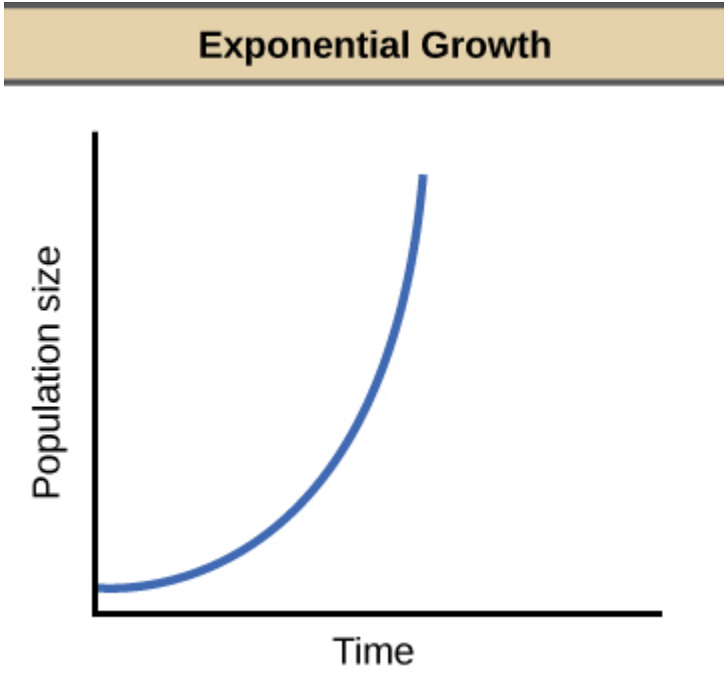
Population Ecology: Part 2

Learning Objectives

1. Define and describe the following terms: population density, carrying capacity (K)
2. Explain what factors can cause populations to reach their carrying capacity, K and connect this idea to population growth (S curves)
3. Predict population size using logistic growth models ($N_t = N_1 + rN_1 [(K - N_1)/ K]$)
4. Visually represent how populations change over time by constructing graphs

Let's take a step back: Exponential growth

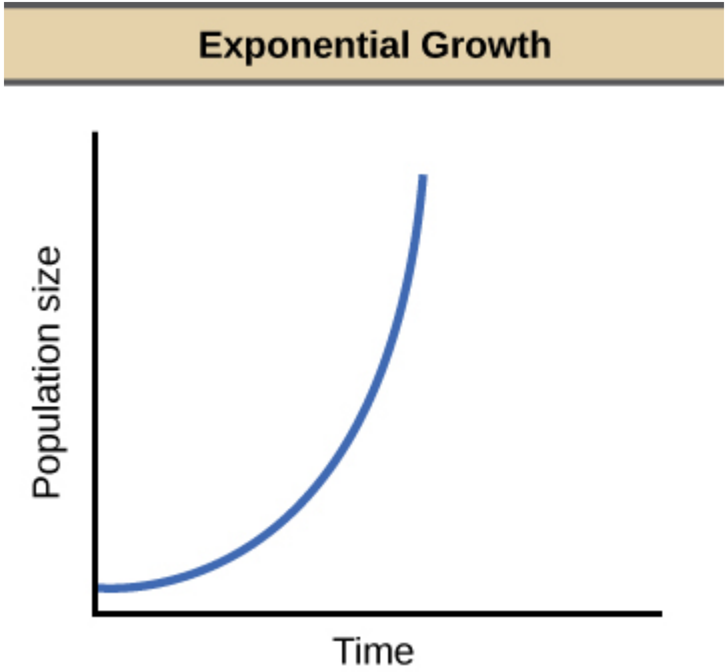
- Exponential growth – Populations grow indefinitely
- $N_t = N_0 \times (1 + r)^{\Delta t}$
- $N_{t+1} = N_1 + r(N_1)$
- Where
  - Δt represents change in time, or difference in time between now (t) and start time (0)
  - N = population size (you might see either N_1 or N_0, meaning initial population size)
  - r = per capita growth rate



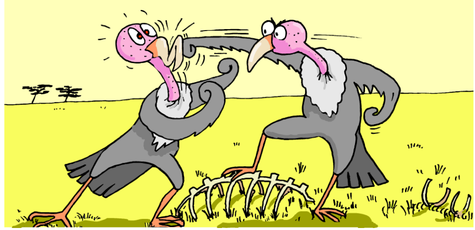
Let’s take a step back: Exponential growth

- What are some of the assumptions for this to work?

- What kind of populations would you expect to observe experiencing exponential growth?



Nature is rough…



- In nature, most of the assumptions for exponential growth are violated:
  - At some point resources will become limiting and within species competition (intraspecific competition) will increase
  - Higher density increases risk of spreading diseases
  - Natural disturbances will occasionally increase mortality

$\Rightarrow$ Growth rate will decrease

C1: Which of these factors is independent of the density of a population?

A. Resources will become limiting and intraspecific competition will increase
B. Risk of disease goes up as the number of individuals in the population increases
C. A hurricane wipes out over half of a population of fish
D. All of the above
E. A and B only

C1: Which of these factors is independent of the density of a population?

A. Resources will become limiting and intraspecific competition will increase
B. Risk of disease goes up as the number of individuals in the population increases
C. **A hurricane wipes out over half of a population of fish**
D. All of the above
E. A and B only

C2: Which of these factors is dependent on the density of a population?

A. Resources will become limiting and intraspecific competition will increase
B. Risk of disease goes up as the number of individuals in the population increases
C. A hurricane wipes out over half of a population of fish
D. All of the above
E. A and B only

C2: Which of these factors is dependent on the density of a population?

A. Resources will become limiting and intraspecific competition will increase
B. Risk of disease goes up as the number of individuals in the population increases
C. A hurricane wipes out over half of a population of fish
D. All of the above
E. <u>A and B only</u>

What prevents continued exponential growth?

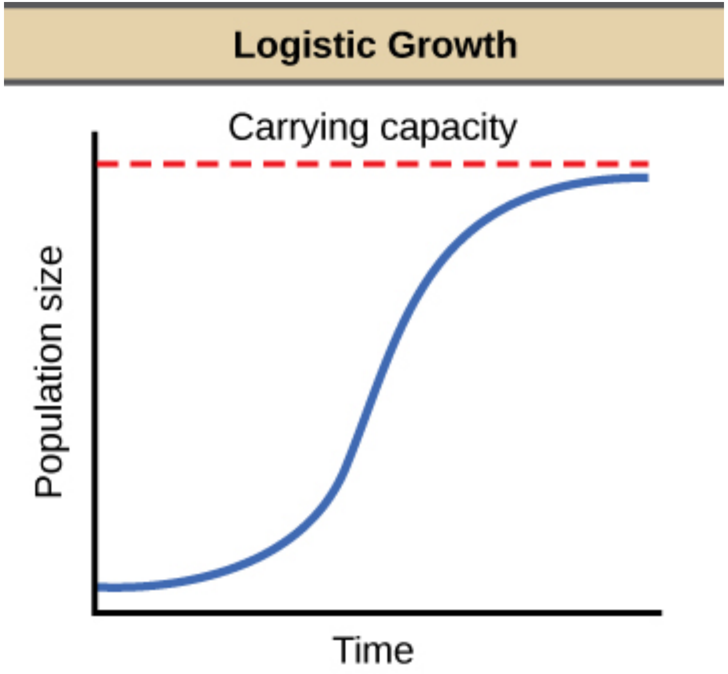
- External (density independent factors)
  - Weather, hurricanes, floods, drought etc.
  - Catastrophic events
- Self regulation (density dependent factors)
  - Resources becoming limiting (competition)
  - Toxic build-up
- Interactions with other species (density dependent factors)
  - Disease
  - Predation

