ACTIVITY 4

Modeling Factors Affecting a Population

COMPUTER SIMULATION

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Modeling Factors Affecting a Population

ACTIVITY SUMMARY

Using computer models, students investigate the inclusion of factors in a model based on their relative impact, known as *orders of understanding*. The first model explores the changing distribution of two fictional butterfly species. Students use this model to determine how each of four environmental factors appears to affect each species. A second model provides a clearer picture of the orders of understanding of factors on each species. Students make predictions about the likely future population size and distribution. They then apply their findings to make a decision about possible actions to address the changing butterfly populations.

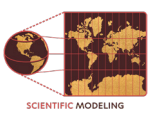
ACTIVITY TYPE
COMPUTER SIMULATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
1–2

KEY CONCEPTS & PROCESS SKILLS

1. When constructing a model, it is helpful to distinguish those factors that have a greater impact on the question being studied from those with a lesser impact. This framework for differentiating among factors is known as *orders of understanding*.
2. Scientific models are constructed to explain phenomena and make predictions. They represent aspects of the natural world that are too small, too large, too complex, or too difficult to observe or explain directly.
3. Different scientific questions about a single system may be best addressed by different scientific models, or one model may be used to answer multiple questions.

CONCEPTUAL TOOLS



NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTIONS:

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. *(Science and Engineering Practice: Analyzing and Interpreting Data)*

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. *(Science and Engineering Practice: Developing and Using Models)*

VOCABULARY DEVELOPMENT

orders of understanding

the factors included in a model based on which factors have a greater impact on the system than others

TEACHER BACKGROUND INFORMATION

Orders of Understanding

Since complex systems are affected by many factors, it is often useful to distinguish between those factors having the greatest impact and those factors that have a lesser impact. For example, the factors most affecting a student's success in outdoor basketball shots may be regular practice and distance from the hoop, while a less important factor may be weather. A qualitative distinction can be made between the cause(s) with the greatest impact on a given variable (known as the first-order factor), the causes with somewhat lesser impact (second-order factor), and the much less influential causes (third-order factor and higher).

In Activity 4, students are introduced to orders of understanding as they explore the effects of various factors on two butterfly populations. Students use a rating scale from 1–3 to distinguish between those factors that have the greatest impact on the population size (rated as 1) and those that have a smaller impact (rated as 3). Because this rating is a scale and not a ranking, two or more factors may have the same rating.

Later in the unit, students apply the concept of orders of understanding to construct models. When constructing a model, it is important to consider the scientific question being investigated and the effect size of different factors in the system. Constructing a model usually requires identifying and including first-order factors—factors with a greater impact on other parts of the system. A more detailed model will also include factors with a lesser impact (i.e., second-order factors and higher). Differentiating orders of understanding is useful in deciding what factors to include in a model.

Orders of understanding can be thought of as the level of detail included in a model. A first-order understanding includes only first-order factors (those with a big impact), a second-order understanding includes first-order and second-order factors (those with a medium impact), and a third-order understanding also includes factors with a small impact.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 4.1 "Population Factors"
- TOPOGRAPHIC MAP OF LOCAL AREA (OPTIONAL)

FOR EACH PAIR OF STUDENTS

- COMPUTER WITH INTERNET ACCESS

FOR EACH STUDENT

- STUDENT SHEET 4.1 "Butterfly Bluff Simulation: Model 1 Data"
- STUDENT SHEET 4.2 "Butterfly Bluff Simulation: Model 2 Data"
- STUDENT SHEET 4.3 "Butterfly Bluff Park: 2050"
- STUDENT SHEET 4.4 "Writing Frame: Evidence and Trade-offs" (OPTIONAL)
- STUDENT SHEET 1.3 "Unit Concepts and Skills (OPTIONAL)

Review the Butterfly Bluff Simulation before class so you are familiar with how it functions and are prepared to answer questions.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in pink.

GETTING STARTED (10 MIN)

1 **Present the fictional scenario found in Procedure Step 1.**

- Remind students they looked at a model of the distribution of monarch butterflies in Activity 2. Ask, Have you observed any butterflies in this area? Ask students to share their observations and what they deduced about the role of butterflies in the local ecosystem. Butterflies are pollinators (transferring pollen between flowering plants to enable plants to produce seeds and fruits) and a part of the food chain. The presence of butterflies can indicate environmental health, while a lack of butterfly populations can signal ecosystem stress. Explain to students that they will investigate factors that affect butterflies, utilizing a fictional scenario based on real-world data.

