Plankton vs. Viruses: Host/Parasite Interactions

Materials

For the leader:

Computer

Projector

Phytoplankton and Virus Population Sizes Figure

For the activity:

Area – indoor or outdoor – large enough for the students to run around

Flipchart with graphs

Writing utensils (at least two colors)

Overview

Microbes make up 98% of the biomass in the oceans. There is both a large abundance and amount of diversity within the microbial community and many species live in the same area at the same time. Scientists are studying the ways in which many species coexist. Dr. Kay Bidle and his colleagues are looking at the relationship between two microbial groups, phytoplankton and viruses.

Like other primary producers, the diversity and abundance of phytoplankton, tiny, plant-like organisms, can be determined by the amount of light and nutrients in the water. However, infection by viruses can also influence the populations of phytoplankton in the ocean. When viruses make their way into a phytoplankton, they are able to use the host cell machinery to replicate themselves and form more viruses. During this replication process, some viruses, referred to as lytic viruses, can cause the host cell to rupture and die, decreasing the phytoplankton population. Meanwhile, viruses rely on the living cells of another organism in order to survive and replicate. Therefore, the other impacts the growth and survival of each population. Phytoplankton survival is terminated by virus infection and viruses depend on phytoplankton to survive.

In this activity, students role-play the population interactions of phytoplankton and viruses that infect them and then observe real data of host/parasite population densities over time. The activity illustrates that: access to necessary resources is key to survival, a population will continue to increase in size until some limiting factors are imposed, and limiting factors contribute to fluctuations in populations.

Students are transformed into resources, phytoplankton, and viruses for the simulation. They each need their resources to survive and reproduce. Through many rounds of gathering resources they will graph their results and compare the population success of phytoplankton and viruses over time. Students discover that populations of phytoplankton fluctuate based upon both the available resources (bottom-up control) and the presence and abundance of viruses (top-down control).

This lesson has been developed to compliment the work published in: Vardi A., L. Haramaty, B.A.S. Van Mooy, H.F. Fredricks, S.A. Kimmance, A. Larsen, and K.D. Bidle. 2012. Host–virus dynamics and subcellular controls of cell fate in a natural coccolithophore population. Proceedings of the National Academy of Sciences 109: 19327-19332.

Motivating Questions:

- **How does the population size of phytoplankton and viruses compare over time?**
- **How would you classify the relationship between phytoplankton and viruses?**

Take Home Message

Phytoplankton and marine viruses are a host/parasite symbiotic interaction. The growth and survival of each population is impacted by the other, phytoplankton survival is terminated by virus infection and viruses depend on phytoplankton to survive.

NOTE – This lesson assumes that your students have an understanding of producers, plankton, viruses, and symbiosis.

Structure

Through a hands-on demonstration and real phytoplankton-virus population size data, students will be exposed to the relationship between phytoplankton and a marine virus as well as think through what symbiotic interaction this relationship demonstrates.

Time Required

One 45-minute class period

Activity Outline

Engage: Students will participate in a hands-on demonstration that presents the interactions between phytoplankton and viruses over time.	20 minutes
Explore: Students will interpret data from an experiment in Norway looking at host-virus dynamics to explore the relationship between phytoplankton and a marine virus.	15 minutes
Make Sense: Through small group and class discussions students will reflect on what they have learned and classify the type of symbiotic relationship observed between phytoplankton and viruses.	10 minutes
Total:	**45 minutes**

Audience

Middle school students (6^{th}-8^{th} grade).

