott text, with a special section about our island:

http://physics.hpa.edu/physics/apenvsci/texts/withgott/withgott%206e/3-4.pdf

Frog book chapter 5:

Click for full-size image

Questions:

1. What three things in order are necessary for evolution to succeed?
2. What are the characteristics of an r specific species. Give an example.
3. What are the characteristics of a K specific species. Give an example as well.
4. The population of wolves may rise and fall along with rabbits, but not at the same time. Explain why.

withgott 7e ch.3 evolution.pdf

withgott 7e ch.4 species interactions.pdf