

Bighorn Sheep and Wolves in Nevada



The Phenomenon

Bighorn sheep are native to Nevada. However, this species disappeared from the area around Pyramid Lake in the early 1900s as a result of overhunting. The Nevada Department of Wildlife (NDOW) and the Pyramid Lake Paiute Tribe decided to reintroduce 21 bighorn sheep to this area in January 2020. Take a minute to watch a news report about this project. As you watch the video, write down some things you notice and wonder about.

Things I noticed ...	Things I wonder about...

The Task

The video you watched highlighted how NDOW and the Paiute Tribe worked together to capture 21 bighorn sheep and then release them near Pyramid Lake. They hope this small population of bighorn sheep will grow to at least 100 individuals by 2025. NDOW and the Paiute Tribe are now working together on a project to reintroduce wolves to the same area. Wolves, however, are known predators of sheep.

Before they can reintroduce the wolves, NDOW and the Paiute Tribe need to determine when the sheep population will be large enough to support a population of wolves in the same area. They also need to determine how many wolves to release, because releasing too many wolves might cause the sheep population to become unstable and die off. On the other hand, releasing too few wolves into the area would decrease the likelihood that the wolves will survive after they are reintroduced. Your goal in this investigation is to figure out how large the population of sheep in the area needs to be before a wolf population can be introduced and to figure out how big the initial wolf population can be without causing one or both of the populations to die out. The guiding question of this investigation is:

How many wolves should be released, and when should they be released to ensure that the wolf and sheep populations will be able to coexist in the Pyramid Lake region?

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Initial Ideas

Before you start this investigation, take a few minutes to think about how the population of bighorn sheep and a new population of wolves may or may not interact with each other around Pyramid Lake once the wolves are reintroduced. Then draw a model in the space below depicting how you think these two populations will interact with each other and the environment. Be sure to include labels to help explain your thinking.

Some **ideas** that I have...

Now list some things that you think will be important to learn more about during this investigation in the space below.

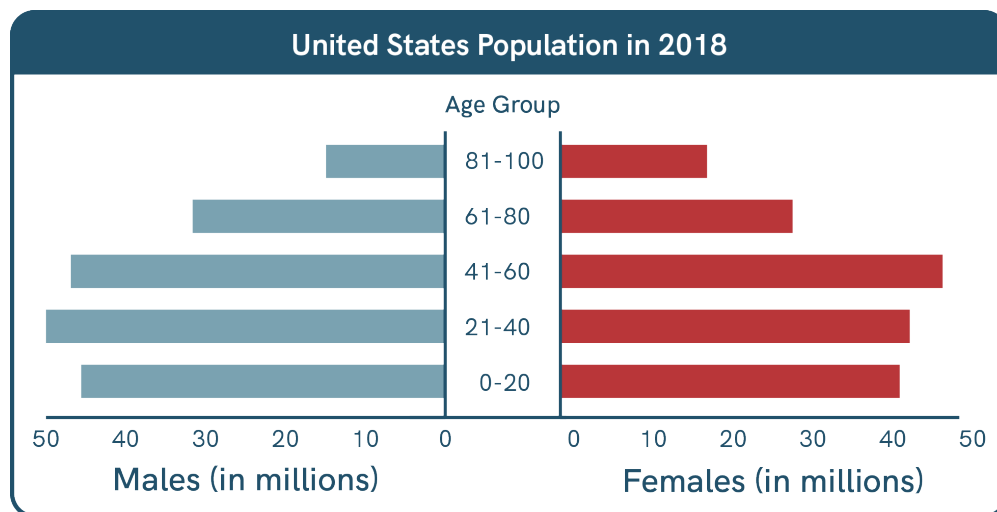
Some **things** that I want to know more about...

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Some Ideas You Can Use: Populations

A **population** is a group of individuals that belong to the same species and live in the same region. Populations have unique characteristics such as a birth rate, a death rate, an age structure, and a sex ratio. The birth rate is the number of births within a population during a period of time, and the death rate is the number of deaths during a time period. The age structure refers to the distribution of individuals based on age. The sex ratio is the proportion of males and females in the population. The picture below is called a population pyramid. This population pyramid shows both the age structure and sex ratio of the United States population in 2018.



