Lecture 4

Stochasticity

WILD3810 (Spring 2020)

Readings

> Mills 84-92

Assumptions of the B-D models

Remember from the lecture 3 that our simple models of population growth were based on the following assumptions:

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3) Birth and death rates are independent of an individual’s age or biological stage

4) Birth and death rates are constant

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The B-D population model ignored all of these sources of variation

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Just because something is stochastic doesn't mean it's completely unpredictable

Stochasticity

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In population models, we can use probability to characterize and account for stochastic processes that effect population growth

Two types of stochastic processes

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1) **Environmental stochasticity**

> variation in the *mean* demographic parameters and population growth that occurs due to random changes in environmental conditions

2) **Demographic stochasticity**

> variability in demographic parameters and population growth that arises from random outcomes among *individual* survival and reproductive fates due to random chance alone

Environmental stochasticity

Environmental stochasticity

The expected value of demographic parameters can fluctuate over time in response to:

- rainfall
- temperature
- fires and disturbance
- competitors
- predators
- pathogens

Environmental stochasticity

If environmental attributes change stochastically over time, so will demographic vital rates and population growth rate

Modeling environmental stochasticity

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Over years, abundance will be:

Modeling environmental stochasticity

For example, if and:

then:

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What *is* the average (which we'll call)?

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In our example, this equals:

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But that can't be right!

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The issue that the population growth is a multiplicative process

This means that shrinking by 30% and then growing by 30% does not get you back to where you started

Modeling environmental stochasticity

To estimate the average of a multiplicative process, we need to take the *geometric* mean rather than the arithmetic mean:

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For our population, that means:

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> Populations with variable growth rates will tend to grow more slowly (or decrease faster) than populations in constant environments even if their mean vital rates are the same.

Modeling environmental stochasticity

Let's see what that looks like:

Modeling environmental stochasticity

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Initially, assume a large population with:

-
-
- and **neither parameter varies over time**

Thus:

Modeling environmental stochasticity

Over 100 years, the population growth will be:

Modeling environmental stochasticity

Now let's look at the dynamics of a second population with the same starting population size, the same mean demographic rates but with annual variation of 20%

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Finally, let's add a third population with the same starting population size, the same mean demographic rates but now with annual variation of 40%.

Modeling environmental stochasticity

Because environmental stochasticity tends to reduce regardless of population size, it has important consequences for the extinction risk of **both small and large populations**

We'll explore this idea more in lab

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Demographic stochasticity is essentially the difference between the **expected** survival/reproductive rate and the **realized** rates in our population.

Demographic stochasticity

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Going back to the coin flip, if we flip the coin 1000 times, we would expect to get pretty close to 50% heads

But as the number of flips gets smaller, the realized success rate could differ more from the expected value

Effects of demographic stochasticity

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To see this in action, we can use R to simulate the abundance of populations that experience demographic stochasticity

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Effects of demographic stochasticity

Demographic stochasticity increase extinction risk of small populations because there's an increased chance that, purely due to randomness, more individuals die than are born

At large abundances, this is much less likely

Stochasticity and extinction risk over time

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Given long enough, each population will eventually experience a string of years with high mortality and low reproductive success

The time it takes for this to occur will be longer for large populations but even still, it will eventually happen