Which leads to a different growth model:

- **Logistic growth** - The population increases until it reaches carrying capacity
- $$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

Where

- N = population size
- r = per capita growth rate
- K = carrying capacity

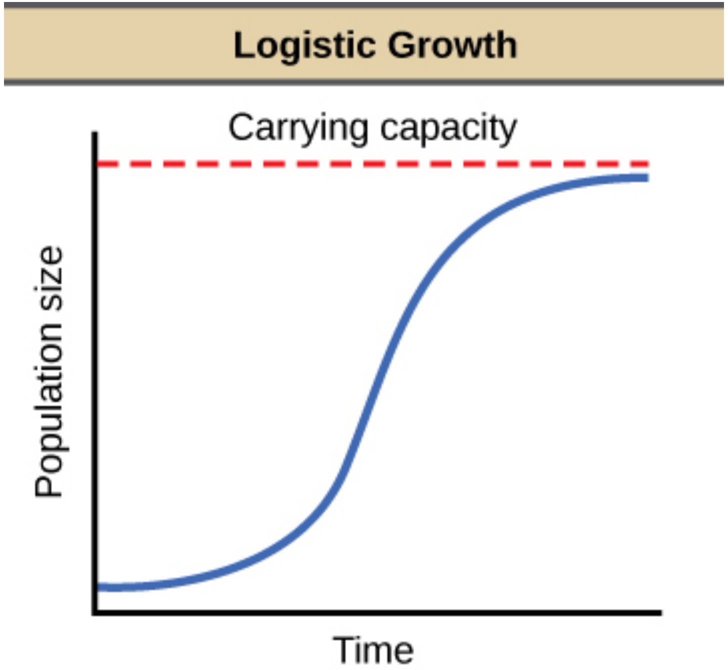


Let's take a closer look:

$$N_t = N_1 + rN_1$$

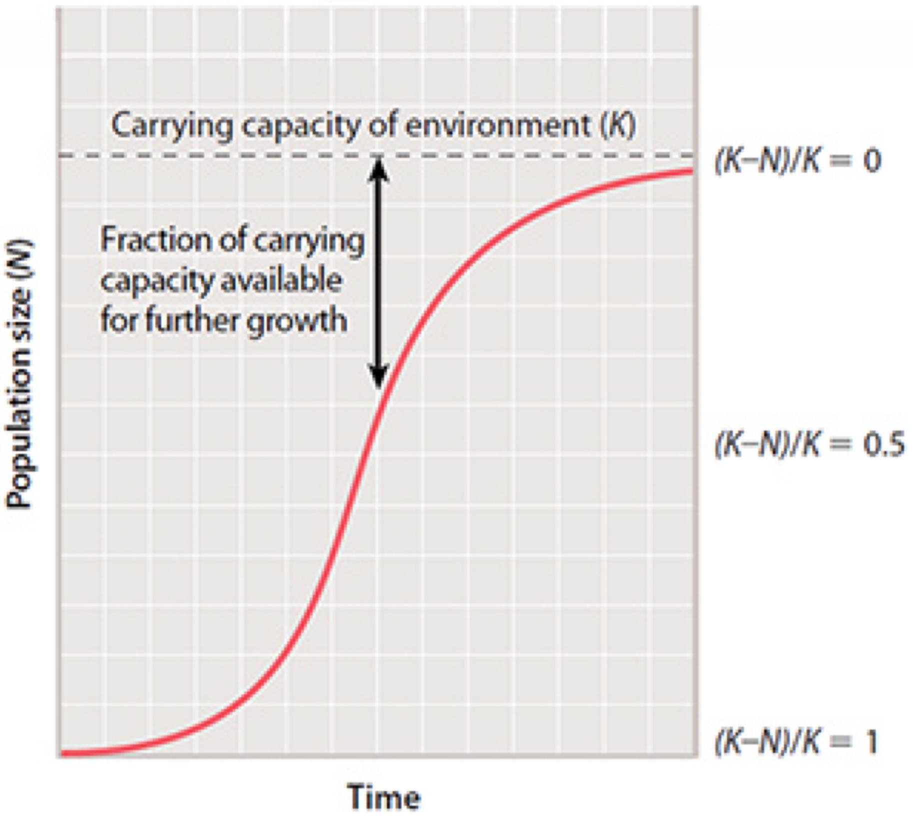
This is exponential growth

This adjusts the growth relative to carrying capacity



Logistic growth model

- At first, N is much smaller than K, thus the population grows nearly exponentially
- When N is half of K, population growth is at it's highest
- When N = K, the population no longer increases



N is much smaller than K, thus the population grows nearly exponentially

What is N_t for this population?

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

N is much smaller than K, thus the population grows nearly exponentially

What is N_t for this population?

N_t = 100 + r(100)[(K-100)/K]

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

N is much smaller than K, thus the population grows nearly exponentially

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

What is N_t for this population?

$N_t = 100 + r(100)[(K-100)/K]$

$N_t = 100 + 2(100)[(K-100)/K]$

N is much smaller than K, thus the population grows nearly exponentially

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

What is N_t for this population?

$N_t = 100 + r(100)[(K\text{-}100)/K]$

$N_t = 100 + 2(100)[(K\text{-}100)/K]$

$N_t = 100 + 2(100)[(1000\text{-}100)/1000]$

N is much smaller than K, thus the population grows nearly exponentially

What is N_t for this population?

N_t = 100 + r(100)[(K-100)/K]

N_t = 100 + 2(100)[(K-100)/K]

N_t = 100 + 2(100)[(1000-100)/1000]

N_t = 100 + 2(100)[900/1000]

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

N is much smaller than K, thus the population grows nearly exponentially

What is N_t for this population?

N_t = 100 + r(100)[(K-100)/K]

N_t = 100 + 2(100)[(K-100)/K]

N_t = 100 + 2(100)[(1000-100)/1000]

N_t = 100 + 2(100)[900/1000]

N_t = 100 + 2(100)[0.9]

Population of giraffes

$N_1 = 100$

$r = 2$

$K = 1000$

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

N is much smaller than K, thus the population grows nearly exponentially

What is N_t for this population?

