Density-independent population growth

<u>Learning goals</u>

1. Read p1-8 of Vandermeer and Goldberg 2013: *Population Ecology* - be able to solve all the Exercises.
2. Be able to calculate the future population size at any time, t.
3. Be able to calculate the time, t, when the population size is a specific value.
4. Be able to sketch a graphs, and know how λ affects increases/decreases in population size.
5. Know how to estimate parameters from data (Protection Island exercise).
6. Know the assumptions of density-independent population growth.
7. Be able to give an example of a population that might undergo density-independent population growth
8. Be able to identify/know the difference between discrete time and continuous time formulations of density-independent population growth formulations and assumptions.

General formula for future population size: no immigration/emigration

$$N_{t+1} = N_t + \text{births} - \text{deaths}$$

Variables

N_{t+1} : popn size next year (number)

N_t: popn size this year (number)

t: time in years (or the number of years since starting the study)

births: number of births each year that survive to next year

deaths: number of deaths each year

Geometric growth (density-independent)

$$N_{t+1} = N_t + bN_t - dN_t$$

N_{t+1} : popn size next year (number)
N_t: popn size this year (number)
b: per capita number of surviving births each year (unitless)
d: fraction of popn that dies each year (unitless)

$$N_{t+1} = N_t + \text{births} - \text{deaths}$$

bN_t: Number of surviving births this year (number)
dN_t: Number of deaths this year (number)

Geometric growth rate, λ

$$N_{t+1} = N_t + bN_t - dN_t$$

$$N_{t+1} = \lambda N_t$$

Variables

N_{t+1} : popn size next year (number, N_{t+1} ≥0)

N_t: Popn size this year (number, N_t≥0)