New Jersey Core Curriculum Content Standards - Science

Content Area	Content Statement	CPI#
Science Practices: Understand Scientific Explanations	Results of observation and measurement can be used to build conceptual-base models and to search for core explanations.	5.1.8.A.2
Science Practices: Generate Scientific Evidence Through Active Investigations	Mathematics and technology are used to gather, analyze, and communicate results.	5.1.8.B.2
	Scientific reasoning is used to support scientific conclusions.	5.1.8.B.4
Science Practices: Reflect on Scientific Knowledge	Scientific models and understandings of fundamental concepts and principles are refined as new evidence is considered.	5.1.8.C.1
Science Practices: Participate Productively	Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.	5.1.8.D.1

in Science	In order to determine which arguments and explanations are most persuasive, communities of learners work collaboratively to pose, refine, and evaluate questions, investigations, models, and theories (e.g., argumentation, representation, visualization, etc.).	5.1.8.D.2
Life Science: Interdependence	All organisms cause changes in the ecosystem in which they live. If this change reduces another organism's access to resources, that organisms may move to another location or die.	5.3.6.C.3
Life Science: Interdependence	Symbiotic interactions among organisms of different species can be classified as: parasite/host	5.3.8.C.1

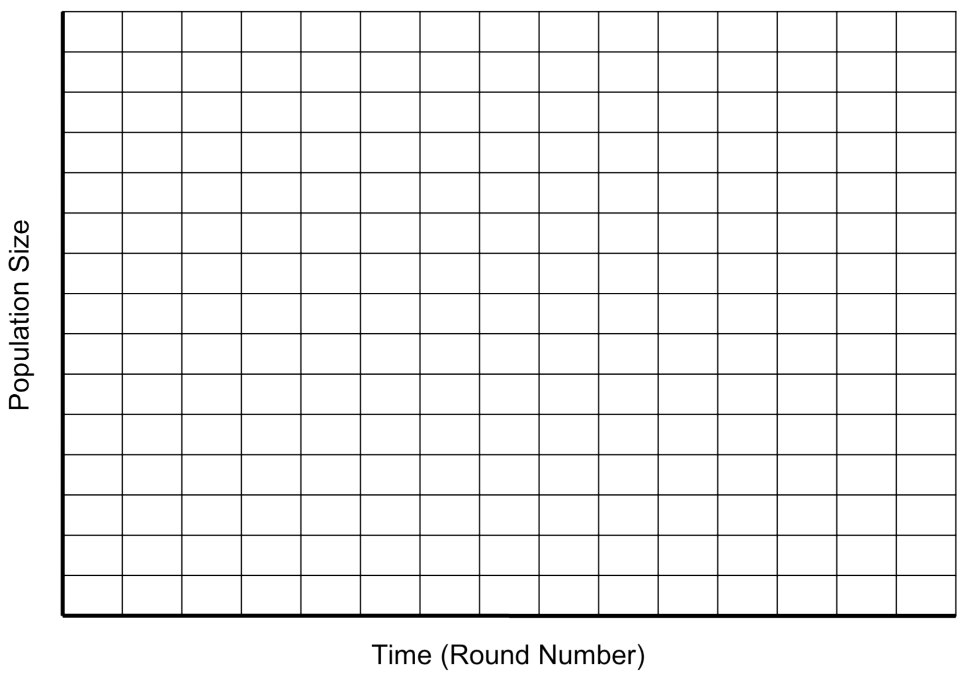
Preparation (20-40 minutes)

1. Write the motivating questions up on the board:

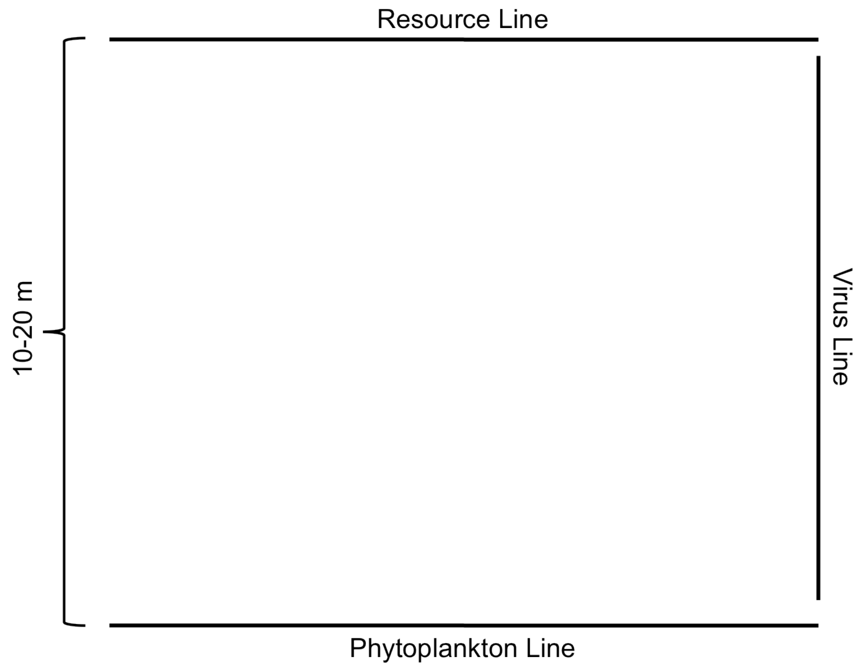
   Q. How does the population size of phytoplankton and viruses compare over time?