The age structure and sex ratio of a population can change over time because the birth and death rates of different types of individuals vary from year to year. For example, after several years of many births, the population's age structure might shift, causing the average age of the individuals in a population to be younger than it was before. The characteristics of a population can also change as different individuals join (emigrate) or leave (migrate) the population or when some event affects certain individuals more than others (such as a disease that is deadly to older individuals).

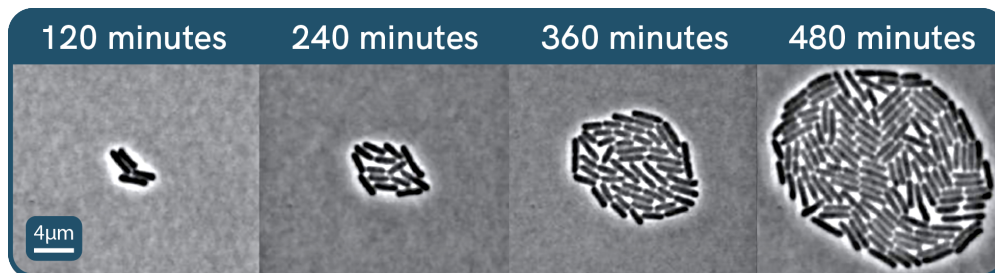
Some things I **know** from what I read...

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Some Ideas You Can Use: Changes in Population Size

Several factors affect the size of a population over time. First, population size is affected by the **per capita growth rate**, which is how much the size of a population changes per individual in the population. This growth rate is determined by the population's birth and death rates. When the per capita growth rate is positive and does not change for several generations, a population will experience exponential growth. The picture below shows a population of bacteria called *Escherichia coli* (*E. coli*) undergoing exponential growth.

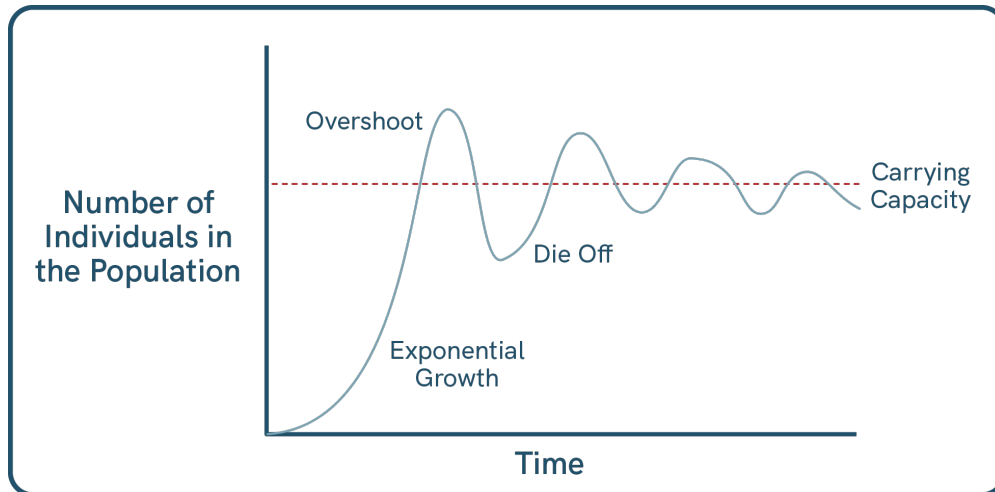


These single-celled organisms reproduce by dividing into two separate cells. As soon as a new cell forms, this cell and the original cell can divide again. A population of *E. coli* cells can therefore grow quickly and reach enormous numbers in a relatively short period of time when it has access to unlimited food, space, and other resources.

Most populations, however, do not have access to the unlimited food, space, and other resources they need to survive. Therefore, another factor that affects the size of a population is the **carrying capacity**. The carrying capacity is the maximum population size that an environment can sustain. The carrying capacity of an environment is limited by the resources available in that area, such as the amount of food to eat or water to drink. As the number of individuals in a population increases, these individuals must compete with other members of the population (and with individuals from other populations in the area) for the limited available resources. Some individuals, as a result, will not be able to find the resources necessary for their survival. The death rate of the population will therefore increase when competition for resources increases. At this point, the per capita growth rate of the population will decrease.