$N_t = 500 + r(500)[(K-500)/K]$

$N_t = 500 + 2(500)[(K-500)/K]$

$N_t = 500 + 2(500)[(1000-500)/1000]$

$N_t = 500 + 2(500)[500/1000]$

$N_t = 500 + 2(500)[0.5]$

$N_t = 500 + 500$

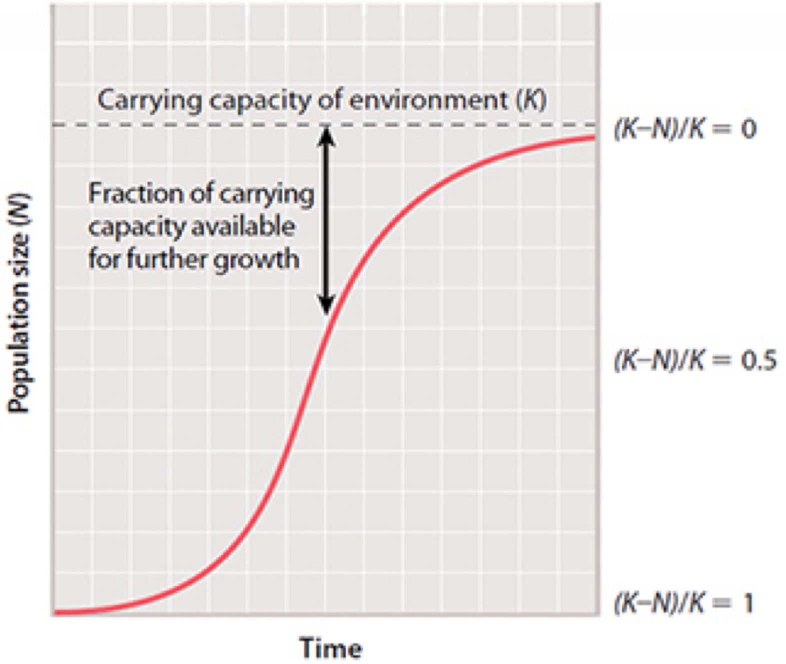
$N_t = 1000$

Population of giraffes

$N_1 = 500$

$r = 2$

$K = 1000$



Carrying Capacity and Logistic Growth

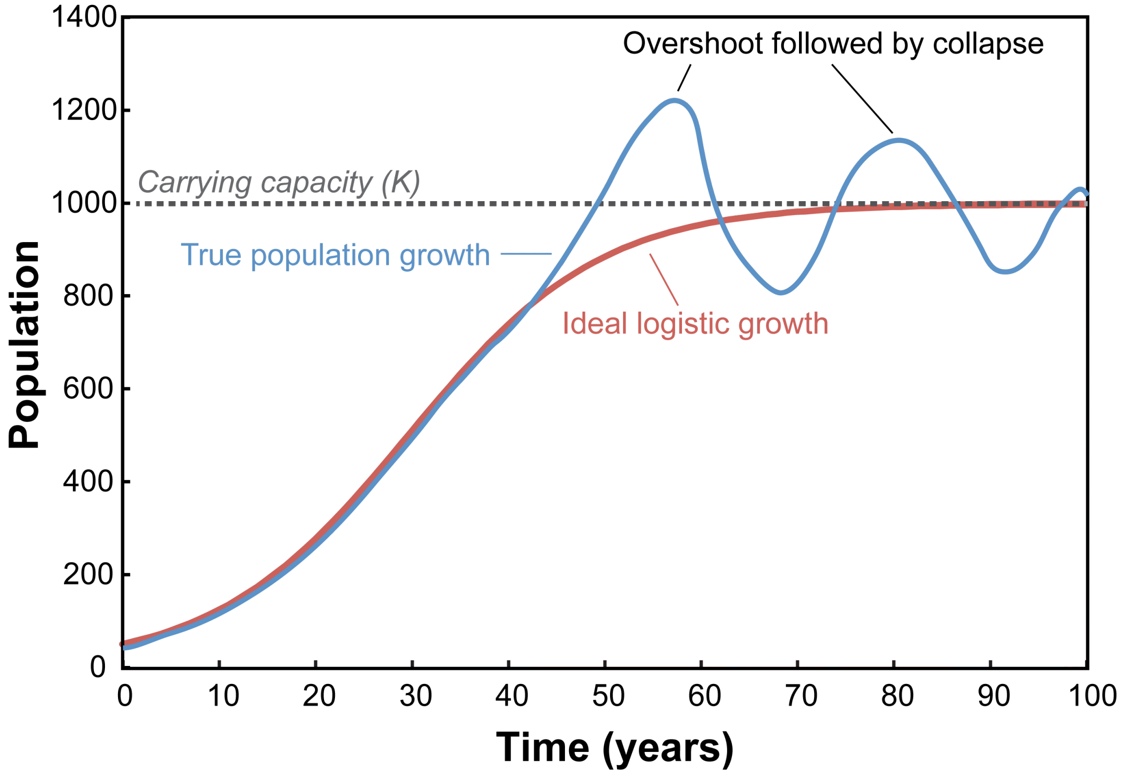
- The role of “carrying capacity”
  - the maximum population size a given environment can support
- What causes carrying capacity?
  - Limited resources
  - Limited space
  - Limited light
  - Limited nutrients

Can a population exceed carrying capacity?

Is carrying capacity constant?

Nature doesn't always follow the models

- Sometimes a population needs some time to stabilize around carrying capacity



C3: If a population has a birth rate r = 1, a carrying capacity of 1000, and currently has 600 individuals, how would you expect it to change over time?

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

A. The population will grow
B. The population will stay the same size
C. The population will shrink

C3: If a population has a birth rate r = 1, a carrying capacity of 1000, and currently has 600 individuals, how would you expect it to change over time?

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

A. **<u>The population will grow</u>**
B. The population will stay the same size
C. The population will shrink

C4: If a population has a birth rate r = 1, a carrying capacity of 1000, and currently has 2000 individuals, how would you expect it to change over time?

$$\boldsymbol{N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)}$$

A. The population will grow
B. The population will stay the same size
C. The population will shrink

C4: If a population has a birth rate r = 1, a carrying capacity of 1000, and currently has 2000 individuals, how would you expect it to change over time?

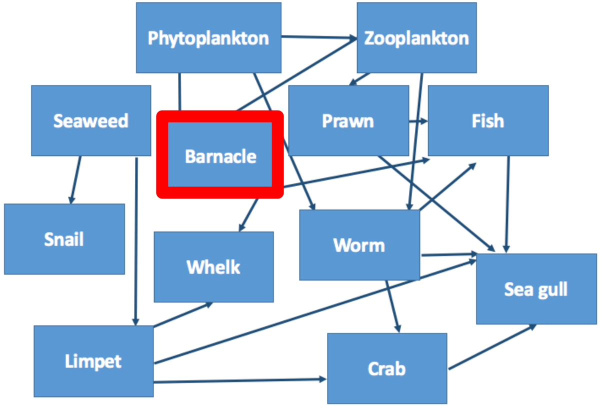
$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

A. The population will grow
B. The population will stay the same size
C. **<u>The population will shrink</u>**

Describing and Modeling Populations Over Time: Barnacles as a Case Study

Activity by: Trenckman et al., 2017

Studying barnacles provided important understanding to the developing field of ecology



Why barnacles?