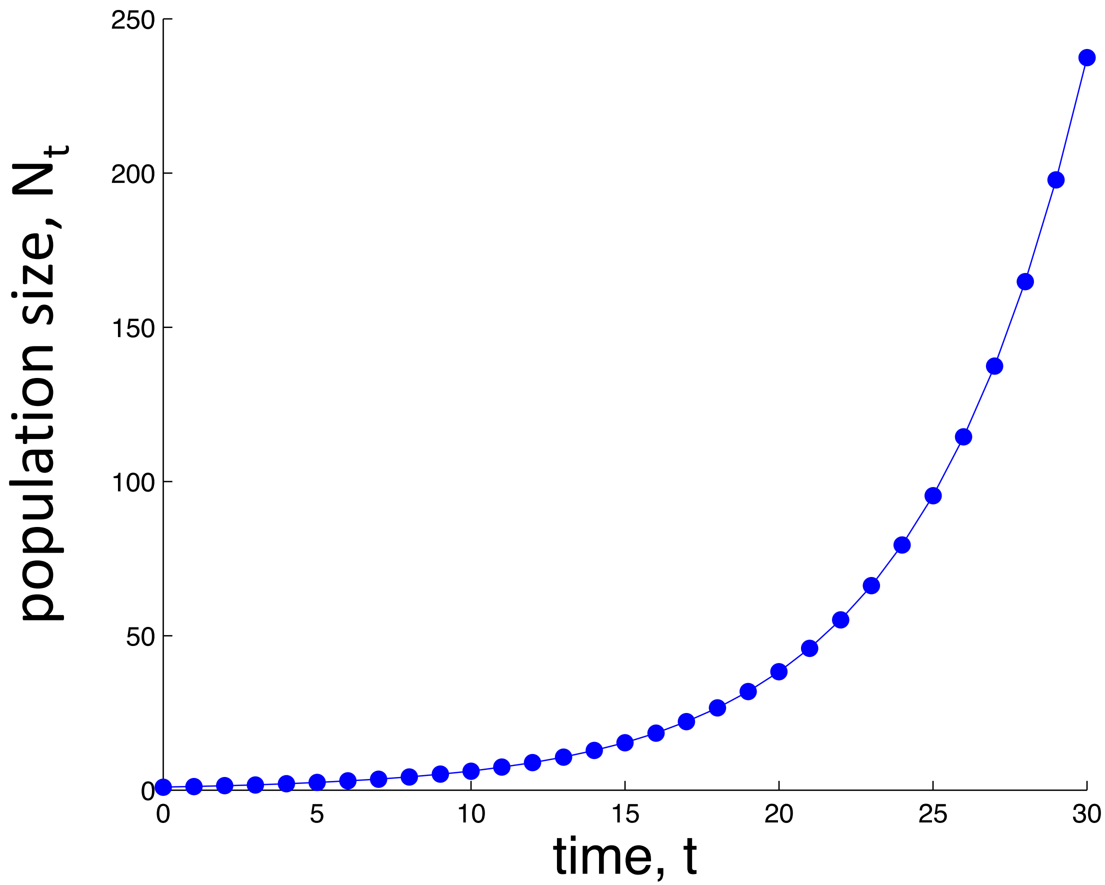
Parameters

b: per capita number of surviving births each year (unitless; b≥0)

d: fraction of popn that dies each year (unitless; 0≤d≤1)

λ = 1+b-d: geometric rate of increase/decrease (unitless; *λ*≥0)

Geometric growth is density-independent population growth (discrete time)



What are examples of species whose population sizes increase/decrease geometrically/exponentially?

i.e. density-independent population growth

Note: for these examples the time step may not be 1 year

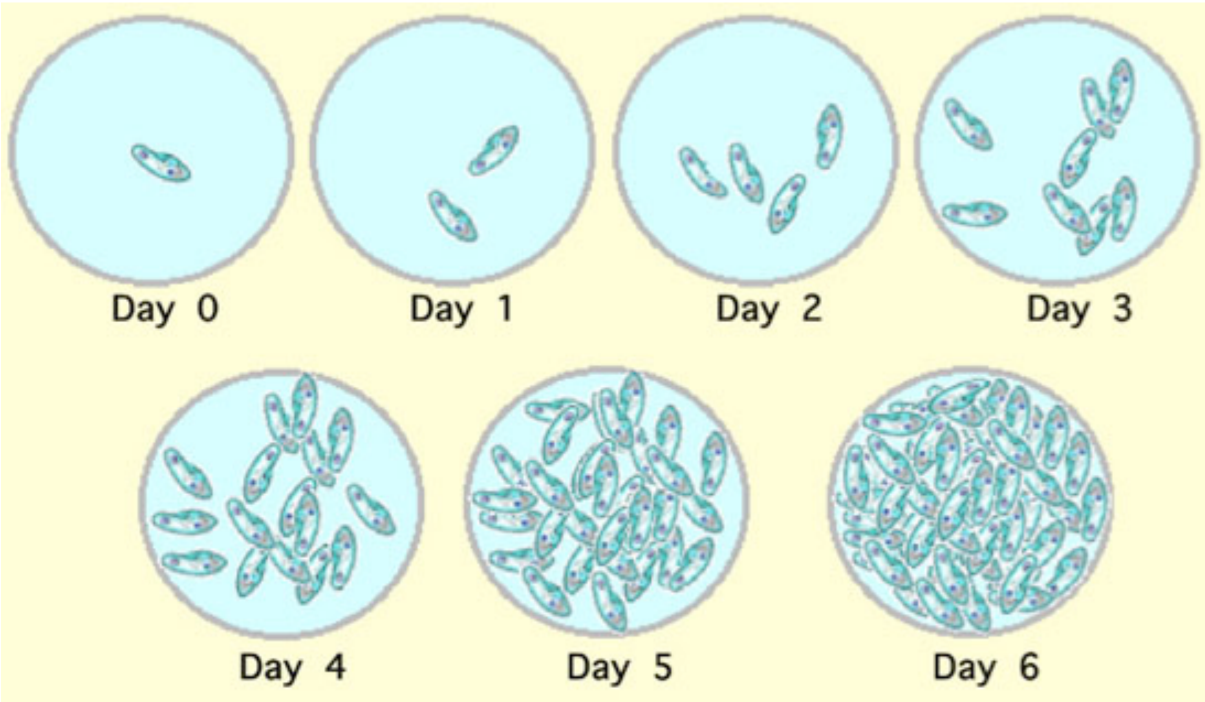
Aside: Discrete vs. continuous time

Discrete time

- Offspring take 1 time step to be reproductive
- Births occur during a short window of the time step
- Density-independent growth is referred to as *'geometric growth'* (except some, including Vandermeer and Gordon, use 'exponential growth')