The graph below shows how the size of a population changes as it reaches the carrying capacity of an environment. The graph also illustrates how a small population of living things will grow exponentially while there are plenty of resources available. The population will then "overshoot" the environment's carrying capacity. Overshoot occurs when the size of the population is greater than the carrying capacity, so some individuals in the population die off because they cannot find enough resources to survive. At this point, the death rate of the population is greater than the birth rate. Once the population size is less than the carrying capacity, it will start to increase again.

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As the birth rate and the death rate of the population change, the number of individuals in the population will fluctuate above and below the carrying capacity. Eventually, the population reaches a stable equilibrium point at or near the environment's carrying capacity. The carrying capacity of an environment, however, is not static. It can decrease due to resource destruction resulting from disease, a natural disaster (such as a drought), or human activity. On the other hand, the carrying capacity can also increase when more resources are available than usual.

Some things I **know** from what I read...

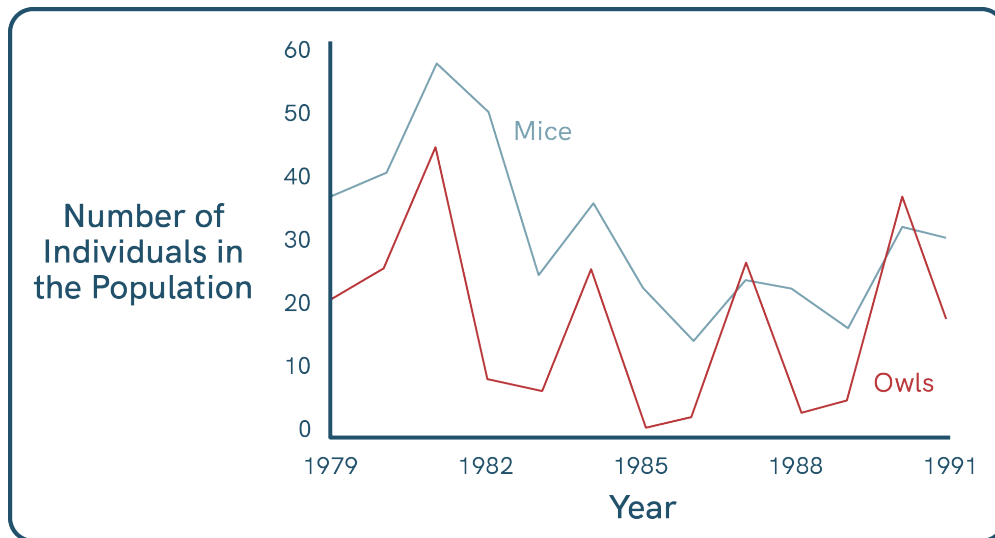
Some Ideas You Can Use: Predator-Prey Population Size Relationships

Predation is an interaction between species in which one species (the **predator**) uses another species as food (the **prey**). Predation often leads to an increase in the population size of the predator and a decrease in the population size of the prey. However, if the size of a prey population gets too small, many of the individuals that compose the population of predators may no longer have enough food to eat and will

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die. As a result, the predator population size and the population size of its prey are linked. The sizes of a predator population and a prey population change in a predictable pattern. This predictable pattern is often described as a **predator-prey population size relationship**. The graph below depicts an example of a predator-prey population size relationship that exists between a population of mice and a population of owls.



The pattern in the graph above begins with an increase in the size of the mouse population. The increase in the size of the mouse population then leads to an increase in the size of the owl population. An increase in the size of the owl population then results in a decrease in the size of the mouse population, which causes a decrease in the owl population. The whole cycle then starts again. A predator-prey population size relationship that results in both populations surviving over time, despite fluctuations in their respective sizes over several generations, is described as **stable**. The predator-prey population size relationship between the owl and mouse populations illustrated in the graph above is an example of a stable relationship. A predator-prey relationship that results in the disappearance of one or more populations, in contrast, is described as **unstable**.

Some things I **know** from what I read...

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Plan Your Investigation

Prepare a plan for your investigation by filling out the chart below.

I am trying to answer the following **question**...

I will use the following **observations or measurements**...

I will **analyze** these observations or measurements by...

I approve of this investigation plan

Teacher's Signature

Date

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Collect Data

Keep a record of what you observe or measure during your investigation in the space below.