- The fictional scenario presented in Procedure Step 1 can be shared with the class in multiple ways. Read it aloud to the class or have individual students read it aloud while others follow along with the text (either as a whole class or in small groups. Depending on your student population, use oral storytelling to support diverse learners in decoding scientific ideas and constructing meaning and ask questions about the main points of the scenario to ensure comprehension. Students can refer to the text in the Student Book as needed.

- Reading the scenario aloud can better support comprehension for many students, including neurodiverse students and emerging multilingual learners who often have more highly developed listening and oral skills than reading comprehension skills. Alternatively, students can read the scenario independently.

- Let students know that the two butterfly species described in the scenario are not a real species. The Alpine Crystal butterfly is loosely based on an Alpine butterfly that depends on a specific host plant, while the Indigo Longwing is more of a generalist species that has a broader number of resources in its diet.

PROCEDURE (20 MIN)

2 Brainstorm factors that could affect the distribution of a species.

- In Procedure Step 2, have students brainstorm factors that could affect the population size and range of a butterfly species. Generate a list that can be revisited at the end of the activity. If appropriate for your student population, such as with emerging multilingual learners, consider having students initially respond in pairs and then share their ideas with the larger class.

Sample Student Response, Procedure Step 2

- availability of food
- humans moving into area/new construction
- changes in predator population
- looking for water
- changes in temperature
- natural hazard, such as a hurricane (moving organisms into new areas)

3 In Part A, students use Model 1 to observe how factors affect the distribution of two fictional butterfly species over time.

- Model 1 provides data on a map and utilizes a key to distinguish butterfly species, geographic features, and regional factors. Note that the key changes based on which elements of the simulation are selected. There is also a compass rose on the bottom-right corner of the map indicating the four cardinal directions: north, south, east, and west. Depending on your student population, you may wish to review the use of the key, a compass rose, and the meaning of the term *mean temperature* (i.e., average).

- Note that the simulation relies on color to identify changes to a factor over time and to distinguish among factors. If you have a student with limited visual acuity or color blindness, you may need to provide additional guidance or pair the student with someone who can help interpret the simulation.

- Model 1 allows students to toggle the topographic map on and off, as described in Procedure Step 4. To check for student understanding, ask, Where are the highest and lowest points on the topographic map of the Butterfly Bluff area? Students should be able to tell that the highest point is the top of the bluff, which is 1,600 meters (5,249 feet) and that the lowest point is Bluff Lake and the shoreline of the ocean, both below 200 meters (656 feet). For students who need more support with the use of a topographic map, use a few online topographic maps to show how elevation is presented. It may be helpful to provide a topographical map of your local area with a familiar landform.

- In Procedure Step 5, hand out Student Sheet 4.1, "Butterfly Bluff Simulation: Model 1 Data," and assign each pair to a butterfly species. Have students explore changes to their assigned butterfly population over the three time periods presented on the map: 1975, 2000, and 2025. In this step, they do not select any of the factors, though the river width on the map does visually change over

time; when the River Width factor is selected, data on the exact width of the river can be seen on the map. As students work, have them record their observations of Model 1 on the student sheet. A sample student response can be found at the end of this activity.

- In Procedure Steps 6 and 7, students look at how each factor changes over time and how each factor affects a butterfly population. Students may deduce that river width is the one factor that does not affect either species. If students do not notice this at this point in the activity, you need not explain it as it will become apparent in Model 2.

- In Procedure Step 8, students should have observed that the population distribution of both species changed over time. When pairs compare notes with another pair, they should share that the Indigo Longwing range has moved along the river and shrunk slightly and that its population size has been slightly declining. The Crystal Alpine butterfly range has shrunk significantly and moved up in elevation, and its population size has been declining significantly.

  Sample Student Response, Procedure Step 8

  Similarities:
  Both species' ranges moved, and their populations declined.

  Differences:
  The Crystal Alpine moved up in elevation and lost more land area than the Indigo Longwing.
  The Indigo Longwing moved along waterways such as the river and lake.