Stationary marine animals that live in the intertidal zone

- Begin their life as larva floating in the water
- Settle and live cemented on hard surfaces (e.g., rocks)
- Feed on plentiful plankton in the water

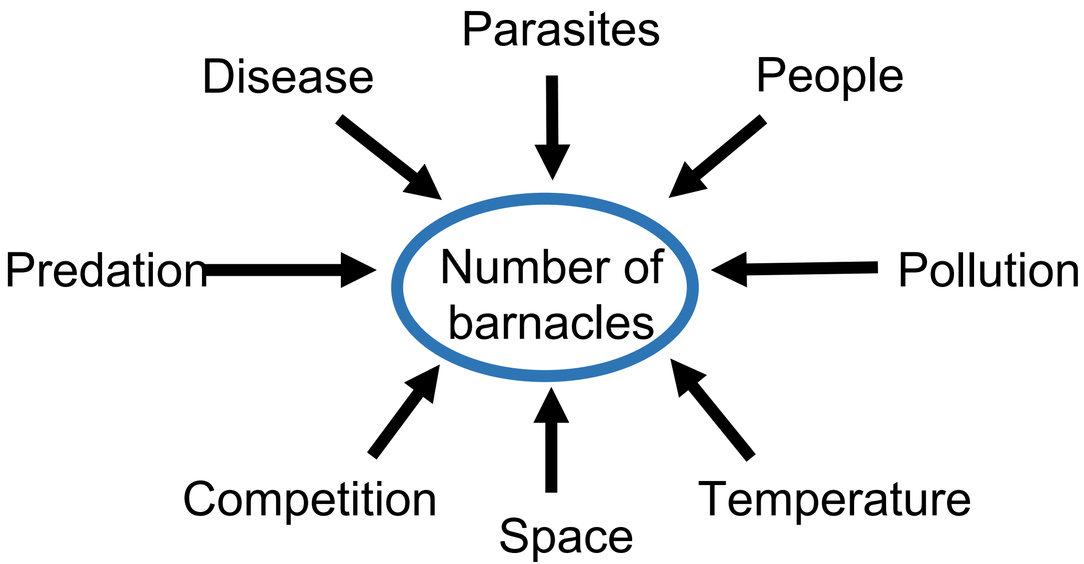
Stationary = easy to count and observe over time

Activity by: Trenckman et al., 2017

What affects barnacle population size?

Activity by: Trenckman et al., 2017

Barnacle population size is impacted by a number of different factors



Activity by: Trenckman et al., 2017

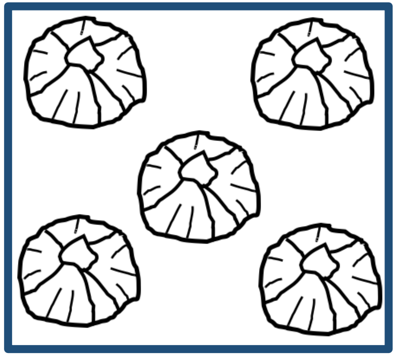
Different measures of population size can be used depending on the study organism

Ecologists can measure :

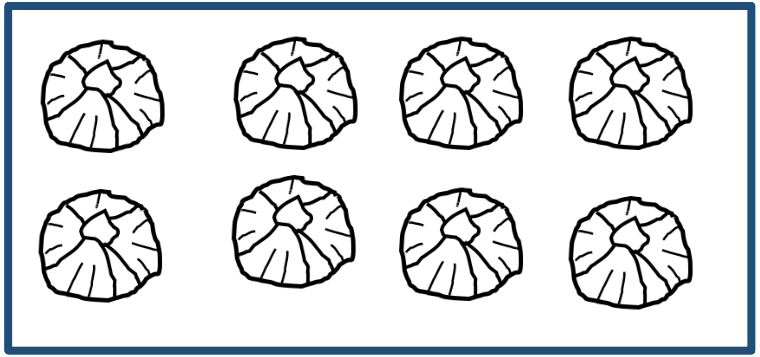
Total number of individuals in the population	**Abundance/size**
Total number of individuals per unit area or volume	**Density**

Activity by: Trenckman et al., 2017

C5: Which of the following statements describes the two study sites below?



Site 1 Area= 4 cm^2



Site 2 Area= 8 cm^2

A. Site 2 has a greater abundance and density than site 1.

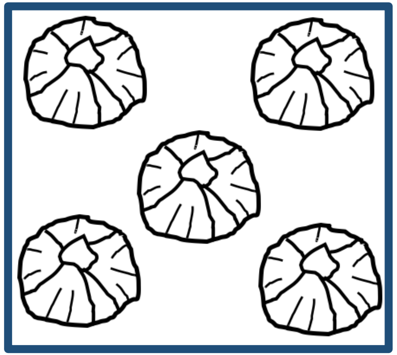
B. Site 1 has a lower abundance but equal density to site 2.

C. Site 1 has a lower abundance but greater density than site 2.

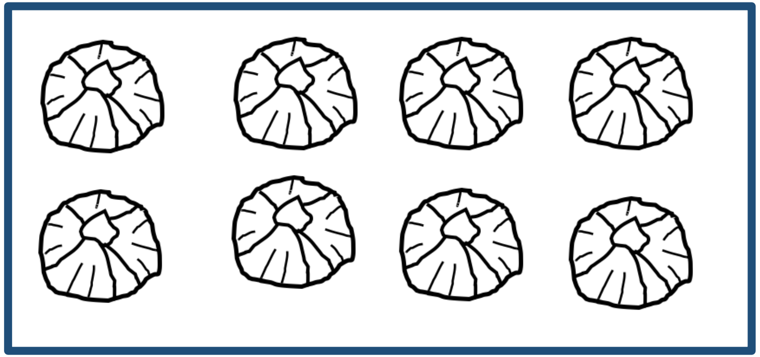
D. The density and abundance are equal for both sites.

Activity by: Trenckman et al., 2017

C5: Which of the following statements describes the two study sites below?



Site 1 Area= 4 cm^2



Site 2 Area= 8 cm^2

A. Site 2 has a greater abundance and density than site 1.

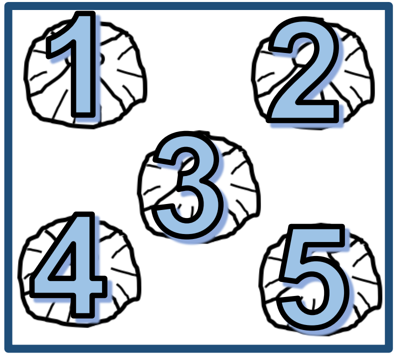
B. Site 1 has a lower abundance but equal density to site 2.

C. **<u>Site 1 has a lower abundance but greater density than site 2.</u>**

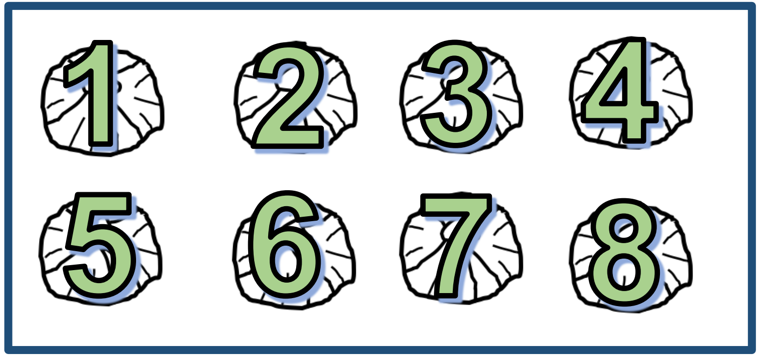
D. The density and abundance are equal for both sites.