   Q. How would you classify the symbiotic interaction between phytoplankton and viruses?

2. Prepare the flipchart graph for the class data, with Population Size on the y-axis and Time (Round Number) on the x-axis.



3. In the space that you will use for the activity, mark two parallel lines (a Resource Line & a Phytoplankton Line) on the floor about 10-20 meters apart (see image below). At the end of these 2 lines, mark a third line perpendicular to the two parallel lines (Virus Line).



4. Make a copy or prepare to project the Phytoplankton and Viruses Population Sizes Figure.

Engage (20 minutes)

Engaging in the Simulation

1. Tell students that they will be participating in an activity that demonstrates how phytoplankton and viruses survive and reproduce over time. Review what phytoplankton need to survive: sunlight and nutrients. Also review what viruses need to survive: other organisms like phytoplankton.
2. Ask the students to count off in fours. Have all of the ones line up behind the Phytoplankton Line; the rest of the students (2s-4s) line up behind Resource Line, facing the 1s on the Phytoplankton Line.
3. The 2s, 3s, and 4s are the resources that phytoplankton need to survive. Again, ask the students what the essential resources are (sunlight and nutrients). Each student should choose at the beginning of each round what resource component s/he will be during the round (sunlight or nutrients). If a student is sunlight, he/she should stand with his/her hands in a circle above his/her head. If he/she is nutrients, he/she should put his/her hands on his/her stomach.
4. The 1s become "phytoplankton." All phytoplankton need resources to survive. The phytoplankton (the 1s) need to find sunlight and nutrients to survive and reproduce. When a phytoplankton is looking for a particular resource s/he should indicate this in the same way as the resources show what they are (i.e., placement of hands). A phytoplankton can choose to look for only one resource during each round of the activity. The phytoplankton cannot change what it is looking for within a round (e.g., when it sees what is available during that round). However, since phytoplankton need both of these essential resources for survival, the students acting as phytoplankton must change which resource they choose between each round.
5. Begin the each round by asking all of the students to face away from each other and make their signs – each phytoplankton deciding what it is looking for and each nutrient deciding which it will be for that round. Give the students a few moments to put their hands in place.
6. Explain that when the students are ready, you will say, "Ready, Set, Eat!" and each phytoplankton and resource should turn to face each other while holding their hands in place.