- At the end of Part A, you may want to ask students to hypothesize why the butterfly distribution is changing. Responses may vary, depending on students' awareness of changing regional temperatures and its relationship to climate change. Students who understand the impact of a warming climate may point out that a higher temperature could change the location of the food source. Or, in the case of the Indigo Longwing, the species could be found by a water source. If students do not yet see that the Crystal Alpine range is shifting to a higher elevation as a result of climate change, do not share this as it will become evident as they progress through the activity.

4 **In Part B, students use Model 2 to further investigate how factors affect the population size of both fictional butterfly species.**

- Model 2 shows the impact of 6 different factors on the population of a butterfly species. Students can move each factor independently to see its impact on a population.

- Before students begin Part B, remind them that in Model 1, they were able to see that the changes over time indicated that there are some relationships between the factors and butterfly distribution. Ask, Did Model 1 allow you to know which factors have a greater or lesser impact on the species distribution? No, Model 1 provided data about potential relationships between the distribution of a species and several factors, but it did not provide enough information to conclude exact effects or the relative impact of one factor over another. Let students know that in Part B, they will explore a second model to further explore the effects of each factor on each species, as well as two additional factors: disease and predation.

- In Procedure Step 10, hand out Student Sheet 4.2, "Butterfly Bluff Simulation: Model 2 Data." Stu-

dents collect data to help determine which factors are having an impact on their butterfly species. Students should find that, while food availability is critical to both species, each species has different relative factors that impact them. For example, the Crystal Alpine is more affected by disease compared to the Indigo Longwing. The Indigo Longwing is more sensitive to precipitation than to predation. A complete sample student response for Student Sheet 4.2 is shown at the end of this activity.

- Use Visual Aid 4.1, "Population Factors," to help describe the relationship between the species and the six factors in the model.

5 Students determine the orders of understandings for the factors in Model 2.

- The factors affecting the two species are different and have different relative impacts. As students rate the factors by applying orders of understanding, point out that the factors having the greatest impact are rated as "1" and factors having less impact are rated as either "2" or "3." Be clear that this rating is not a ranking. They may choose to use the same rating number for factors that appear to have similar impacts. They can label two factors as a 3, and/or they may not end up using every rating number. For example, for the Crystal Alpine, disease, food availability, and temperature appear to have a significant impact on its population size and, therefore, all could be rated a 1 for having a greater impact than other factors.

- If your student population needs additional support, create a list of word cues associated with each rating. For example, factors that have "serious impact/significantly reduce/primary impact" could be rated 1 (largest impact), factors that are "constant/steady" rated 2 (medium impact), and factors that are "little/no impact" rated 3 (lowest impact).

- Support students, particularly emerging multilingual learners, in sensemaking and language acquisition by adding the term *orders of understanding* to the word wall and providing an example as needed. For more information on a word wall, see Appendix 1: Literacy Strategies.

- In Procedure Step 13, when pairs compare their conclusions from their butterfly species to the conclusions of another pair who were assigned a different species, they should see that the two species have different orders of understanding for the various factors. Without having distinguished orders of understanding in Model 1, these differences may have been missed. Identifying the factors that have the greatest impact on a species and knowing how that factor is likely changing over time can be used to make more accurate future predictions. Students use this information to make a prediction about population distribution of both species in the year 2050.

- Students should notice that some factors have a positive impact on populations, and some have a negative impact. In Model 2, food availability had a positive effect on population size, and other factors had a negative effect. Challenge students to think about the direction of the effect (positive or negative) and how it relates to orders of understanding. Point out that in the context of orders of understanding, it doesn't matter if the factors have a positive or negative effect. It is the quantity, or absolute value, of the factor that determines its orders of understanding.

6 Students use Model 1 and Model 2 to predict the future of the species.

- Ask students to consider how information from both models can be used together to help explain observed changing population distribution of the species. For example, Model 1 showed that the Crystal Alpine butterflies are now found in a narrower range of higher elevation. Model 2 provides data that indicates that the Crystal Alpine are sensitive to temperature and likely moving to a cooler climate at a higher elevation. The fact that there is less food availability in this smaller geographical area helps explain its population decline.
- In Procedure Step 14, students have to combine their understanding of how the distributions are changing over time (Model 1) with the relative impact of the factors on population (Model 2). On Student Sheet 4.3, "Butterfly Bluff Park: 2050," students predict a possible species distribution for both species in the year 2050. Responses may vary, but one possible sample student response is shown at the end of this activity.
- In Procedure Step 15, lead a discussion in which students share and compare their predictions. While students explain their predictions, encourage them to cite which model they used for each aspect of their prediction.

