OVERVIEW

This worksheet complements the *Population Dynamics* Click & Learn and provides a sample of procedures students could perform using this tool. The published versions of the student worksheet and educator materials are available on the *Population Dynamics* Click & Learn page.

This worksheet also includes a preview of activities from a forthcoming Click & Learn that uses the lionfish invasion in the Caribbean to teach students about logistic population growth and mechanisms regulating populations (available in 2020).

KEY CONCEPTS

- Scientists construct mathematical models to predict the growth of populations and understand factors that can affect the rate at which a population changes over time.
- In the exponential growth model, the rate of population growth depends on the per capita growth rate and population size.
- In the logistic growth model, population growth slows down as the population size approaches a maximum number called the carrying capacity (*k*). A variety of density-dependent factors contribute to *k*.

EXAMPLE STUDENT LEARNING TARGETS

- Explain how changing the variables of time, per capita growth rate, and the initial population size affect population growth.
- Explain the differences between an exponential growth model and logistic growth model.
- Describe assumptions of the population growth models and how those assumptions align with biological populations.

PART 1: Exploring Exponential Growth

Proceed to the exponential model simulator. Click on the "How to Use" button and notice the explanations provided to students regarding the components of the tool. Click on the gear icon to change the scale of the graph and the range of values you can select for each parameter.

The worksheet questions are designed to get students exploring the slider tools and recording the outcomes of changing the parameters for exponential growth. After gaining familiarity with the tool, students should be able to change the parameters to generate particular scenarios. Identify the parameter levels (e.g., large or small growth rate, large or small initial population size) that generate the following graphs:

1. A long period of almost no growth—the curve looks nearly flat.

2. A long period of slow but clearly accelerating growth—the curve starts to become steeper at the end.

3. Extremely rapid growth from the very beginning.

PART 2: Applying Parameters from a Natural Population

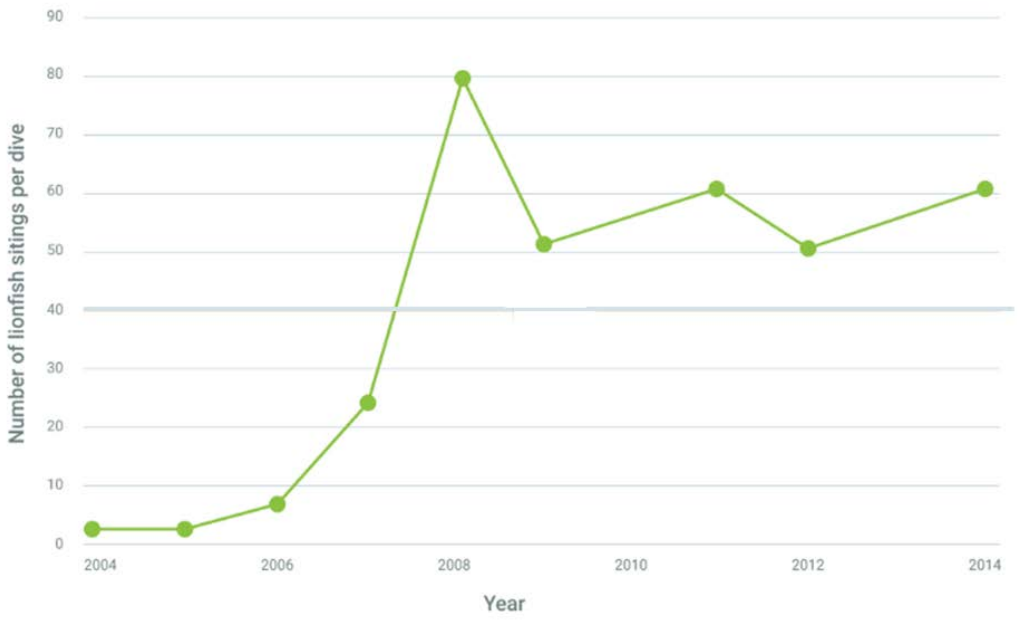
Students can use the *Population Dynamics* Click & Learn to explore hypothetical scenarios for any organism or situation. The first example in the currently available student worksheet asks students to consider waterbuck populations in Gorongosa National Park in Mozambique that are recovering after a devastating civil war (using b = 0.67, d = 0.06, N_0 = 140 as the starting values, where students use the equation: ***r = b – d*** to determine that the waterbuck population would exponentially grow at a rate of ***r = 0.61***).