7. When phytoplankton see the resource that they need, they should walk to it. Each phytoplankton must hold the sign of what it is looking for until getting to the resource student with the same sign. When the phytoplankton reaches a resource that it needs, he/she should take the resource back to the phytoplankton line. "Capturing" a resource represents the phytoplankton successfully meeting its needs and successfully reproducing as a result. Any phytoplankton that fails to find a resource, dies and becomes part of the resource pool. That is, any phytoplankton that died will be a resource in the next round and so available as a resource to the phytoplankton that are still alive.
8. To gather data during the simulation, record the number of phytoplankton and the number of viruses at time 0 (start of the simulation) and at the end of each round on the flipchart graph. Continue the simulation with just the resources and phytoplankton participating for approximately 5 rounds.
9. After the first 5 rounds, introduce the virus as a predator in the system and designate someone to be the first "virus". The virus starts in the designated "virus" area off to the side of the game space (behind the Virus Line). The virus needs living phytoplankton, so s/he can tag a phytoplankton only when the phytoplankton is going toward the resources. Once a phytoplankton has been tagged by the virus, the virus escorts the phytoplankton back to the "virus" area. Because the virus was able to get a phytoplankton he/she was able to reproduce, so the phytoplankton becomes another virus. Viruses that fail to tag a phytoplankton die and become resources. That is, in the next round the virus that died joins the resources line. They will become available to surviving phytoplankton.
10. Continue to record the number of phytoplankton and viruses at the end of the round on the flipchart graph. Continue the activity for approximately 10-15 more rounds.

Making Sense of the Data

11. At end the of 15-20 rounds, bring the students together to discuss the activity. Encourage them to talk about what they experienced and saw.
12. Use the flipchart graph to have the students look at the data from the activity. The number of phytoplankton at the beginning of the activity and at the end of each round represents the number of phytoplankton in a series of days. That is, the beginning of the activity is day one and each round is an additional day. The students will see this visual reminder of what they experienced during the activity: the phytoplankton population fluctuated over a period of days. This process is natural as long as the factors that limit the population do not become excessive to the point where the phytoplankton cannot successfully reproduce. The populations will tend to peak, decline, and rebuild; peak, decline, and rebuild – as long as there are enough resources and sufficient numbers of phytoplankton to reproduce.

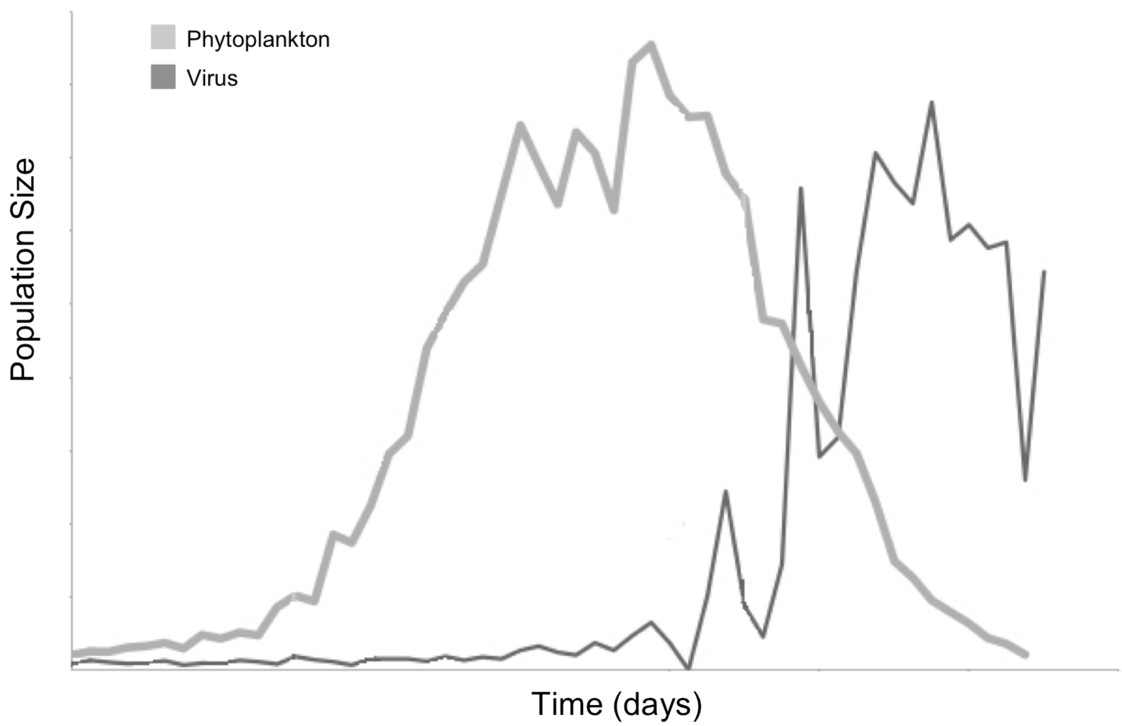
Explore (15 minutes)