SYNTHESIS OF IDEAS (20 MIN)

7 Discuss the similarities and differences between Model 1 and Model 2.

- Both models provide information about butterfly populations. Model 1 shows a changing range and population density with a potential correspondence to different factors, while Model 2 shows relationships between individual factors and butterfly population size.
- Discuss the kinds of questions each model can answer. Through the experiences with both models, students should be able to brainstorm questions related to the characteristics of each model, as shown in the following table:

MODEL	CHARACTERISTICS OF EACH MODEL	POSSIBLE FUTURE QUESTIONS
1	• Population density • Species range • Food availability, precipitation, river width, temperature over time • Map (visual data)	• How many butterflies can be found within the park boundary? • Where can the greatest number of Indigo Longwing be found? • What mean temperature range appears to provide the most suitable habitat for the species?
2	• Population size • Relative impact of each factor on population size (orders of understanding) • Impact of food availability, precipitation, river width, temperature, disease, and predation on population • Numerical data • Potential relationships between factors	• Is the Crystal Alpine species more likely to be affected by changes in predation or temperature? • Which species will be more affected if average precipitation levels increase? • What factor is most likely to result in an increase in population?

- Use the characteristics of the two models to emphasize the key concept that different scientific questions about a single system may be best addressed by different scientific models, or one model may be used to answer multiple questions.

8 Discuss the role of orders of understanding in designing a model.

- To reinforce the concept of orders of understanding, ask, If you could only model one factor in the butterfly simulation, which one would it be? Students are likely to say food availability or temperature since these factors had the greatest impact on both species. These factors had higher orders of understanding for the model. Follow up by asking, If the butterfly model only used a factor with a lower orders of understanding, how useful would the model be? The predictions made with such a model would not be very useful; for example, a model based on river width alone would not show any effect on butterfly distribution. For the Indigo Longwing, if the factor that was modeled was disease, which was a lower order relative to the others, or predation for the Crystal Alpine, then the model would provide little insight into changes in species distribution. In the class discussion, reinforce the idea that any model reflects the information that is used to build that model.

9 Students make a decision about the Butterfly Bluff scenario in Build Understanding item 2.

- Build Understanding item 2 applies the concepts of evidence and trade-offs to decision-making. For students who need support organizing and writing their responses, you may wish to provide optional Student Sheet 4.4, "Writing Frame: Evidence and Trade-Offs," to compose their responses. Students could also use Student Sheet 4.4 only as a reference or as a checklist as they write their responses. A sample student response for this student sheet is shown at the end of this activity. For more information on a Writing Frame, see Appendix 1: Literacy Strategies

10 **Use optional Student Sheet 1.3, "Unit Concepts and Skills," to help track important concepts of the unit.**

- You may wish to have students revisit optional Student Sheet 1.3, "Unit Concepts and Skills," and add information about orders of understanding.
- Finish the activity by revisiting the Guiding Question, *What factors should be included in a scientific model?* Use responses to this question to formatively assess students' understanding of the key concepts and process skills. Students' responses should indicate their understanding that models should include factors that have the greatest impact (higher orders of understanding), as determined by the scientific questions that are being investigated.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

1. **When constructing a model, it is important to know which aspects of the real world to include and which to leave out. Imagine you were asked to construct a model to investigate a previously unstudied population of butterflies in Butterfly Bluff Park. The model should answer the scientific question *Why is the population of this species increasing at lower altitudes?* What factors would you include in the model and why?**

   I would include food availability, elevation, and temperature because these factors address the scientific question being asked and because the models used in this activity showed that food availability was the only included factor that increased population.

2. **Butterfly enthusiasts who visit Butterfly Bluff Park are concerned about the changes in the populations of Indigo Longwing and Crystal Alpine butterflies. They are discussing the following four options with local park managers.**

   - A **Expand the boundary of Butterfly Bluff Park to the east and north so Bluff Lake and the surrounding areas are maintained as a protected food source for the Indigo Longwing.**
   - B **Actively plant the host plant at the top of Butterfly Bluff, which is the primary food for the Crystal Alpine.**
   - C **Increase the treatment of disease for both butterfly species.**
   - D **Do nothing.**

   Which option(s) would you recommend as the highest priority? Support your answer with evidence from the models and identify the trade-offs of your decision.

