Lecture 3

Introduction to population growth

WILD3810 (Spring 2019)

Readings:

> Mills 79-84

Abundance

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Abundance

> the number of individual organisms in a population at **a particular time**

- Is the number of individuals of a threatened/endangered species growing or shrinking?
- Is the abundance of a game species stable in the face of hunting pressure?
- Is a non-native species increasing in abundance to the point where it could cause ecosystem harm?

The BIDE model

Remember from lecture one:

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Abundance can due to:

- births
- deaths
- immigration
- emigration

The BIDE model

The **number** of births or deaths is not usually useful

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Instead, births or deaths are often expressed as per capita (per individual) rates

Think of these as averages:

The BIDE model

Because   and   (and assuming no movement), the BIDE model can be written as:

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Because and (and assuming no movement), the BIDE model can be written as:

Which can be simplied to:

Discrete-time population growth model

The terms is usually expressed as a single parameter :

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is referred to as the **finite rate of population growth**

Properties of

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- What is the value of when the birth rate equals the death rate ?

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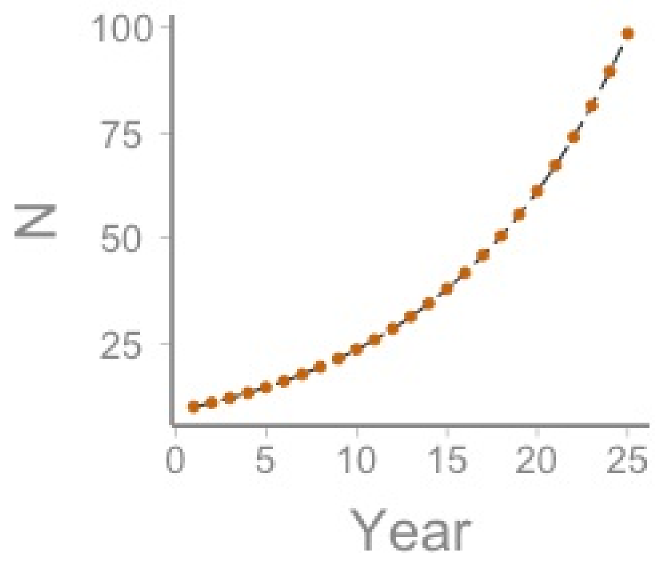
Properties of

- What is the value of when the birth rate equals the death rate ?
- What is the value of when the birth rate exceeds the death rate ?
- What is the value of when the birth rate is less than the death rate ?
- What happens to the abundance of the population under each scenario?



Discrete-time population growth model

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First, write the forumula for from :

We know that so:

which simplifies to:

Discrete-time population growth model

Growth from to :

So we get the general form :

where is the number of years (or weeks, or months), is the final population size and is the initial population size.

Discrete vs. continuous time

The discrete population growth model is useful for **birth-pulse** species:

> all births happen at a single point in time (i.e, a pulse)

Discrete vs. continuous time

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Change in abundance of birth-pulse species happens at discrete point in time

- usually during distinct breeding season

Discrete vs. continuous time

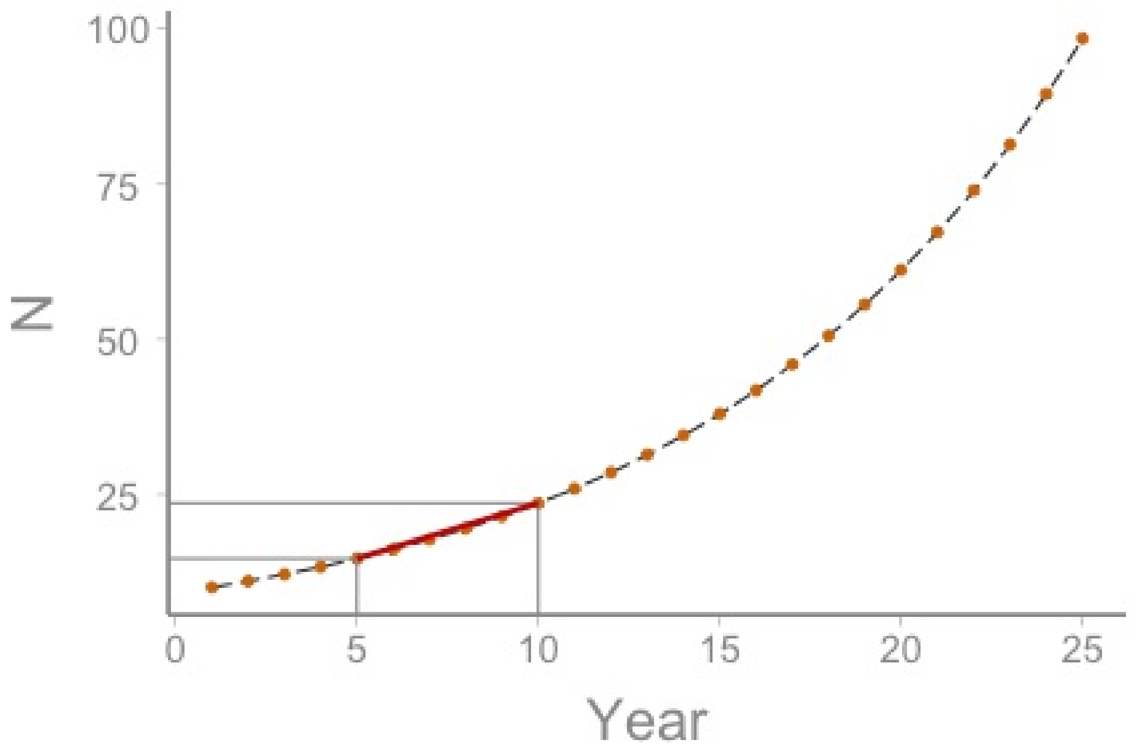
Species that reproduce throughout the year are called **birth-flow** species:

> births happen continuously throughout the year (i.e, flow)

Abundance of birth-flow species is always changing

Continuous-time population models

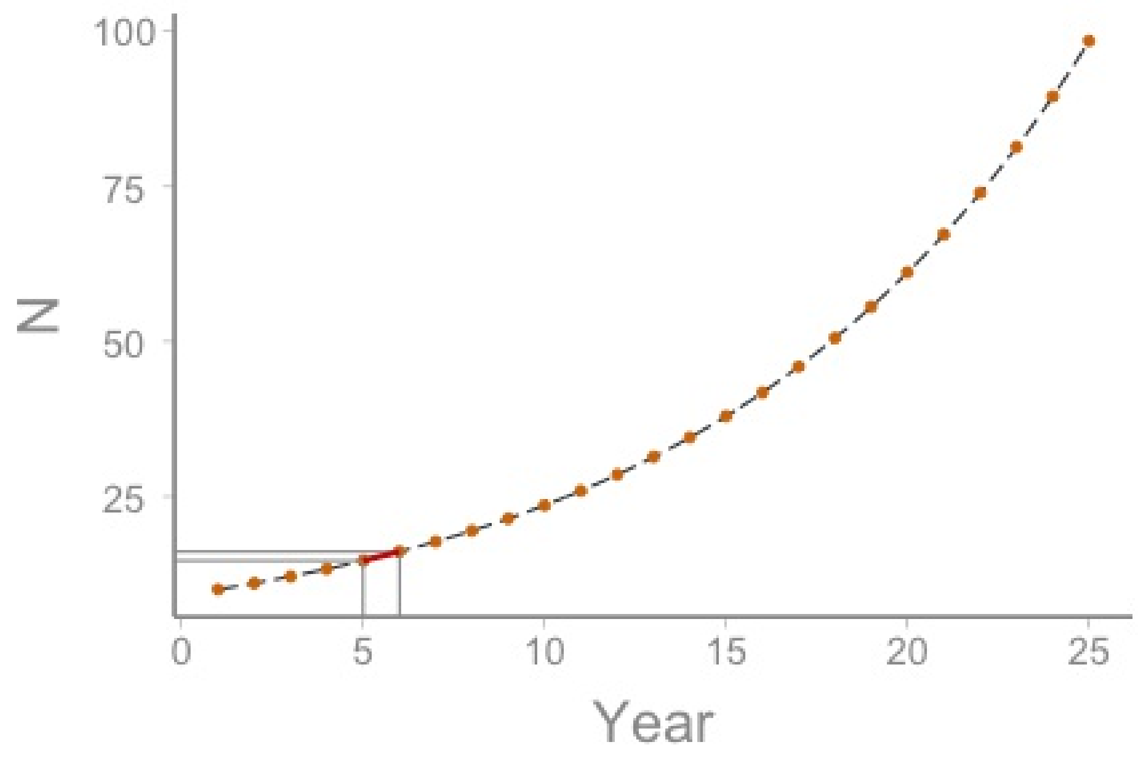
We could model the growth of birth-flow populations using the discrete model and by making very small.