Stochasticity and extinction risk over time

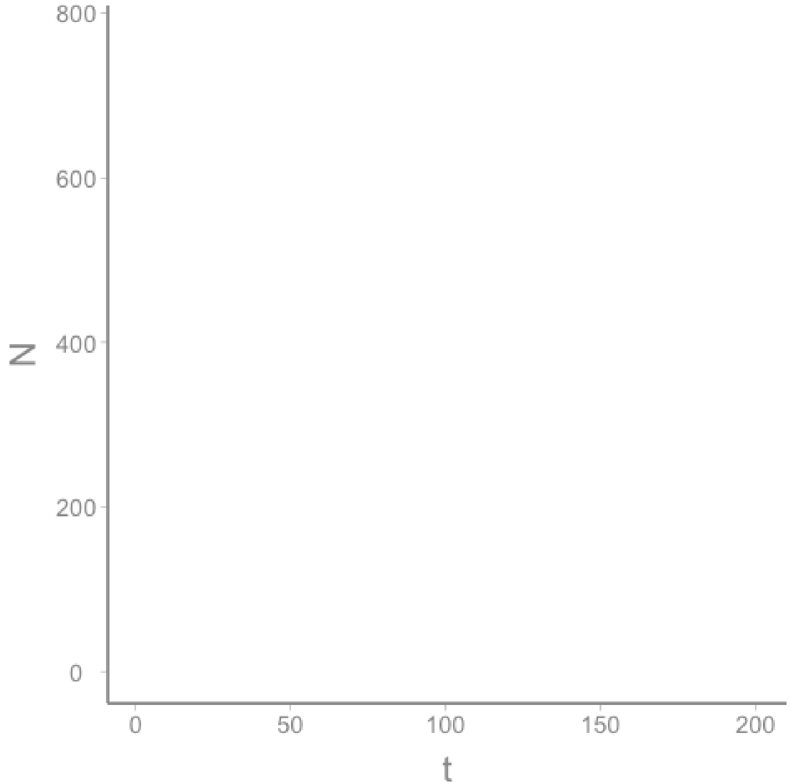
Again, we can use data simulations to show this:

Stochasticity and extinction risk over time

Again, we can use data simulations to show this: If we start with populations of 100 individuals and simulate 50 years of population change, 1% of populations go extinct

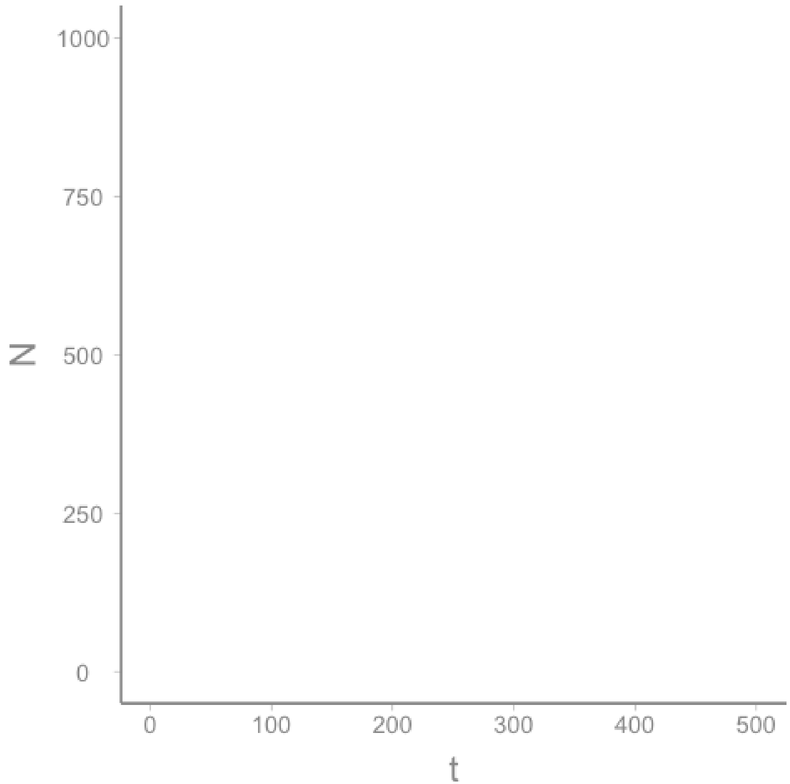
Stochasticity and extinction risk over time

If we extend our simulation out to 200 years, 23% of populations go extinct



Stochasticity and extinction risk over time

500 years? 57% of populations go extinct



Stochasticity and extinction risk over time

10,000 years? 99% of populations go extinct