Intro to population ecology

NRES 470/670

Spring 2019

Central Questions of Population Ecology

Ecological

- Why are some species more abundant than others?
- What causes population densities to vary in space and time?
- What causes populations to become extirpated? Recolonized?
- What processes *regulate* population growth?
  - Extrinsic vs intrinsic factors (Nicholson vs Andrewartha debate)
- What prevents predator-prey relationships from collapsing?
- What factors allow competitors to coexist?
- What factors allow metapopulations to reach a stable equilibrium?

Conservation and Management

- What is the conservation status of a focal species or population?
- How do anthropogenic structures and land uses affect populations?
- What is the *Maximum Sustainable Yield* for a focal game species?
- How can pest species be most effectively controlled?
- What land areas are most important for preserving at-risk populations?
- What are the likely population-level effects of alternative conservation or management strategies?

What is a population?

From Krebs (1972): â€œA population is defined as a group of organisms of the same species occupying a particular space at a particular time, with the potential to breed with each other'

Spatial boundaries defining populations sometimes are easily defined, but more typically are vague and difficult to determine.

Population size, or abundance, is often represented as N, and is the most basic measurement of a wild population.

Exponential growth: the fundamental principle of population ecology

Giant puffballs produce 7 trillion offspring in one reproductive event ... If all of those individuals reached adulthood, the descendants from just two parent puffballs would weigh more than the entire planet in two generations!

The reason? Populations exhibit a process called **exponential growth**, in which each new addition to the population expands the reproductive potential of the population in a **positive feedback loop**. This is the

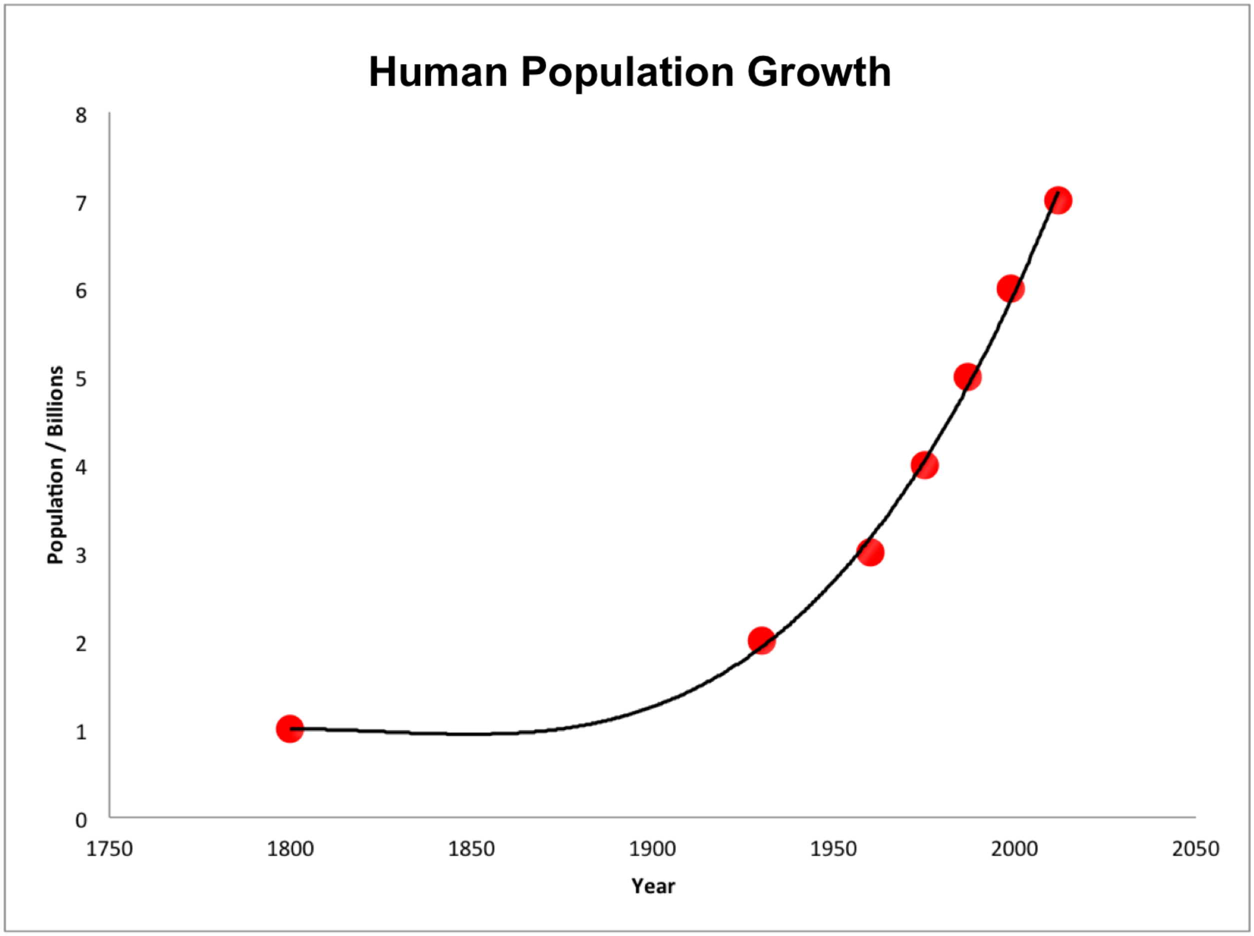
Human Population Growth
8
7
6
5
4
3
2
1
0
Population / Billions
1750
1800
1850
1900
1950
2000
2050
Year

Figure 1:

Figure 2:

Figure 3:

most basic concept in population ecology. We will go over this concept in detail in upcoming in-class activities and labs.