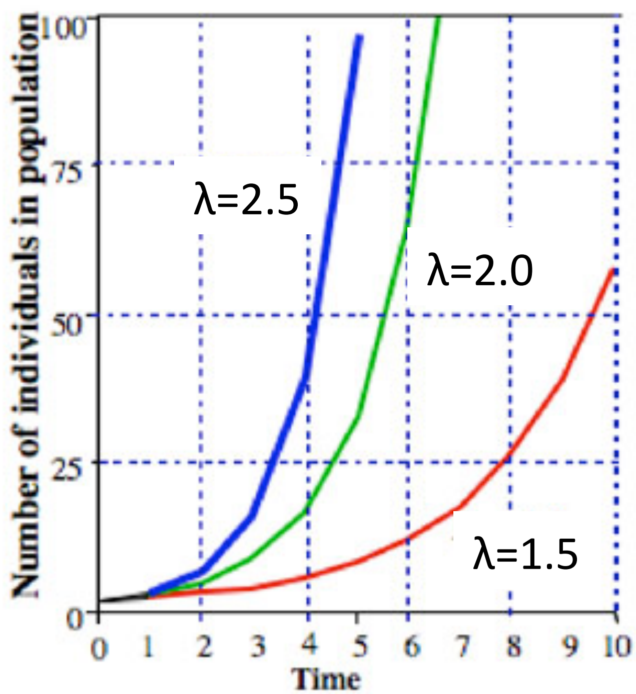
Continuous time

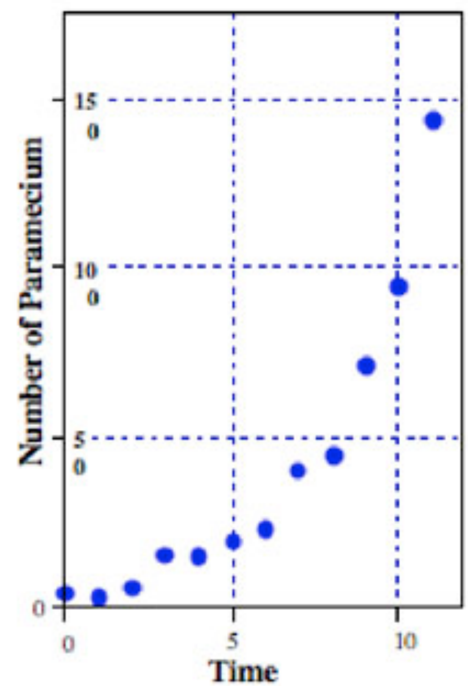
- Offspring can immediately reproduce
- Births occur at any time (not pulse reproduction)
- Density-independent growth is referred to as *'exponential growth'*