In this figure, and = 8.94 individuals . So the population increased by about 61% over a 5 year period. What if we make smaller?

Continuous-time population models

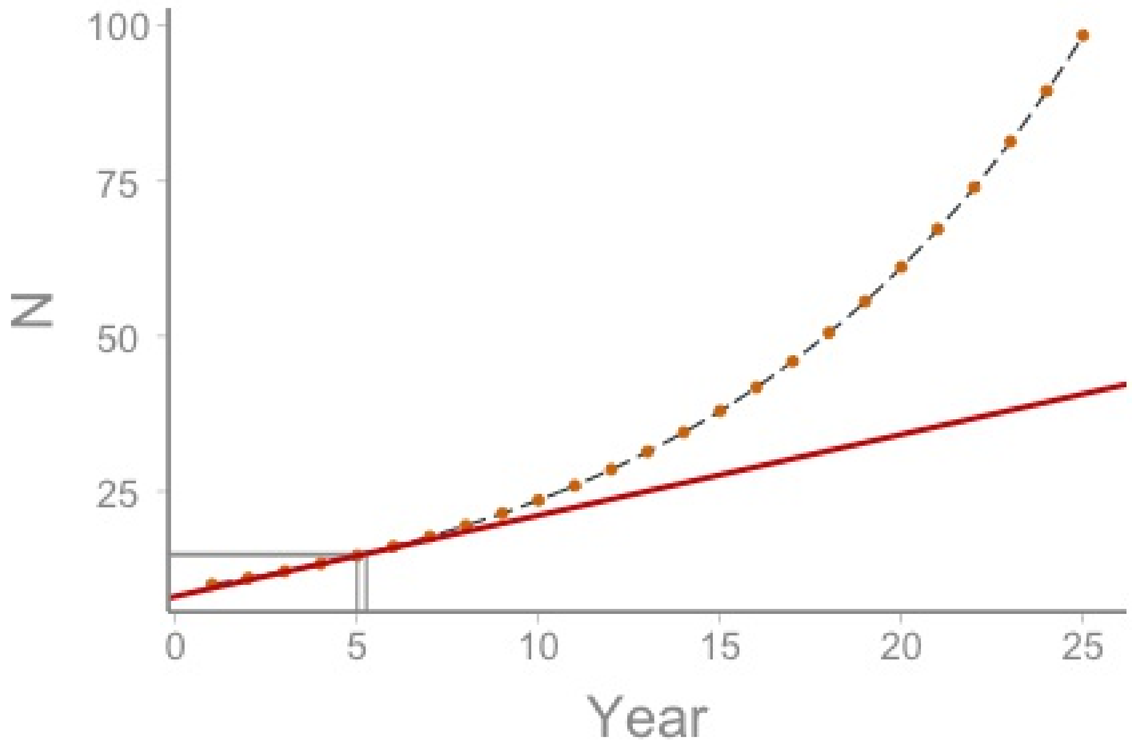
:



= 1.46

Continuous-time population models

:



= 0.33

Continuous-time population models

Rather than manually making smaller and smaller, we can use calculus to figure out that as becomes really, really small (i.e., approaches zero), we end up with:

This the continuous-time equivalent of the discrete model and is called the **instantaneous growth rate**

Continuous-time population models

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Populations with remain at the same population size. Populations with grow and populations with will shrink.

Continuous-time population model

How does compare to ?

Continuous-time population model

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So for a continuous-time model, we can project population growth by substituting in the equation we used to project discrte population growth:

Doubling time

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Start by dividing both sides by :