Mathematics and Population Ecology

'Mathematics seems to endow one with a new sense.'
- Charles Darwin

'Like most mathematicians, he takes the hopeful biologist to the edge of the pond, points out that a good swim will help his work, and then pushes him in and leaves him to drown'
- Charles Elton, in reference to a work by Alfred Lotka

The importance of the method is this: if we know certain variables, mostly desired by ecologists and in some cases already determined by them, we can predict certain results which would not normally be predictable or even expected by ecologists. The stage of verification of these mathematical predictions has hardly begun; but their importance cannot be under-estimated, and we look forward to seeing the further volumes of Lotkaâ€™s studies.
- Charles Elton

Population ecology is central to many of the most pressing questions in modern day ecology and evolution

This class is mostly about how important Population Ecology is to wildlife conservation and management. But it is worth mentioning that Population Ecology is a very active field of basic science, and that population ecology is at the core of many of the central questions of ecology and evolution.

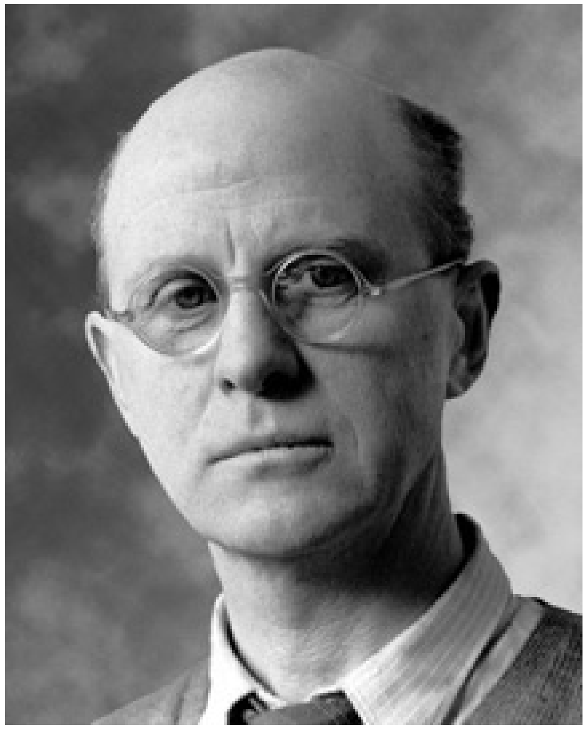

Figure 4:

These questions are from Sutherland et al. 2012. This paper is on WebCampus (optional). Of course there are many more interesting questions- limited only by your imagination.

You may not understand all these questions now- we will revisit this list at the end of the semester!

- What are the evolutionary consequences of species becoming less connected through **fragmentation** or more connected through globalization?
- What are the evolutionary and ecological mechanisms that govern speciesâ€™ **range margins**?
- How can we upscale detailed processes at the level of individuals (e.g., behavioral interactions) into patterns at the population scale?
- To what degree do trans-generational effects on life histories, such as maternal effects or epigenetic factors, impact population dynamics?
- What is the relative importance of direct (**predation, competition**) vs. indirect (induced behavioural change) interactions in determining the effect of one species on others?
- What demographic traits determine the **resilience** of natural populations to disturbance and perturbation?

And many more!

- In what ecological settings are **parasites** key regulators of population dynamics?
- How does species loss affect the extinction risk of the remaining species?
- How important are **dynamical extinction-recolonization equilibria** to the persistence of species assemblages in fragmented landscapes?

Figure 5:

Figure 6:

Figure 7:

Figure 8:

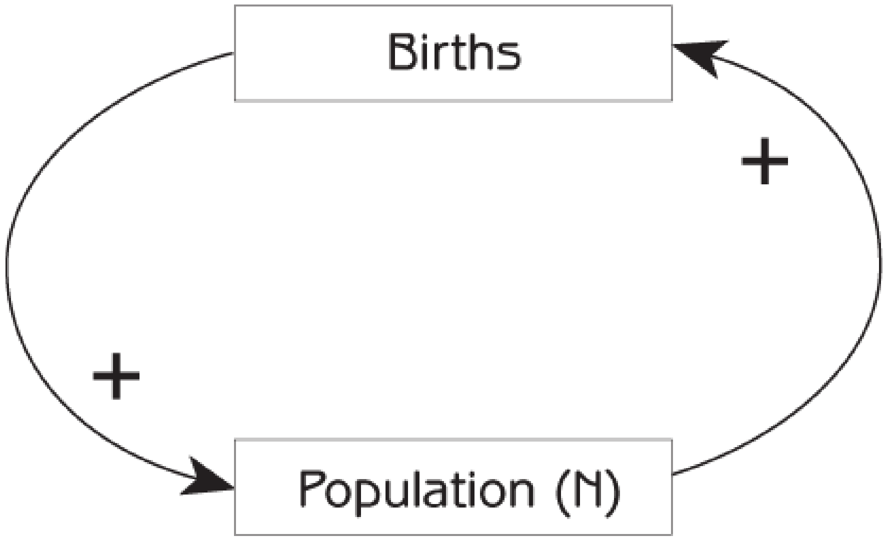

Figure 9:

- How do **resource pulses** affect resource use and interactions between organisms?
- How important are rare species in the functioning of ecological communities?
- What is the magnitude of the **â€˜extinction debtâ€™** following the loss and fragmentation of natural habitats, and when will it be paid?
- To what extent will climate change uncouple trophic links due to phenological change?
- How do natural populations and communities respond to increased frequencies of **extreme weather events** predicted under global climate change?
- In the face of rapid environmental change, what determines whether species adapt, shift their ranges or go extinct?
- What determines the rate at which species distributions respond to climate change?
- Under what circumstances do landscape structures such as **corridors** and **stepping stones** play important roles in the distribution and abundance of species?
- How do **interspecific interactions** affect species responses to global change?
- To what extent are widely studied ecological patterns (species-abundance distribution, **species-area relationship**, etc.) the outcomes of statistical rather than ecological processes?
- How much does modelling **feedbacks** from the observation process, such as the responses of organisms to data collectors, improve our ability to infer ecological processes?

In-class Exercise: Feedbacks

Feedbacks occur when the inflows and outflows (e.g., births and deaths) depend upon the value of the stock (e.g., a wildlife population!).

Feedbacks are what lead to complex ('interesting') system behaviors.

A reinforcing, or **positive feedback** (often called a 'vicious circle') leads to *exponential growth*, leading quickly to insanely high numbers! If you don't understand this yet, you will see soon enough!

A **negative feedback** is stabilizing, leading to nice, orderly, regulated systems (and homeostasis in organismal biology!).

In the previous in-class exercise the model structure produced linear growth as the [Flow] added to the [Stock].

1. What do the following have in common: snowball, people, rabbits, fire, bacteria, fleas, savings accounts, cancer?

Let's build a model to help us better understand this process.

This model adds a **feedback** using a [Link] from the [Stock] to the [Flow]. The [Link] communicates the value of the [Stock] to the [Flow]. A [Link] only communicates information transfer from one element of the model to another, it doesn't actually change the value of the [Stock] (that is what a [Flow] does).

2. Open InsightMaker. Create a [Stock] and a [Flow] as you did in the previous model (flow should be an input, not an output) and just name them *Stock* and *Flow* for now.
3. If you mouse over *Stock* or *Flow* a small [= Sign] will appear. If you click this it will open the **Equation** window where you can set values. Open this window for the [Stock], enter a value of 1, then close the window.
4. The value of the [Stock] can be communicated to the [Flow] with a [Link] (representing a feedback process!). To create a [Link], click **Link** in the **Connections** part of the toolbar (at the top). When you mouse over the [Stock] click on the blue arrow, drag the [Link] to the [Flow] and release. You now have a [Link] on top of the [Flow]. Now hold the Shift Key and click in the middle of the [Link] and a little little green node will be created on the [Link]. You can select this node and drag it up so the [Link] isn't directly on top of the [Flow] (now you can see the [Link]).
5. Usually there is some type of factor governing the **rate** the [Stock] influences the [Flow]. Let's introduce a variable named *Rate*. To create a variable, right-click on the canvas and select **Variable** from the drop-down. Now draw a [Link] from *Rate* to the [Flow]. Open the **Equation** window for *Rate* and set it to 0.5.
6. Open the **Equation** window for the [Flow] and set it to [Stock] times [Rate]. That is, the total inflow into the [Stock] is equal to the value of the [Stock] multiplied by the value of *Rate*.
7. Now click [Run Simulation] and you have just finished your first reinforcing loop simulation model! Does it do what you would expect?

Q: If [Stock] is a population – say, rabbits – then what is the interpretation of [Flow]? What is the interpretation of *Rate*? *Rename your variables accordingly* and change the parameters to make the more biologically realistic. Run the simulation again.

8. Just like in the last exercise, set the 'Show Value Slider' to "Yes" for the [Stock] and the *Rate* parameter. Now you can play around with the values, re-running the simulation each time. Think about *question 1* while doing this (snowball, people, rabbits, fire, bacteria, fleas, savings accounts, cancer). How would you change the values to represent each of these quantities? Pick 2 or more of these and try it out!

You should notice that the population tends to grow slowly at first and then very rapidly. This is referred to as *exponential growth*. If you've read the first chapter of the Gotelli book, you will recognize this as the *foundational concept of population ecology*!

Q Can you model the puffball example from earlier in the lecture? How many giant puffballs are in the population after two generations??

Q Can you (approximately) replicate the human population graph at the beginning of this lecture? What is the per-capita growth rate of the human population??

And just for fun, here is a video about exponential growth you might want to check out..

–go to next lecture–