Activity by: Trenckman et al., 2017

Abundance is the total number of individuals in the population



Site 1 Area= 4 cm^2



Site 2 Area= 8 cm^2

Site 1 Abundance →

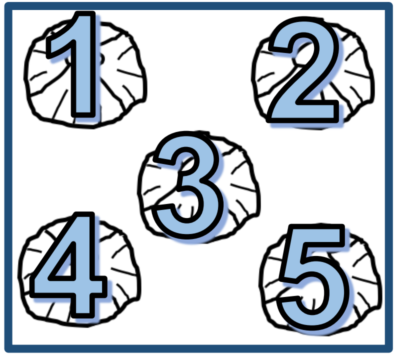
5 barnacles

Site 2 Abundance →

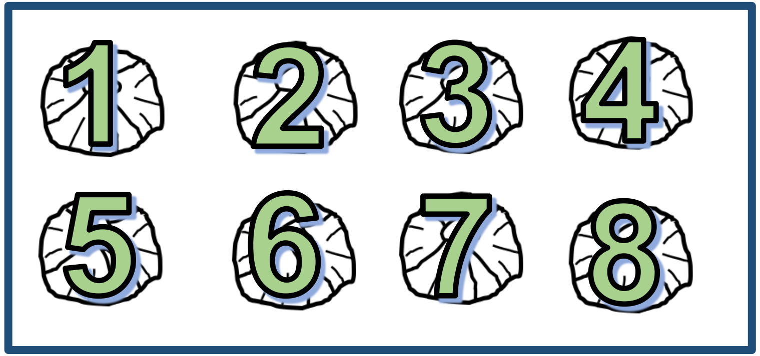
8 barnacles

Activity by: Trenckman et al., 2017

Density is the total number of individuals per unit area or volume



Site 1 Area= 4 cm^2



Site 2 Area= 8 cm^2

$$\text{Density (D)} = \frac{\text{Number of individuals (n)}}{\text{Unit area or volume (A)}}$$

<u>Site 1 Density →</u>

$$\text{Density (D)} = \frac{\text{5 barnacles}}{4\ \text{cm}^2}$$

D= 1.25 barnacles per cm^2

<u>Site 2 Density →</u>

$$\text{Density (D)} = \frac{\text{8 barnacles}}{8\ \text{cm}^2}$$

D= 1 barnacle per cm^2

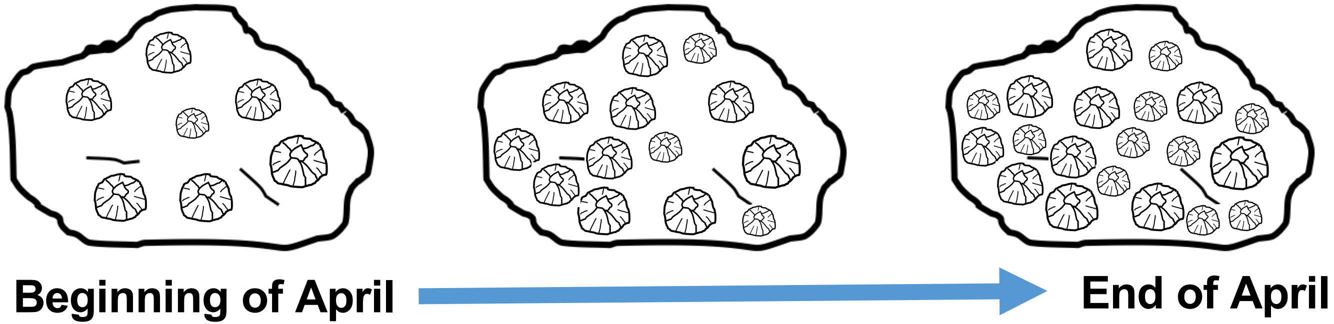
Activity by: Trenckman et al., 2017

In this study, density was used to measure barnacle population size over time

Empty rocks were placed in the intertidal zone.

Cages were placed on the rocks to prevent predation.

The population of settling barnacles on these rocks was observed daily for the month of April.



Connell, J. 1961. Effects of competition, predation by *Thais lapillus*, and other factors on natural populations of the barnacle *Semibalanus balanoides*. Ecological Society of America, 31: 61-104.

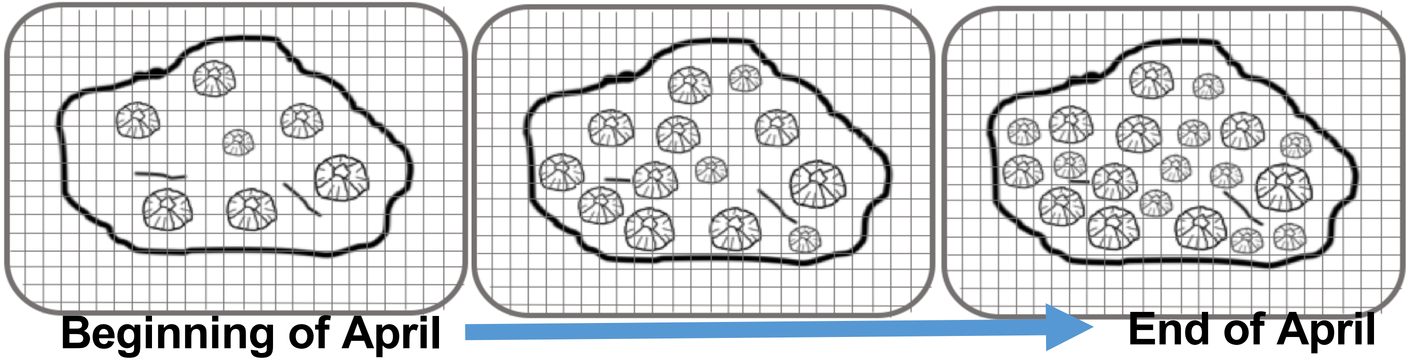
Activity by: Trenckman et al., 2017

In this study, density was used to measure barnacle population size over time

Empty rocks were placed in the intertidal zone.

Cages were placed on the rocks to prevent predation.

The population of settling barnacles on these rocks was observed daily for the month of April.