Today, we will explore the simulation using lionfish data! Below are some sample questions from the *Population Dynamics* Click & Learn (C&L) Student Worksheet adjusted for lionfish. You can adjust the questions to any organism or system, or consider this a preview for the Lionfish C&L coming soon!

4. In a study by Côté and Smith (2018), lionfish were surveyed in the Bahamas in 2004, when 2 individuals were first sighted. Fill in the chart below using the exponential model simulator to predict how the population is expected to grow under the early years of the invasion. Use ***r = 0.95*** as the estimate of lionfish population growth rate in a novel habitat.

Time	1 (2005)	2 (2006)	3 (2007)	4 (2008)	5 (2009)
Population size (N_t)					
Slope ($\frac{dN}{dt}$)					

5. How do your model estimates compare to the field data collected by Côté and Smith (2018) in the Bahamas?



Note: The data above is reported as number of sightings of lionfish per dive. This measure can be used to estimate density based on the amount of area surveyed. As reported here, this measure can only be used as an index to represent lionfish density and not as a direct measure of population size (N).

PART 3: Logistic Growth Models

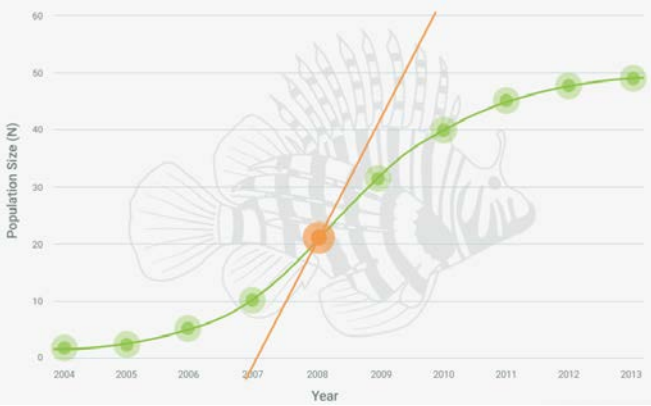
A. Exploring Carrying Capacity

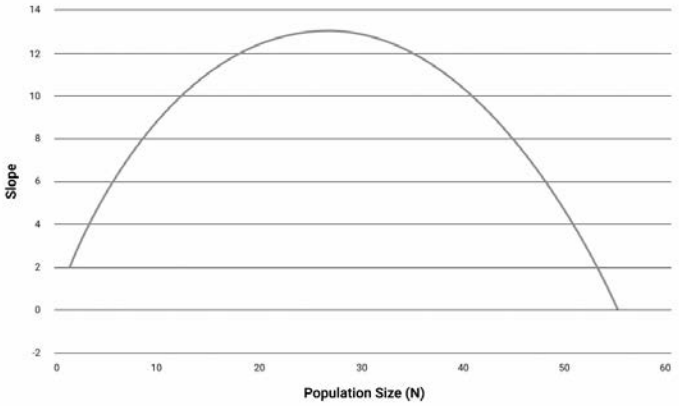
The logistic model adds the concept of **carrying capacity, *k*** when modeling changes in population size over time. This is the maximum number of individuals that the community can support without exhausting resources.

6. Given the data in the previous figure, what would be an appropriate carrying capacity to include in a logistic model for lionfish? *Note: You may need to use the settings to adjust the range of the input variables.*

B. Extensions in Lionfish Click & Learn: Exploring Changes in Instantaneous Growth Rate

7. How does slope ($\frac{dN}{dt}$) change in relation to *N*? Refer to the graphs and practice questions:





Question 1

From 2004-2006, when the population size and density is small, the population growth rate is:

- ○ Greater than 2008-2010
- ○ Less than 2008-2010
- ○ About the same as 2008-2010

Question 2

Which of these best explains the low population growth rate during 2004-2006?