1. Tell the students that they just completed a model of the interaction between phytoplankton and virus populations in the ocean. Scientists at Rutgers University and other universities were interested in looking at interactions between phytoplankton and viruses in the ocean. Therefore, they performed multiple experiments in Norway using a phytoplankton called coccolithophore (*Emiliania huxleyi*) its double-stranded DNA-containing coccolithoviruses (EhVs).
2. Explain to the students that they will work in small groups to interpret the data from the Norway research experiments. The students need to work together to draw conclusions from their data about the relationship between phytoplankton (coccolithophore) and viruses (coccolithoviruses). The students will present their data to the class at the end of their 3 minutes. Encourage the students to consider:
    a. What conclusions they can draw from the data? Was there a pattern or relationship over time between the population sizes of the phytoplankton and viruses?

b. What does their data tell them about the relationship between phytoplankton (coccolithophore) and viruses (coccolithoviruses)?

3. Project the "Phytoplankton and Viruses Population Sizes Figure" so that everyone can see it.

Phytoplankton and Virus Population Sizes Figure



4. As the students are talking through the data, circulate and answer questions as needed.
5. After three minutes have passed (or as the students begin to wrap-up their work), have the groups report to the class what they were interpreting in their data:
   a. What conclusions can they draw from the data? Was there a pattern or relationship over time between the size of the populations of phytoplankton and viruses?
   b. What does their data tell them about the relationship between phytoplankton (coccolithophore) and viruses (coccolithoviruses)?
6. As the students are sharing what their groups discussed, capture some of the statements about the relationship between phytoplankton (coccolithophore) and viruses (coccolithoviruses) that they are sharing on the board. Encourage the students to site what data/evidence they used to draw their conclusions.

Make Sense (10 minutes)