The first 6-10 days of Paramecium growth in a lab culture

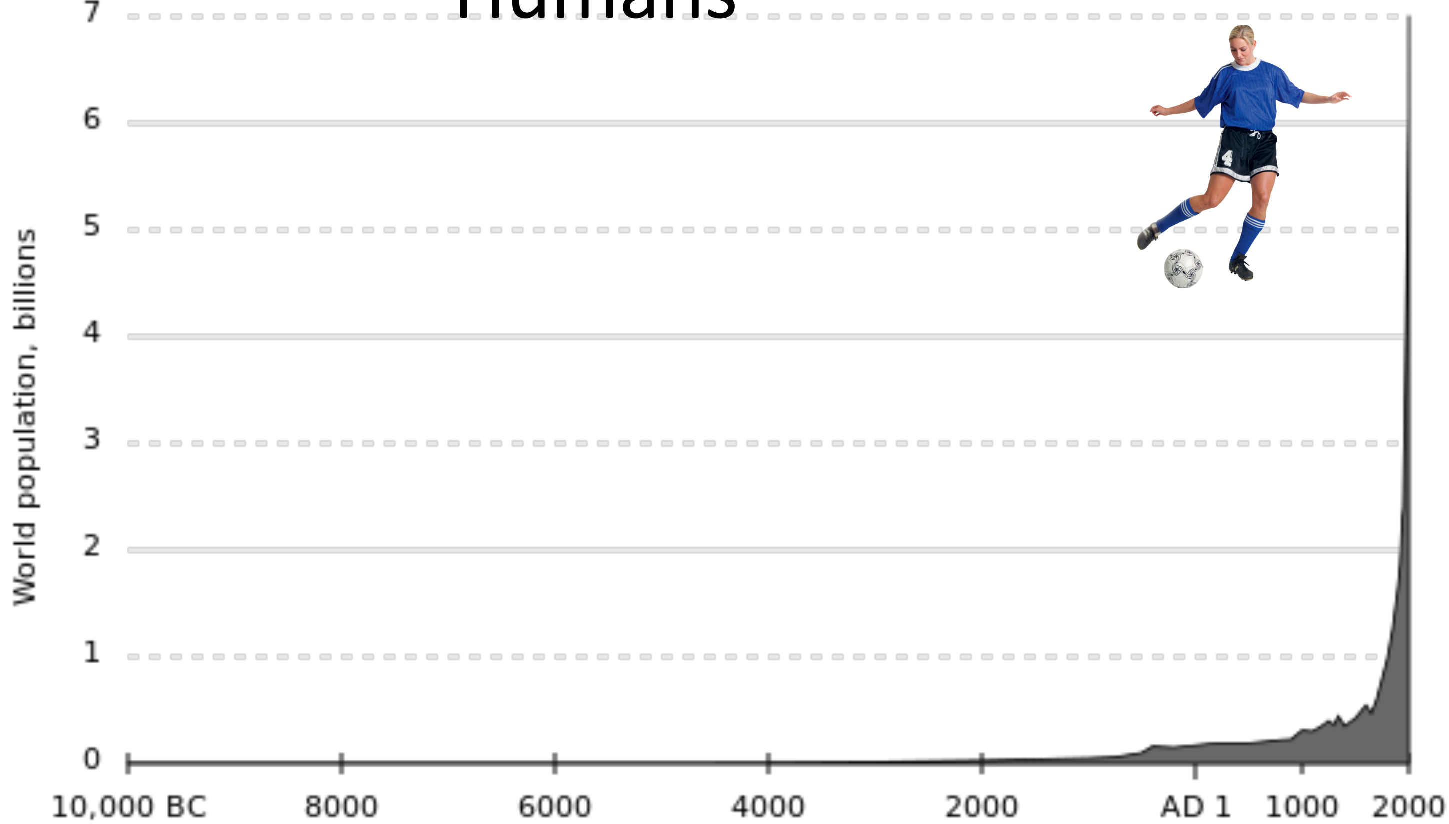
Image credits: Vandermeer 2010. [How poulations grow: The exponential and logistic equations](). Nature Education Knowledge Project





Continuous time

Humans



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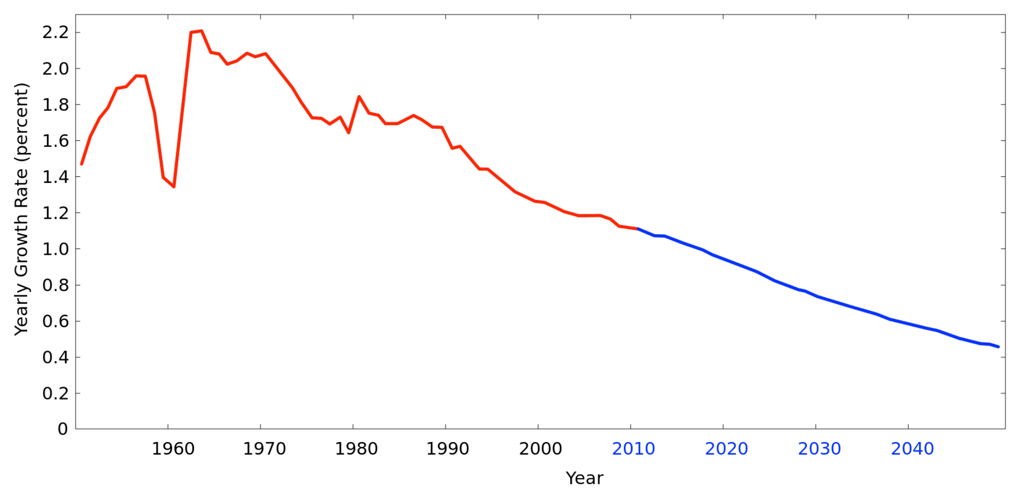


