Lionfish Invasion: Density-Dependent Population Dynamics

hhmi | BioInteractive

Click & Learn
Student Worksheet

INTRODUCTION

Population dynamics are how a population changes over time, including how fast it gains or loses individuals. These dynamics are often affected by **density-dependent factors**, which change how fast the population grows (called the “population growth rate”) depending on how big the population is (called “population size”).

Understanding population dynamics can help us do everything from uncovering what controls the number of organisms in different habitats, to determining how many fish we can take from a population sustainably, to keeping endangered species from going extinct. Population dynamics can also help us manage ecologically harmful species called **invasive species**.

In this Click & Learn, you’ll learn about an invasive species known as **lionfish**, which has had a strong impact on marine ecosystems in the Western Atlantic Ocean. Using both scientific data and mathematical models, you’ll explore the density-dependent population dynamics of lionfish and see what can be done to control them. The Click & Learn also includes case studies that examine density-dependent factors in other species and ecosystems. The concepts you’ll learn can be applied to many real-world populations, including other invasive species near you.

PART 1: Introduction to Lionfish

Open the *Lionfish Invasion* Click & Learn and go through the **“Introduction”** tab, which discusses lionfish as an invasive species.

1. Which characteristics of lionfish helped them successfully invade the Atlantic Ocean?

2. In general, which characteristics do you think make an invasive species successful in its new environment?

Open the “Models” tab and go through the **“Lionfish estimates”** section, which discusses how biologists estimate the size of lionfish populations.

3. Based on the graph at the bottom, estimate the carrying capacity for this lionfish population.

PART 2: Logistic Growth Models

Go through the **“Modeling change”** section, which introduces an equation for modeling lionfish populations. Next, go through the **“Lionfish calculations”** section and fill out the table at the end of that section. A few hints:

- For this table to work, you must **round your result to two decimal places** at each step in the calculation and **immediately use the rounded result in the next step** of the calculation. In most other cases, you should *not* round at every step because it reduces accuracy. Rounding is used here as a simplification.
- You only need to do calculations for 2005, 2006, and 2007. Once you have completed these rows, the rest of the table will be filled in automatically.
- You can click on each term at the top of the table to learn more about it. You can also click on each number in the first row to see how that number was calculated.

4. Copy your values from the table in the Click & Learn into the table below, or insert a screenshot from the Click & Learn.

t	N_t	$r_{max,d}N_t$	$(K - N_t)/K$	$\Delta N/\Delta t$	N_{t+1}
2004	20	23	0.96	22.08	42.08
2005					
2006					
2007					

5. Copy the N_{t+1} values for each year into the table below, or insert a screenshot from the Click & Learn. (These values will be automatically generated by the Click & Learn once you complete the previous rows.)

2008	2009	2010	2011	2012	2013

Go through the **"Revising the model"** section, which explains the differences between the discrete-time and continuous-time logistic growth models.

6. Why is the continuous-time model more appropriate for modeling lionfish?

7. Compare the three curves shown in the graph at the end of the section.
   a. How does the curve for the continuous-time model compare to the curve for the discrete-time model?

   b. How do the curves for both models compare to the population estimates based on diver data? What might explain the differences?

PART 3: Exploring Growth Rates

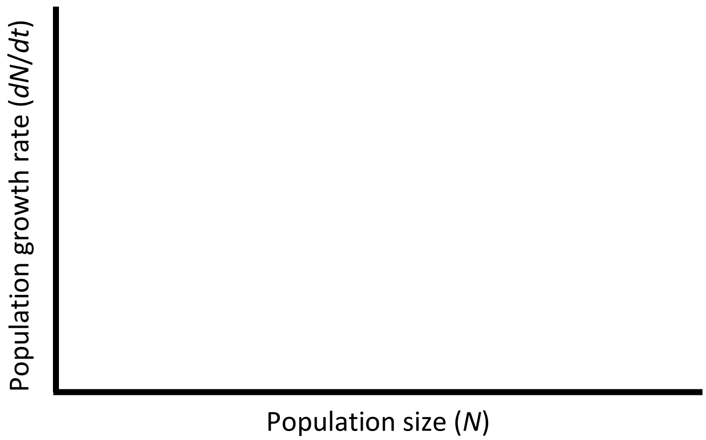
Read through the first part of the **"Visualizing the model"** section, stopping when you reach the graph.