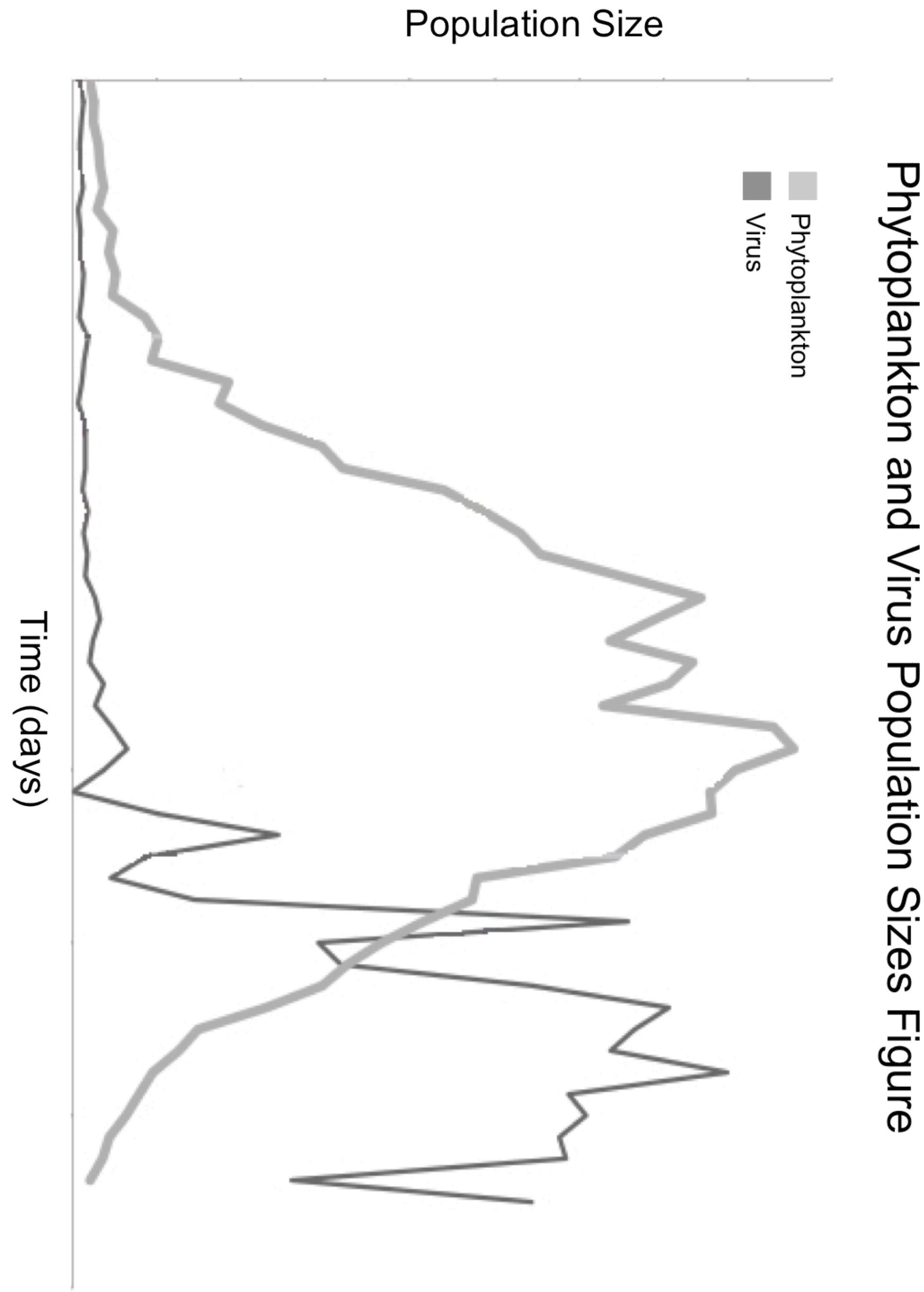
1. Post the flipchart graph next to the projected "Phytoplankton and Virus Population Sizes Figure" to have the students observe both sets of data. Ask the students to think to themselves about the similarities and differences among the patterns in the two datasets.
2. After a minute or two, have the students turn to his/her neighbor to discuss their thoughts about the similarities and differences among the patterns in the two datasets.

3. After a few minutes, pull the class back together and have volunteers share their discussions about the datasets. Be accepting of all responses, as this is a personal reflection activity for the lesson.
4. Once the discussion slows down, point to the first motivating question and ask:

   Q. How does the population size of phytoplankton and viruses compare over time?
5. Then, ask if the students have any additional questions about the comparison of the population sizes over time
6. Once the discussion slows down, point to the second motivating question and ask:

   Q. How would you classify the symbiotic interaction between phytoplankton and viruses?
7. As a class, have the students review what evidence they used to classify the symbiotic interaction between phytoplankton and viruses. This is your opportunity to make sure the students understand the "take home message" of the section.
8. Ask if the students have any final questions about the activities and concepts of the day.

Phytoplankton and Virus Population Sizes Figure



Common Core State Standards Connections: ELA/Literacy and/or Math

English Language Arts

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts.
WHST.6-8.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.

Mathematics

MP.2	Reason abstractly and quantitatively.
6.SP.B.5	Summarize numerical data sets in relation to their context.
7.RP.A.2	Recognize and represent proportional relationships between quantities.

Next Generation Science Standards

Ecosystems: Interactions, Energy, and Dynamics, MS-LS2-1 – Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Science & Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data - Analyze and interpret data to provide evidence for phenomena.	*LS2.A: Interdependent Relationships in Ecosystems* - Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources.	*Cause and Effect* – Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Ecosystems: Interactions, Energy, and Dynamics, MS-LS2-4 – Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Science & Engineering Practice	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence - Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	*LS2.C: Ecosystem Dynamics, Functioning, and Resilience* – Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.	*Stability and Change* – Small changes in one part of a system might cause large changes in another part.