Image credit: Conscious

Continuous time

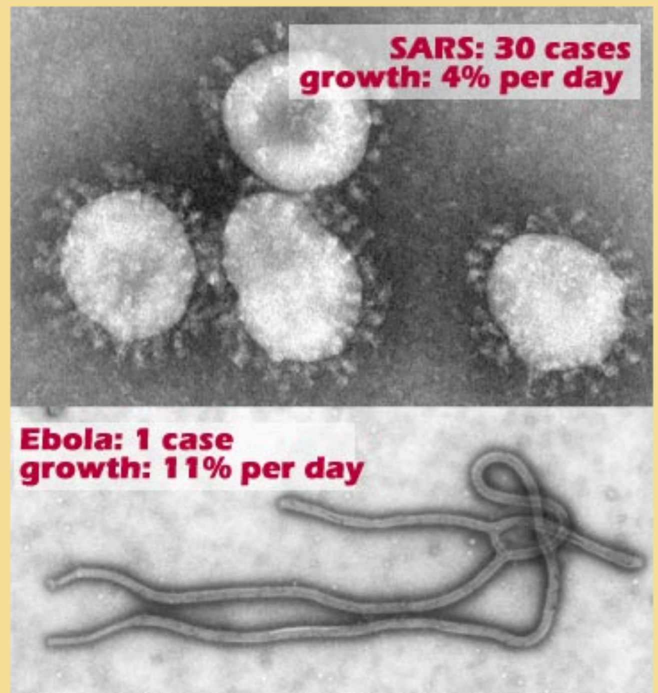
The number of people infected with a disease at the beginning of an outbreak when no vaccine is available

[Math Bench: Biology Modules](#)

Viral growth

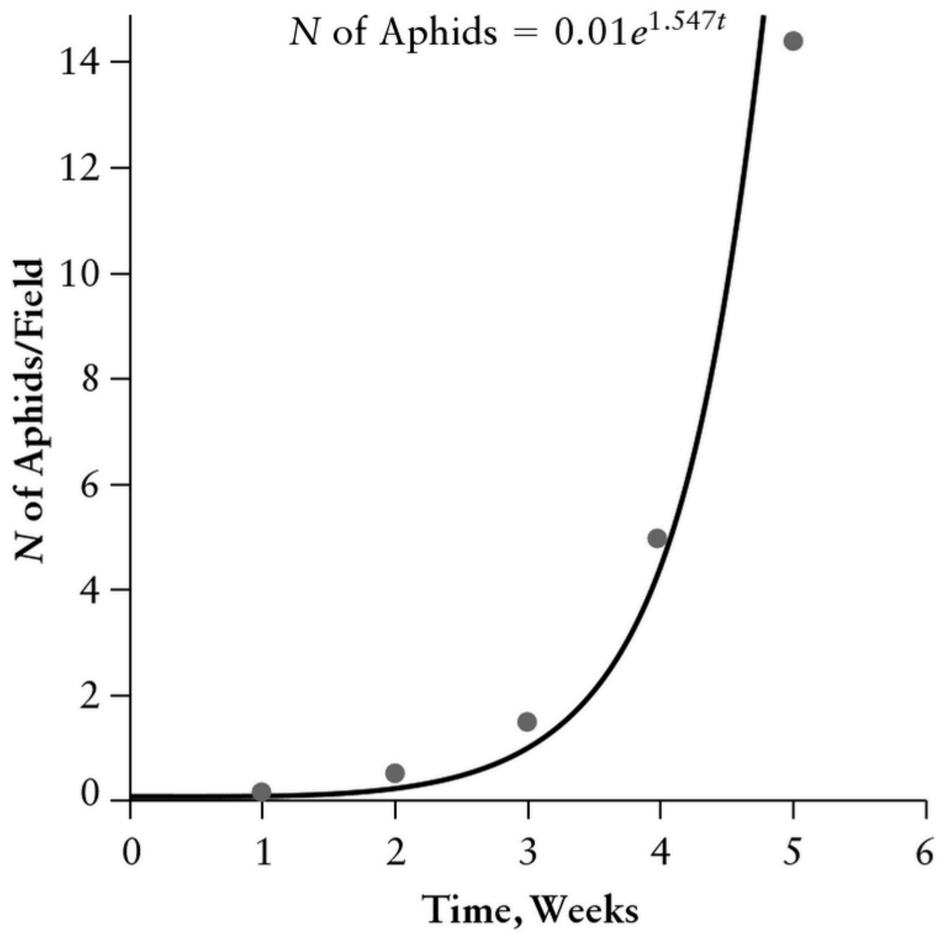
A virus will typically spread exponentially at first if there is no immunization available. Each infected person can infect multiple new people. SARS (Severe Acute Respiratory Syndrome) and Ebola are two such viruses whose impact to affected areas can be devastating. Knowing the rate at which they typically spread is important when you are trying to contain and treat an outbreak.