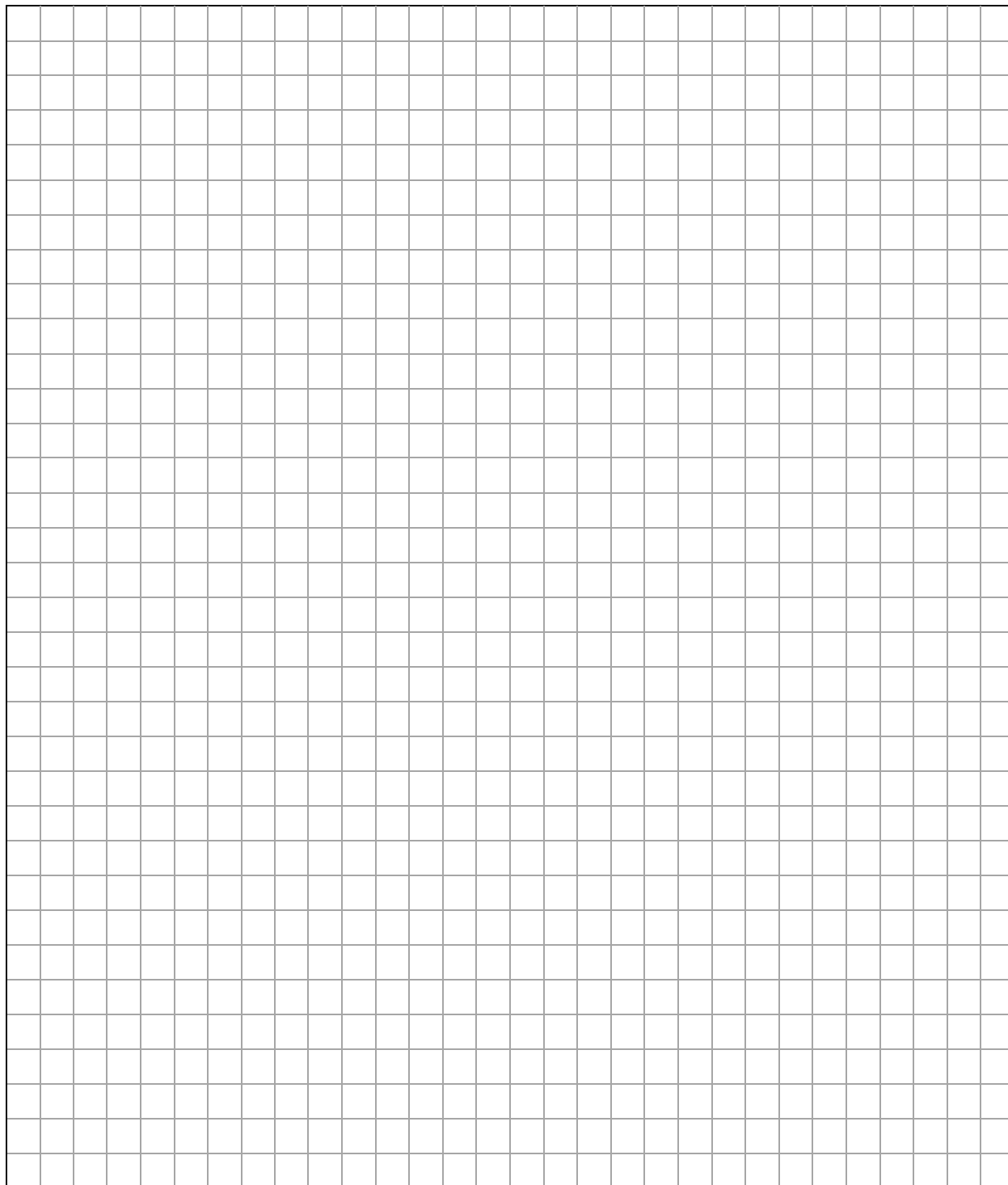
My **observations or measurements...**

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Analyze Your Data

You will need to analyze the data you collected before you can develop an answer to the guiding question. To analyze the data you collected, create one or more graphs to demonstrate how the populations of Bighorn sheep and wolves change over time.



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Draft Argument

Develop an argument on a whiteboard. It should include:

1. A *claim*: Your answer to the guiding question.
2. *Evidence*: An analysis of the data and an explanation of what the analysis means.
3. A *justification of the evidence*: Why your group thinks the evidence is important.

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

Argumentation Session

Share your argument with your classmates. Be sure to keep track of any ideas that you can use to revise your argument and make it better in the space below.

Some possible ways to **improve** our argument...

