Module 19: Growth models

Population growth rates

- r selected (r means rate) species grow exponentially until they reach or exceed the carrying capacity of the ecosystem (fish, bacteria)
- K selected species grow slowly and reach the carrying capacity (humans, whales, elephants)
- Carrying capacity (K) refers to land, water, food or other biotic requirement for the species
- Biotic potential is the reproductive rate if there were no limits

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We describe these r and K species also by their survivorship curves:
Simple version:

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What does this mean?

- Dandelions have many offspring, most of them die, the survivors live on
- Whales have few offspring, take care of them, then live on
- Squirrels die randomly, same for birds, they crash into stuff, old or young
- Where would deer fit into this diagram? Hint: they are another different line

Have a look at the chart above, and think of yourself as an infant.
Compare with Nemo...

Population growth: r and K explained: why do we use those letters?

https://elab.hpa.edu/apes/videos/bozeman_science/Population%20Ecology.mp4

Some math to understand this:
Exponential growth is the opposite of radioactive decay which we demonstrated with M&Ms
At = Ao/2^n or At = Ao* (1/2^n) where n is the number of half-lives

Populations have doubling times, the time for the population to double, using the same formula:
At = Ao*2^n where n is the number of doubling times

Try this:
Take a piece of paper, cut it in two, record your result on a table as you do this 6 times
What was your final total?
Now do this starting with several sheets of paper (be creative), do this 6 times and record on a table.
When you start with one sheet, Ao is one
When you start with several sheets, Ao is the number
r in this case was 0.693 (a very important number)
t is the number of times you tore the paper
Test this out with your calculator

Here's what this looks like, called J-shaped growth:

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Here's where the r comes from in the r-selected species:

Nt = No e ^rt where r is the growth rate in %

(r comes from rate)

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So simple J growth looks like this:

$$\Delta N/\Delta t = rN$$

ΔN means change in population
Δt means change in time
r means reproductive rate
N means initial population

so, ΔN/Δt really means growth rate or slope of the growth curve

Note this depends on two things:

- Initial population (N)
- reproductive rate (r)

What about K-selected species?
Examples: humans, whales and elephants
We use a different equation for this, but it is really the same equation:

ΔN/Δt = rN(1-N/K)

K is the carrying capacity of an ecosystem:

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Look at the formula:
If the population is well below K (the carrying capacity) then the rate of population growth is

ΔN/Δt = rN(1-0) or ΔN/Δt = rN

(J shaped growth again)

As the population approaches K the value in the parentheses becomes 0 (no growth) then negative (die off or overshoot):

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Two types of growth factors:

- Density dependent factors: food, water, land
- Density independent factors: disasters (flood, fire)

Important fact: as food becomes limited, K species will have fewer offspring, so they approach the carrying capacity (K) more gradually, not overshoot and die off.

Try this formula with an island that can hold 100 rabbits, using the numbers above (50% growth rate).
Try this with 50 rabbits, 100 rabbits, 150 rabbits.
What is the value of ΔN/Δt in each case?
What does this mean about the slope of the growth curve?

From Wikipedia:

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where N is the population, r is the maximum growth rate, K is the carrying capacity of the local environment, and dN/dt, the derivative of N with respect to time t, is the rate of change in population with time. Thus, the equation relates the growth rate of the population N to the current population size, incorporating the effect of the two constant parameters r and K. (Note that decrease is negative growth.) The choice of the letter K came from the German Kapazitätsgrenze (capacity limit), while r came from rate.

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Predator Prey oscillations:
Lynx and hare demo:
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Note that the predator peaks after the prey, then overshoots...

Predator prey simulators:
Population Growth Model.numbers

Population Growth Model.xls

Interesting math stuff: (optional)
{\displaystyle {\frac {dx}{dt}}=kx}
saying that the change per instant of time of x at time t is proportional to the value of x(t), and x(t) has the initial value

{\displaystyle x(0)=x_{0}}
.

The differential equation is solved by direct integration:

{\displaystyle {\begin{aligned}{\frac {dx}{dt}}&=kx\\[5pt]{\frac {dx}{x}}&=k\,dt\\[5pt
so that
{\displaystyle x(t)=x_{0}e^{kt}.}

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