Suppose you are working at an international aid organization and there are simultaneous outbreaks of SARS and Ebola. Your organization has only enough resources to travel to and help in one location. Do you rush to help the SARS infected community or the Ebola?



Continuous time

Aphid growth during the first 6 weeks



Discrete time?

Vandermeer, JH and Goldberg, DE. 2013. *Population Ecology: First Principles (2nd Edition)*.

Reindeer growth on islands prior to lichen overgrazing

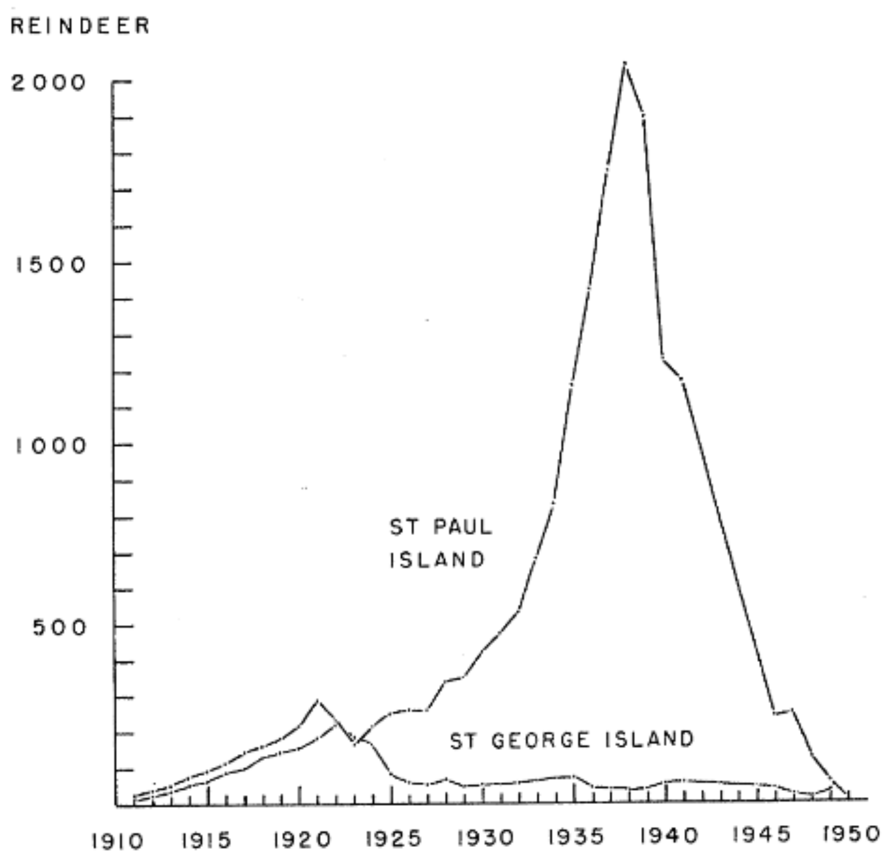


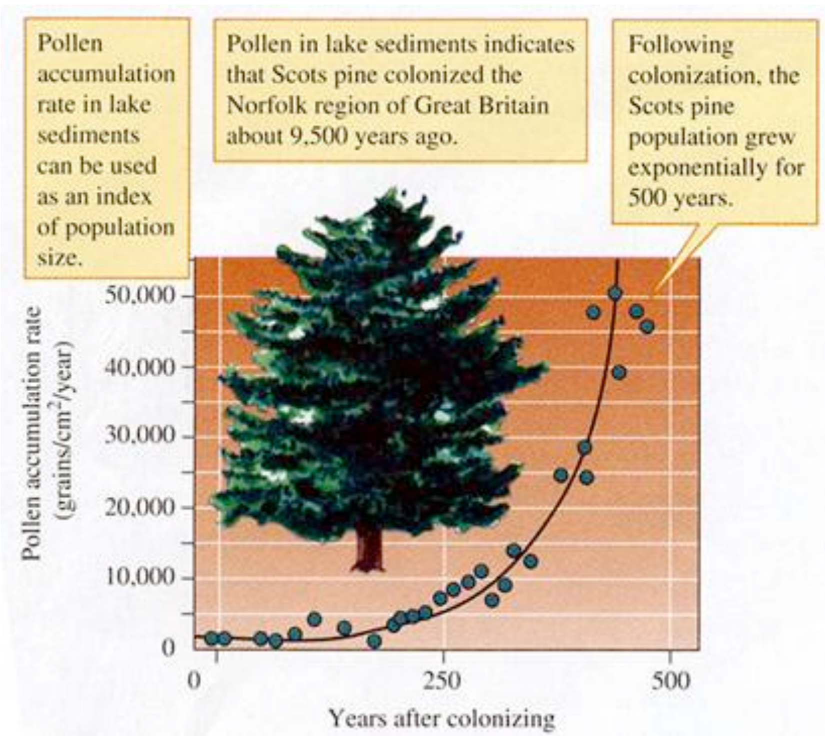
FIG. 1. Reindeer populations of the Pribilof Islands from 1911 to 1950. (Each point represents the combined number of