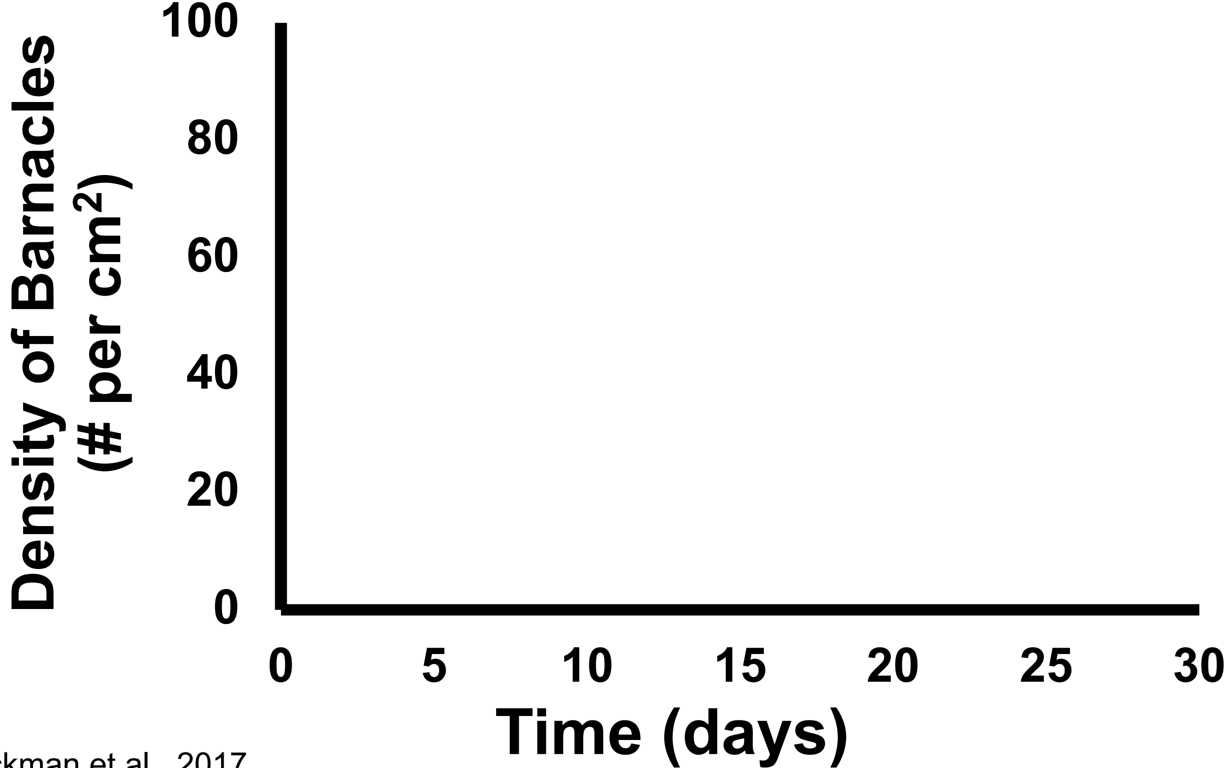


Connell, J. 1961. Effects of competition, predation by *Thais lapillus*, and other factors on natural populations of the barnacle *Semibalanus balanoides*. Ecological Society of America, 31: 61-104.

Activity by: Trenckman et al., 2017

Draw on your paper what you would expect the growth of this population to look like over the 30 day experiment.

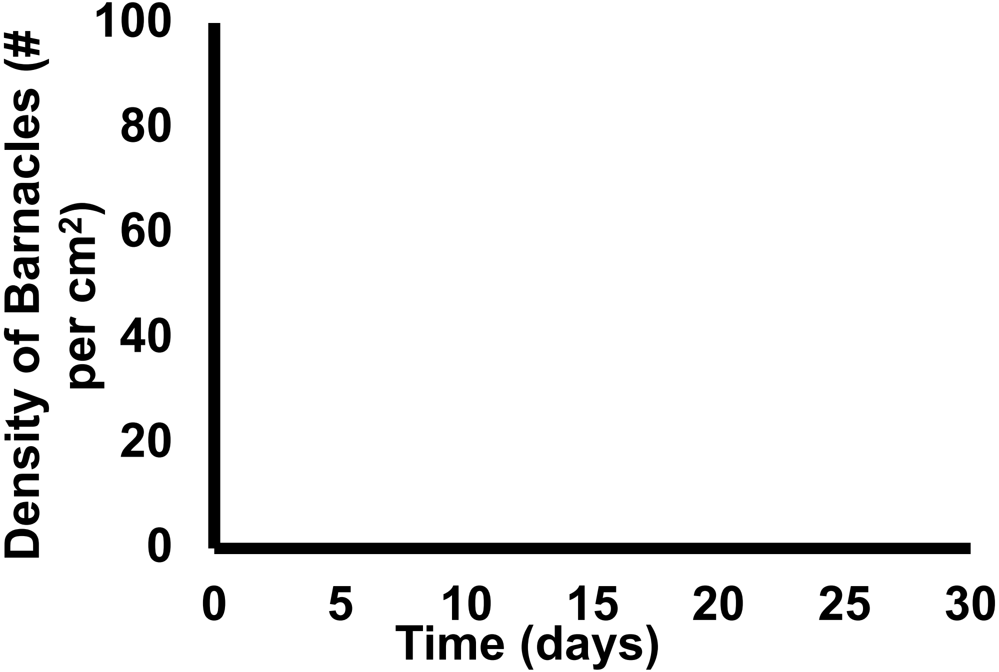
Day 25 ~ 78 barnacles/cm^2



Activity by: Trenckman et al., 2017

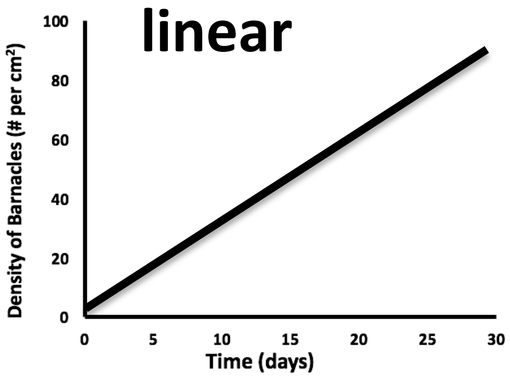
Use the data provided to plot the barnacle population growth.

Time	Density of Barnacles (# per cm²)
1	2
5	12
10	70
15	76
20	79
25	78
30	78



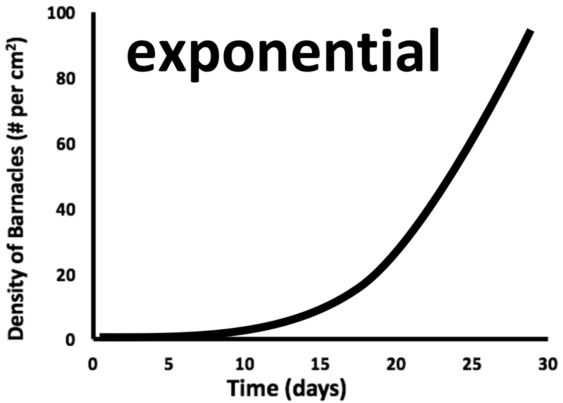
Activity by: Trenckman et al., 2017

Different mathematical models describe how population growth rate changes over time



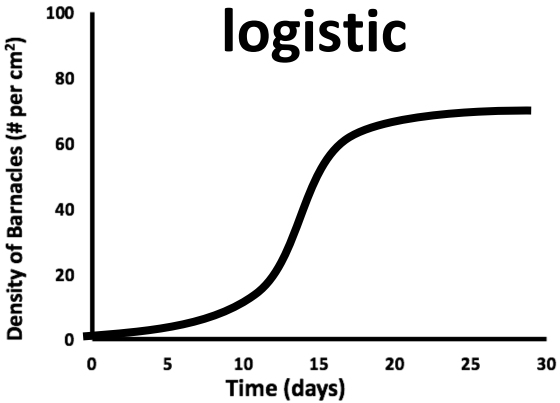
A constant number of individuals are being added over time.

Population growth rate constant



An increasing number of individuals are being added over time.