Doubling time

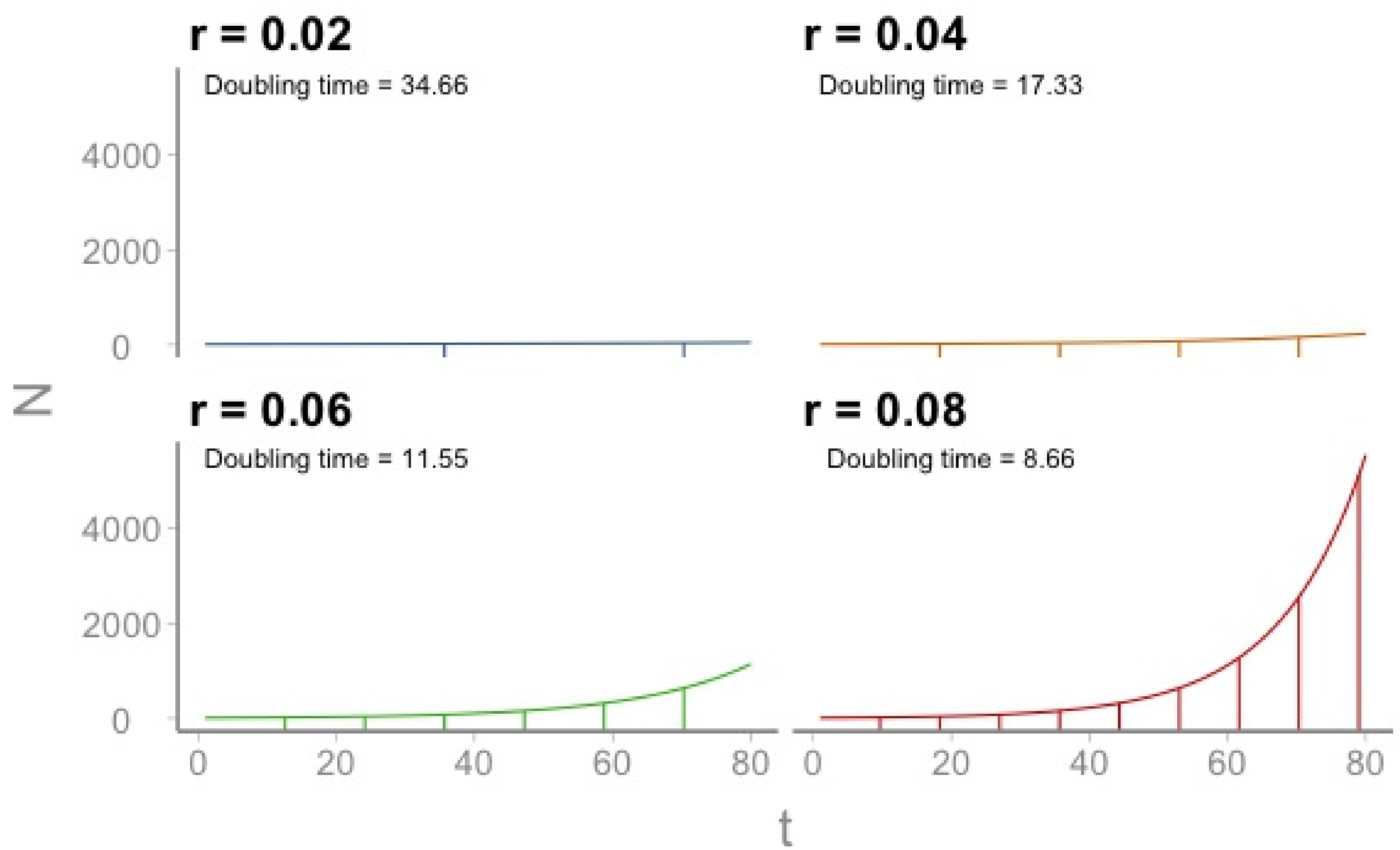
To isolate , take the natural log of both sides:

Doubling time

To isolate , take the natural log of both sides:

Now divide both sides by :

Doubling time



Relatively small changes in   can have profound effects on population doubling time   :

- The population with   doubled twice in 80 timesteps
- The population with   doubled 9 times!

Exponential growth

Note that the doubling time does not depend on population size - the population will double every time steps, no matter what the population size is

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Density-independent population models result in **exponential** growth

- exponential growth occurs because the growth rate is multiplied by the population size at each timestep
- As the population grows, the proportional changes stays the same but the absolute changes get bigger and bigger .

Exponential growth

Exponential growth has profound implications

Imagine putting $1000 in a investment that grows by 6.5% per year:

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- After 10 years, the investment will be worth $1912.69 (~90% return)
- After 20 years, the investment will be worth $3658.38 (~265% return)
- After 30 years, the investment will be worth $6997.33 (~600% return)!

> "Compound interest is the most powerful force in the universe" - Albert Einstein (maybe)

Exponential growth

Example

Tasmanian sheep

- 1820: 200,000 sheep introduced on the Island of Tasmania, Australia
- 1850: 2 million sheep
- 9-fold increase in 30 years

Exponential growth

Example

Ring-necked pheasants

- In 1937, 2 male and 6 female ring-necked pheasants were released on Protection Island, Washington
- 1942: 1,325 adults (Einarson 1942, 1945)
- 220-fold increase in 5 years!

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More often, we have estimates of abundance at different points in time. To estimate population growth for one time step:

Estimating and

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- Sheep: 1.08
- Pheasants: 2.94

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4) Birth and death rates are constant