8. *Before* looking at the graph, predict the population size at which the realized per capita population growth rate ($r_{realized}$) will be highest.

Go through the rest of the "Visualizing the model" section, then continue to the **"Changing rates"** section. Read through the first part of the section, stopping when you reach the graph.

9. *Before* looking at the graph, answer the following questions.
   a. Predict the population size at which the overall population growth rate (*dN/dt*) will be highest.

b. Predict the overall relationship between *dN*/*dt* and *N*, and sketch a graph of your prediction below.



Return to the **"Changing rates"** section and explore both tabs of the graph (*N* vs. *t* and *dN*/*dt* vs. *N*).

10. Use the graphs to answer the following questions.
    a. What is the approximate carrying capacity for this population?

    b. At what population size (*N*) is the overall population growth rate (*dN/dt*) the highest?

    c. How does your answer to Part B compare to the carrying capacity?

Answer the questions at the end of the **"Changing rates"** section. You can answer them in the Click & Learn or mark your answers below.

11. Over 2004–2006, when the population size is small, the population growth rate (*dN*/*dt*) is:
    a. greater than it is over 2008–2010
    b. less than it is over 2008–2010
    c. about the same as it is over 2008–2010
12. Which of the following best explains the low population growth rate (*dN*/*dt*) over 2004–2006?
    a. The number of individuals that can reproduce is low.
    b. Food resources are scarce.
    c. Disease and parasitism are common.
13. What could explain the low population growth rate over 2011–2013, when the population size was high? Select all that apply.
    a. The number of individuals that can reproduce is low.
    b. Food resources are scarce.
    c. Disease and parasitism are common.

PART 4: Case Studies

Go through the **"Growth limits"** section, which is the last section under the "Models" tab. Explore one or more of the case studies based on your instructor's suggestions. Your instructor may give you additional handouts for the case studies.

After you have learned about all of the case studies, go to the **"Match mechanism to study"** section under the "Case Studies" tab. Answer the questions in the Click & Learn or mark your answers below.

14. At lower densities, paprika pepper plants produce a higher total weight of fruit. In this case, the main factor that limits population growth is:
    a. intraspecific competition
    b. interspecific predation
    c. disease and parasites
    d. social behavior
15. Protozoa at higher densities have lower population growth rates, especially when less food is available. In this case, the main factor that limits population growth is:
    a. intraspecific competition
    b. interspecific predation
    c. disease and parasites
    d. social behavior
16. Fish at high densities have more sea lice, which can injure or kill the fish. In this case, the main factor that limits population growth is:
    a. intraspecific competition
    b. interspecific predation
    c. disease and parasites
    d. social behavior
17. When crab densities are higher, the larger crabs eat more of the smaller crabs. In this case, the main factor that limits population growth is:
    a. intraspecific competition
    b. interspecific predation
    c. disease and parasites
    d. social behavior
18. As the density of mosquito larvae increases, more mosquito larvae are eaten by fish. In this case, the main factor that limits population growth is:
    a. intraspecific competition
    b. interspecific predation
    c. disease and parasites
    d. social behavior

PART 5: Further Study

Open and read through the **"Further Study"** tab. Answer the questions in the Click & Learn or provide your answers below.

19. Choose a negative density-dependent factor that you think may affect the lionfish population in the Bahamas. Outline an experiment to test whether this factor is limiting the growth of the lionfish population.

20. Think about the factor you chose in the previous question. Describe what could stop that factor from limiting the lionfish population in the future.

Lionfish are not the only invasive species that harms ecosystems. As mentioned at the end of the Click & Learn, even if you aren't in a place with invasive lionfish, you can still help with the broader problem of invasive species.

21. Learn more about another invasive species near you or one that you are personally interested in. Which invasive species did you choose, and what are its impacts?

22. What is currently being done to control this invasive species and its impacts?

23. How might understanding population dynamics help us better manage this invasive species and its impacts?