Population growth rate increasing

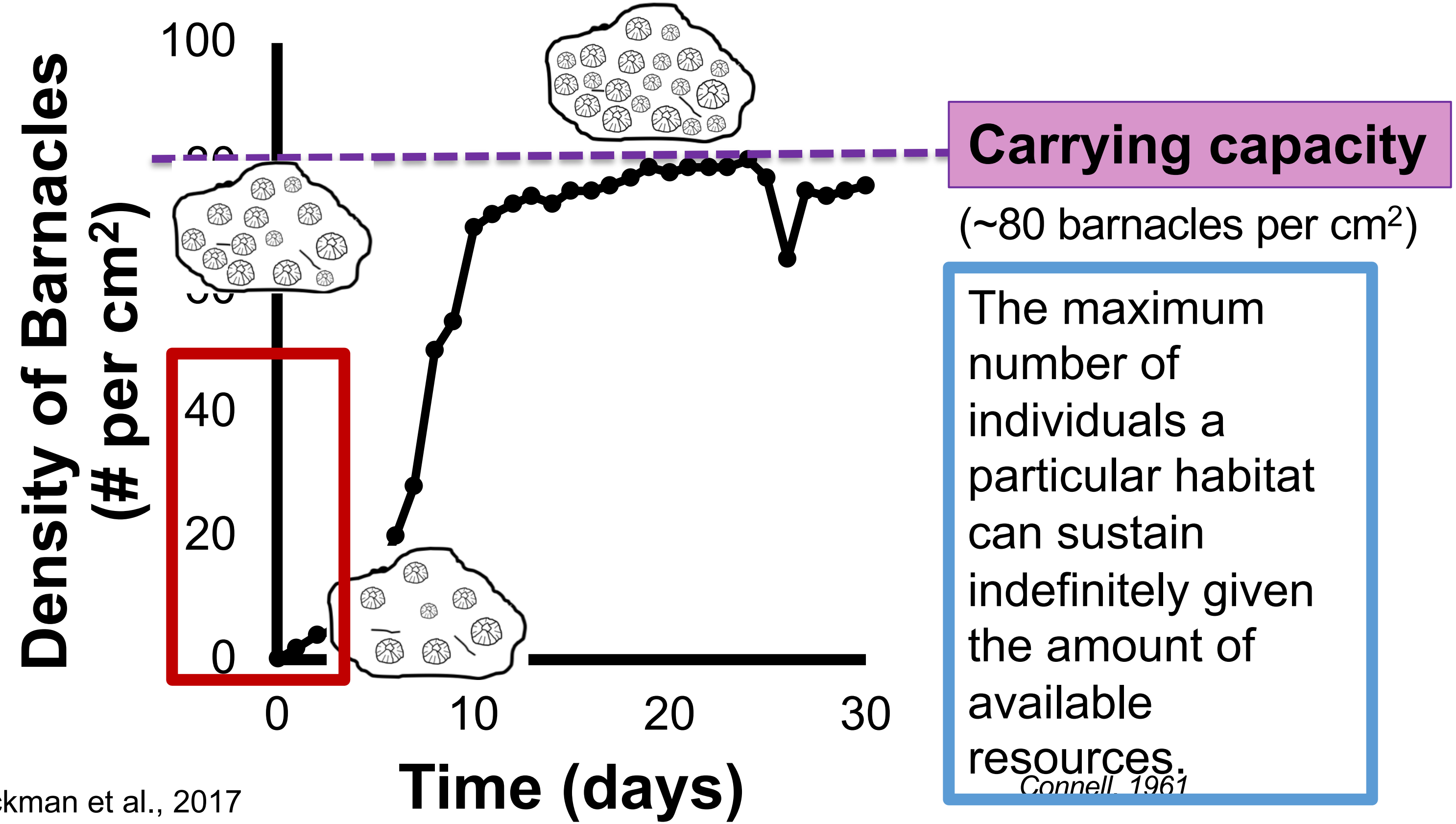


An increasing number of individuals are added initially, then a decreasing number of individuals added over time.

Population growth rate increasing, then decreasing

Activity by: Trenckman et al., 2017

Barnacle population growth was limited by carrying capacity

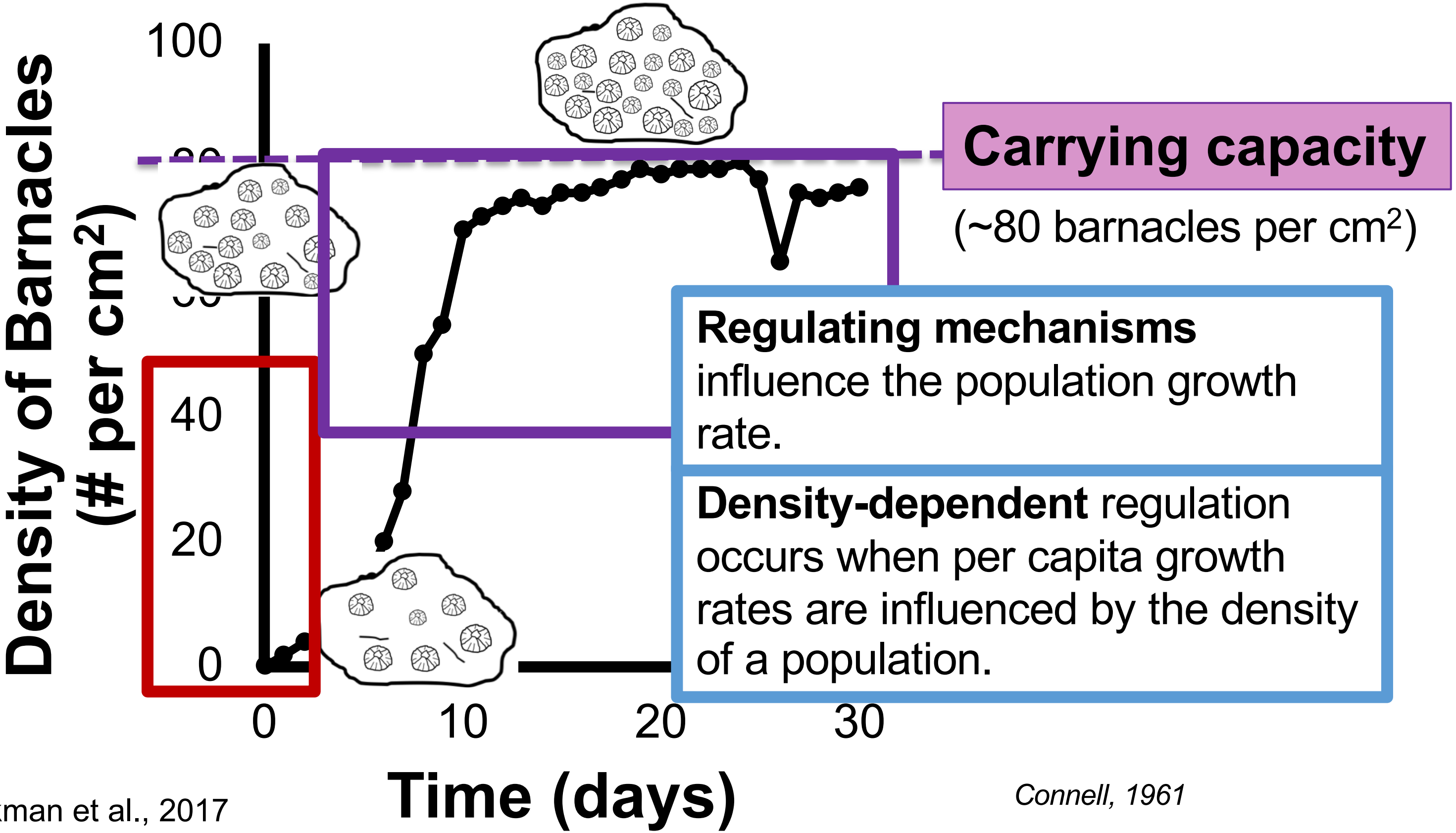


The maximum number of individuals a particular habitat can sustain indefinitely given the amount of available resources.