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Reflective Discussion

You can keep track of any ideas from the discussion that you think are important or will be useful in the future in the space below.

Some important **ideas**...

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Draft Report

Prepare a *report* to share what you figured out during your investigation.

Introduction

We have been studying _____ in class. Before we started this investigation, we explored _____

We noticed _____

Our goal for this investigation was to figure out _____

The guiding question was _____

Method

To answer this question, _____

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Argument

We figured out _____

The _____ below includes information about _____

This analysis suggests _____

This evidence is based on several important scientific ideas. The first one is _____

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Investigation Information and Standards Alignment

Subject
Science

Discipline
Biology

Grade band
9-12

Task

Students figure how large a population of sheep needs to be before a wolf population can be re-introduced into the area and how big the initial wolf population can be without causing one or both of the populations to die out.

Core Idea(s)

B7: Ecosystem Dynamics and Functions

B8: Social Interactions and Group Behavior in Ecosystems

Practices

SEP1: Asking questions and defining problems

SEP2: Developing and using models

SEP3: Planning and carrying out investigations

SEP5: Using mathematics and computational thinking

SEP7: Engaging in argument from evidence

SEP8: Obtaining, evaluating, and communicating information

Crosscutting Concepts

CC1: Patterns

CC7: Stability and change

Alignment with Academic Standards for Science

Teachers can use this investigation to help students reach any of the performance expectations for science that are listed in the table below.

Source	Code	Performance Expectation
NGSS	HS-LS2-2	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
Alabama	Biology 16	Identify density-dependent and density-independent limiting factors that affect populations in an ecosystem
Arizona	HS.L2U1.19	Develop and use models that show how changes in the transfer of matter and energy within an ecosystem and interactions between species may affect organisms and their environment.
Arkansas	HS-LS2-2	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
Colorado	SC.HS.2.4	Organisms interact with the living and nonliving components of the environment to obtain matter and energy.
Florida	SC.912.L17.1	Discuss the characteristics of populations, such as number of individuals, age structure, density, and pattern of distribution.

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Investigation Information and Standards Alignment

	SC.912.L.17.5	Analyze how population size is determined by births, deaths, immigration, emigration, and limiting factors (biotic and abiotic) that determine carrying capacity.
	SC.912.L.17.6	Compare and contrast the relationships among organisms, including predation, parasitism, competition, commensalism, and mutualism.
	SC.912.L.17.13	Discuss the need for adequate monitoring of environmental parameters when making policy decisions.
Georgia	SB5.a	Plan and carry out investigations and analyze data to support explanations about factors affecting biodiversity and populations in ecosystems
	SB5.c	Construct an argument to predict the impact of environmental change on the stability of an ecosystem.
Indiana	B.3.3	Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions and identify the impact of changing conditions or introducing non-native species into that ecosystem.
Minnesota	9L2.2.1.1	Use a computational model to support or revise an evidence-based explanation for factors that have ecological and economic impacts on different sized ecosystems, including factors caused by the practices of various human groups.
Mississippi	BIO.5.5	Evaluate symbiotic relationships (e.g., mutualism, parasitism, and commensalism) and other coevolutionary (e.g., predator-prey, cooperation, competition, and mimicry) relationships within specific environments.
	BIO.5.6	Analyze and interpret population data, both density-dependent, and density-independent, to define limiting factors. Use graphical representations (growth curves) to illustrate the carrying capacity within ecosystems.
Missouri	9-12.LS2.A.1	Explain how various biotic and abiotic factors affect the carrying capacity and biodiversity of an ecosystem using mathematical and/or computational representations
	9-12.LS2.C.1	Evaluate the claims, evidence, and reasoning that the interactions in ecosystems maintain relatively consistent populations of species while conditions remain stable, but changing conditions may result in new ecosystem dynamics
Montana	LS2.A	Use mathematical or computational representations to support arguments about environmental factors that affect carrying capacity, biodiversity, and populations in ecosystems.
Nebraska	SC.HS.7.2.B	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales
North Carolina	Bio.2.1.3	Explain various ways organisms interact with each other (including predation, competition, parasitism, mutualism) and with their environments resulting in stability within ecosystems.