- ○ Predation is at its peak
- ○ The number of individuals to reproduce is low
- ○ There are few food resources
- ○ Disease and parasitism are common

Question 3

Choose all of the following that could explain the low population growth rate during 2011-2013, when the population size and density was high:

- ☐ Predation is at its peak
- ☐ The number of individuals to reproduce is low
- ☐ There are few food resources
- ☐ Disease and parasitism are common

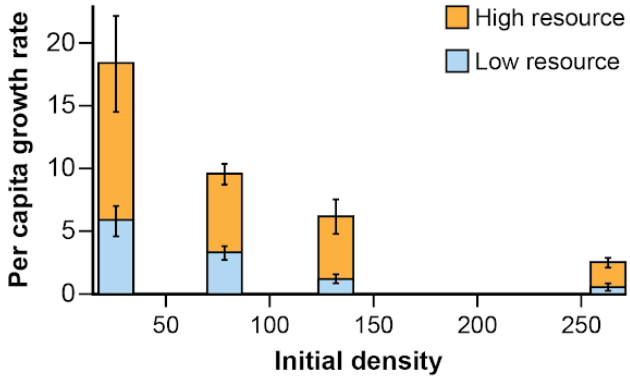
C. Density-Dependent Factors Regulate Growth

C	Intraspecific Competition	SB	Social Behaviors	PD	Parasites and Diseases	P	Predation
Intraspecific competition occurs when individuals of the same species use the same resource to the detriment of their neighbors. Competition may impact growth, development and survival. As population density increases, competition increases which limits the growth of the population.		**Social behaviors** within a population, such as mating behaviors, parental care and even cannibalism, can change as the population density increases. When negative behaviors, such as cannibalism, increase, mortality increases which suppresses population growth.		**Parasites and diseases** increase mortality and decrease fitness of their hosts and can therefore regulate populations. With increased host population density, the number of parasites and the prevalence of disease increases, suppressing population growth.		As prey populations grow, **predation** rates increase which causes increased prey population regulation by predators. As a result, the prey population growth rate declines.	

After reading the definitions of density-dependent factors that regulate population growth, consider the case study based on Holdridge et al. (2016): "A shift from exploitation to interference competition with increasing density affects population and community dynamics."

8. Use evidence from the graph to make a claim about how population growth rates are affected by initial cell densities.

9. How does resource availability affect population growth rate in this study?



10. Other than a food source, what other resources may affect protozoa population growth rate?

D. Apply Your Knowledge on Mechanisms of Population Regulation to Lionfish

11. Choose a density-dependent factor that you think may affect lionfish populations. Outline an experiment that could be conducted to determine whether this factor is limiting lionfish.

References:

Côté, I. M., & Smith, N. S. (2018). The lionfish *Pterois sp*. invasion: Has the worst-case scenario come to pass? Journal of fish biology, 92(3), 660-689.

Holdridge, E. M., Cuellar-Gempeler, C., & terHorst, C. P. (2016). A shift from exploitation to interference competition with increasing density affects population and community dynamics. Ecology and evolution, 6(15), 5333-5341.

SUPPLEMENT: Suggestions for Implementing Click & Learn Resources into Courses

Example: New Lionfish Click & Learn coming in 2020!

A. In the classroom

- Introduction and video together as a class
- In pairs, students work together to complete the activities.
- Set up pause points at the end of each slide activity
    - Determining *k*
    - Completing the tables
    - Examining the slope - *r* relationship and *r* vs. *N* relationship
- In smaller classes (up to ~8 groups), instructors can circulate to check progress and ask challenge questions to check understanding.
- This format will likely require two 50-minute class periods to complete all the parts of the Click & Learn.

B. As homework

- Students work independently or as a small group to complete the Click & Learn outside of class.
- Use online discussion boards or group-based online assignments as part of the LMS for students to record and submit their answers.
- Students come to class with suggestions for experiments to conduct to determine what factors are controlling lionfish populations.
- Sort students into groups based on which regulating mechanism they chose. In the group, they will discuss their individual approaches.
- Jigsaw groups so that students are assigned new groups to compare the experiments that tested different regulating mechanisms.

C. For an online course

- Students complete the Click & Learn.
- Online discussion boards can be used for students to compare results.
- Online assignments based on questions within the Click & Learn are incorporated into an assignment within the course learning management system.
- Online discussion is used to contribute ideas for the development of experiments to test the possible population regulating mechanisms in lionfish.

D. Extensions for advanced courses

- Assign students to find current primary literature about lionfish in the Atlantic to help inform their experimental design
- Assign students to find evidence of population regulation in another system and compare/contrast with the lionfish example
    - Focus on species of conservation concern for a Conservation Biology course