Connell, 1961

Activity by: Trenckman et al., 2017

In this study, space was likely a density-dependent regulating mechanism



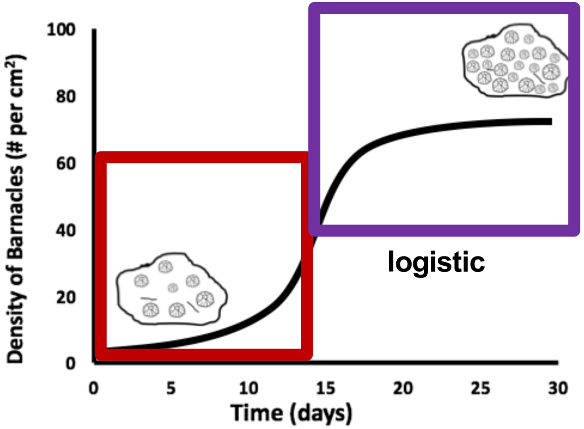
Regulating mechanisms influence the population growth rate.

Density-dependent regulation occurs when per capita growth rates are influenced by the density of a population.

Connell, 1961

Activity by: Trenckman et al., 2017

In logistic growth, the population growth increases then decreases over time



Logistic Model:

Population growth rate

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

r = growth rate = settlement rate – death rate

N= population size

K= carrying capacity

K=The maximum number of individuals a particular habitat can sustain indefinitely given the amount of available resources.

K=~80 barnacles per cm^2

An increasing number of individuals are added initially,

then a decreasing number of individuals added over time.

Activity by: Trenckman et al., 2017

If r=2 per day per individual and K= 80 barnacles per cm^2, how does increasing the population size (N) affect the population growth rate in the logistic model?

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

Population Size (N) (barnacles per cm^2) on sampling day	**How many barnacles would you expect to be in the population the following day? (barnacles per cm^2 / day)**
1	
20	
40	
60	
70	
80	

Activity by: Trenckman et al., 2017

C6: If r=2 per day per individual and K= 80 barnacles per cm^2, how does increasing the population size (N) affect the population growth rate in the logistic model?

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$

Population Size (N) (barnacles per cm^2) on sampling day	How many barnacles would you expect to be in the population the following day? (barnacles per cm^2 / day)
1	
20	
40	
60	
70	
80	

A. As N approaches K, the population growth rate increases.

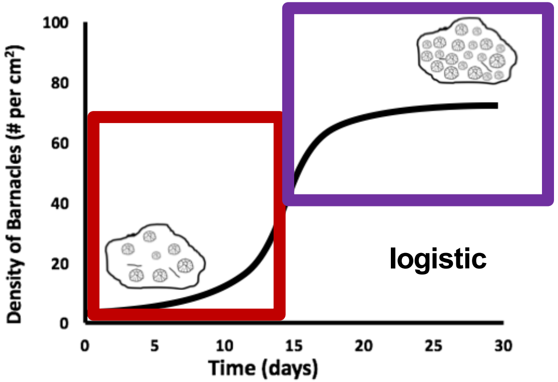
B. As N approaches K, the population growth rate slows.

C. As N approaches K, the population growth rate stays constant.

Activity by: Trenckman et al., 2017

C6: If r=2 per day per individual and K= 80 barnacles per cm^2, how does increasing the population size (N) affect the population growth rate in the logistic model?

$$N_t = N_1 + rN_1\left(\frac{K - N_1}{K}\right)$$



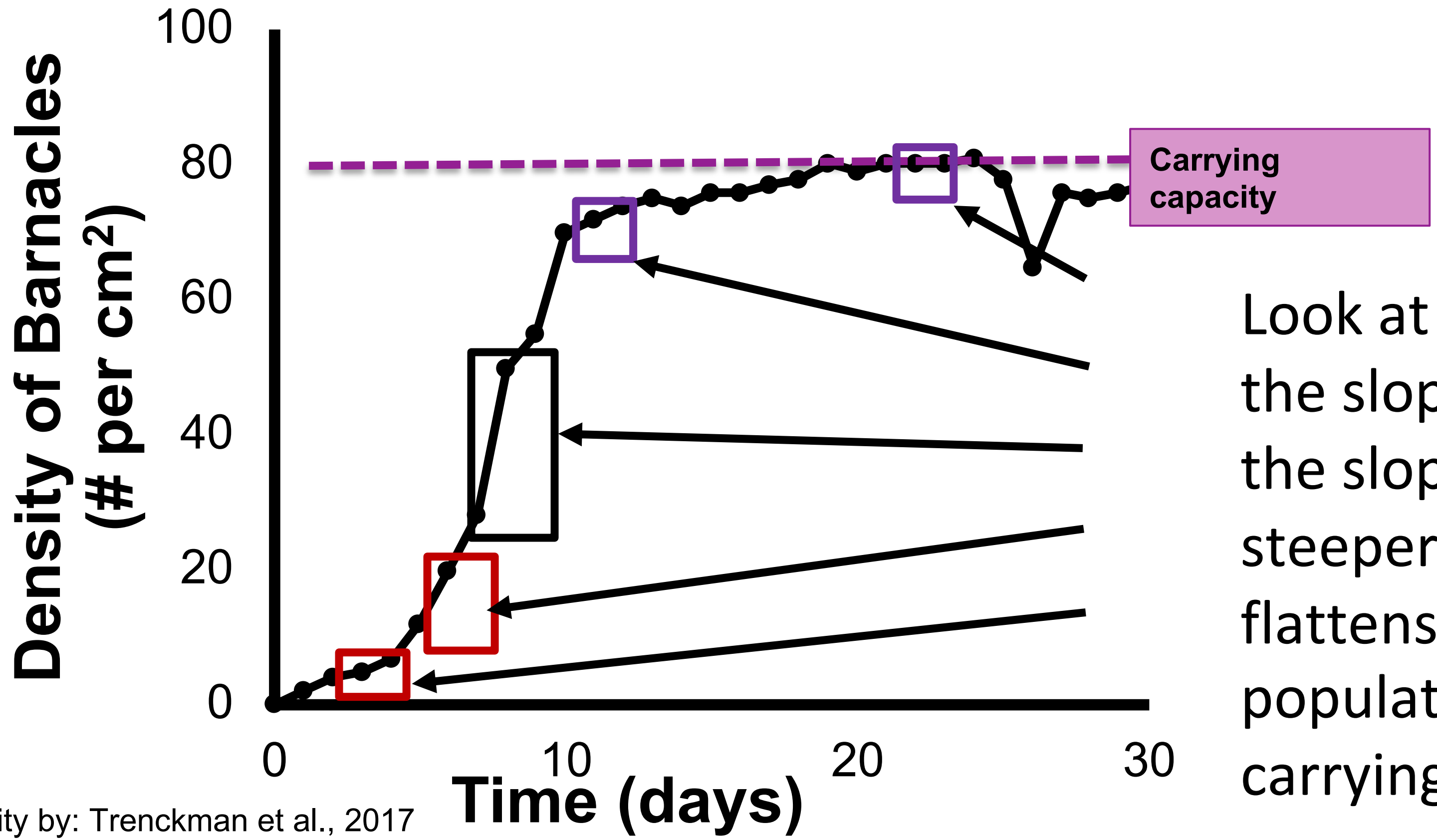
Population Size (N) (barnacles per cm^2) on sampling day	How many barnacles would you expect to be in the population the following day? (barnacles per cm^2 / day)
1	3
20	50
40	80
60	90
70	88
80	80

A. As N approaches K, the population growth rate increases.

B. <u>As N approaches K, the population growth rate slows.</u>

C. As N approaches K, the population growth rate stays constant.

The data collected show a population growth rate that increases then decreases over time



Look at the angle of the slope. Initially, the slope gets steeper initially then flattens out as the population nears carrying capacity.

Activity by: Trenckman et al., 2017