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	Bio.2.1.4	Explain why ecosystems can be relatively stable over hundreds or thousands of years, even though populations may fluctuate.
	Bio.2.2.1	Infer how human activities may impact the environment.
Ohio	B.DI.2	Devise a study to investigate ecosystems in equilibrium and an ecosystem in disequilibrium. Predict how predator/prey population cycles will change if there are changes in the number of either species. Explain how humans can impact predator/prey relationships. Compare equilibrium and disequilibrium. Give examples of each in real populations.
South Carolina	H.B.6.A.2	Use mathematical and computational thinking to support claims that limiting factors affect the number of individuals that an ecosystem can support.
Texas	Biology 12.A	Interpret relationships, including predation, parasitism, commensalism, mutualism, and competition, among organisms.
	Biology 12.E	Describe how environmental change can impact ecosystem stability.
Utah	BIO.1.1	Plan and carry out an investigation to analyze and interpret data to determine how biotic and abiotic factors can affect the stability and change of a population.
	BIO.1.4	Develop an argument from evidence for how ecosystems maintain relatively consistent numbers and types of organisms in stable conditions.
Virginia	BIO.8.a	Investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include interactions within and among populations, including carrying capacities, limiting factors, and growth curves.
Wyoming	SES-HS-LS2-1	Describe how the population of a species changes in relation to the availability of resources.
	SES-HS-LS2-2	Identify factors that affect biodiversity in different environments.

Alignment with Common Core State Standards for English Language Arts

Teachers can use this investigation to help students reach any of the performance expectations for reading, writing, or speaking and listening that are listed in the table below.

Strand	Code	Standard
Reading	RH.9-10.1	Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
	RST.9-10.2	Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
	RST.9-10.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to <i>grades 9-10 texts and topics</i> .
	RST.9-10.5	Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., <i>force</i> , <i>friction</i> , <i>reaction force</i> , <i>energy</i>).

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Investigation Information and Standards Alignment

	RST.9-10.6	Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., <i>force</i> , <i>friction</i> , <i>reaction force</i> , <i>energy</i>).
	RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words
	RST.9-10.8	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words
	RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts
	RST.9-10.10	read and comprehend science/technical texts in the grades 9-10 text complexity band independently and proficiently
Writing	WHST.9-10.1.A	Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence
	WHST.9-10.1.B	Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns
	WHST.9-10.1.C	Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims
	WHST.9-10.1.D	Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing
	WHST.9-10.1.E	Provide a concluding statement or section that follows from or supports the argument presented.
	WHST.9-10.2.A	Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension
	WHST.9-10.2.B	Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
	WHST.9-10.2.C	Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.

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	WHST.9-10.2.D	Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
	WHST.9-10.2.E	Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
	WHST.9-10.2.F	Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
	WHST.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
	WHST.9-10.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
	WHST.9-10.6	Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically
	WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.
	WHST.9-10.10	Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.
Speaking and Listening	SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
	SL.9-10.1.A	Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.
	SL.9-10.1.B	Work with peers to set rules for collegial discussions and decision-making (e.g., informal consensus, taking votes on key issues, presentation of alternate views), clear goals and deadlines, and individual roles as needed.
	SL.9-10.1.C	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
	SL.9-10.1.D	Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections in light of the evidence and reasoning presented.
	SL.9-10.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence.

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	SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
	SL.9-10.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.
	SL.9-10.3	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Alignment with English Language Proficiency Standards

Teachers can use this investigation to help emerging multilingual students reach the performance expectations for English language proficiency listed in the table below.

Modality	Code	Standard
Receptive	ELP 1	Construct meaning from oral presentations and literary and informational text through grade-appropriate listening, reading, and viewing.
	ELP 8	Determine the meaning of words and phrases in oral presentations and literary and informational text.
	ELP 3	Speak and write about grade-appropriate complex literary and informational texts and topics.
Productive	ELP 4	Construct grade-appropriate oral and written claims and support them with reasoning and evidence.
	ELP 7	Adapt language choices to purpose, task, and audience when speaking and writing.
	ELP 9	Create clear and coherent grade-appropriate speech and text.
	ELP 10	Make accurate use of standard English to communicate in grade-appropriate speech and writing.
	ELP 2	Participate in grade-appropriate oral and written exchanges of information, ideas, and analyses, responding to peer, audience, or reader comments and questions.
	ELP 5	Conduct research and evaluate and communicate findings to answer questions or solve problems.
	ELP 6	Analyze and critique the arguments of others orally and in writing.