deer killed for food and spared or, in years when no animals were killed, the number of deer counted at the end of the year. From Table 1.)

Photo credit: Alexandre Buisse

Scheffer, VB. 1951. *The rise and fall of a reindeer herd.* The Scientific Monthly.

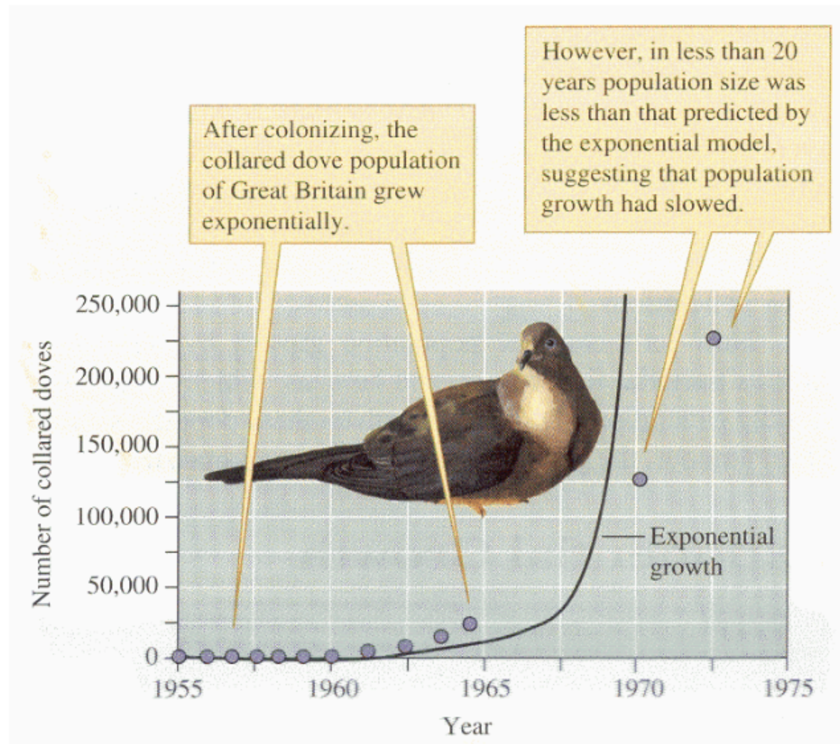
Discrete time

Scots pine colonizing in Britain



Discrete time

Collared dove in Britain



Discrete time

Molles, MC. 2012. *Ecology: concepts and applications*.

There are many examples of density-independent population growth in nature, but

- they apply only to the *initial* phase of population growth

- several examples are from islands were populations are protected form predators