   Answers will vary. One sample response follows:

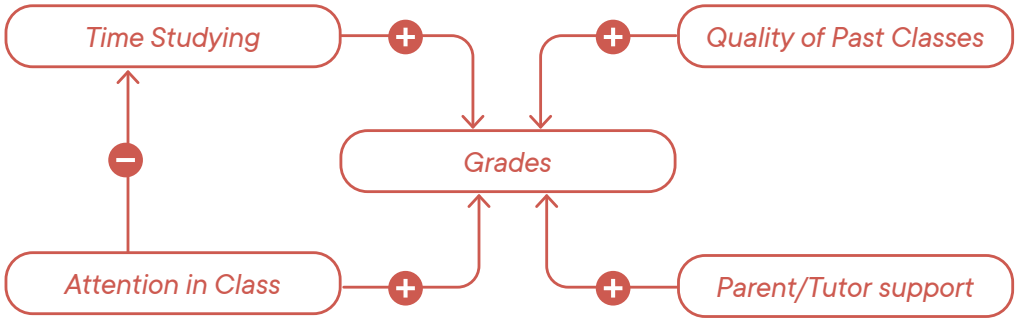
   I support Option B, planting food. My decision is based on three pieces of evidence. First, Crystal Alpine butterflies have been moving up in elevation based on Model 1. Second, they are running out of food availability as they move up in elevation. Third, food availability is one of the factors most affecting Crystal Alpine population size based on Model 2. The trade-off is that it costs time and money, and the plants might not survive. People who disagree with my decision might say that planting food interferes with nature and may have consequences for other species.

CONNECTIONS TO EVERYDAY LIFE

③ **You may spend a lot of time on social media apps. The apps' feeds seem to know what videos you want to watch next. What are three factors you think are incorporated into the apps' models to predict what videos you may like? List these factors according to their impact, considering orders of understanding, and explain your reasoning.**

Previous watch history, viewing time, and shares. Whenever I watch a new show, my feed changes. It seems less affected by my viewing time and shares.

④ **Think about how your actions affect your grade in your favorite class. Construct a model to represent the factors that you control that most affect your grade and whether each factor has a positive or negative effect. Be sure to include arrows showing any relationships between factors.**



STUDENT SHEET 4.1	BUTTERFLY BLUFF SIMULATION: MODEL 1 DATA	NAME

Butterfly Species: _____

Table 1: Butterfly Distribution, 1975–2025

Range	
Population Size	

Table 2: Factors Possibly Affecting Species Distribution

FACTOR	TREND OVER TIME	POSSIBLE CORRELATION BETWEEN FACTOR AND SPECIES DISTRIBUTION
Food availability		
Precipitation		
River width		
Temperature		

Butterfly Species: *Indigo Longwing*

Table 1: Butterfly Distribution, 1975–2025

Range	*Moved east and north along river toward Bluff Lake and got a little smaller, species range has moved out of park over time*
Population Size	*Decreased a little from 2000 to 2025*

Table 2: Factors Possibly Affecting Species Distribution

FACTOR	TREND OVER TIME	POSSIBLE CORRELATION BETWEEN FACTOR AND SPECIES DISTRIBUTION
Food availability	*Food area has decreased, shrinking into the eastern and northern areas.*	*Food availability appears to correspond to changes in the Longwing's distribution over time.*
Precipitation	*Highest levels of precipitation have moved from the coast eastward, lowest levels of precipitation moved westward.*	*No clear correlation: Longwing's initial range was in areas of high and middle precipitation. Over time, its population remained within the middle precipitation level (25-35 cm).*
River width	*Decreased from 200 meters to 175 meters in area with butterflies.*	*Longwing's range moved north and closer to Bluff Lake where river width appears narrow. No clear correlation.*
Temperature	*Area of highest mean temperature has greatly increased, moving northwest; shrinking band of coolest mean temperature in mountain area.*	*Longwing's range remained within middle mean temperature (18°C/64.5°F). Its distribution appears to correspond to changes in temperature over time.*

Butterfly Species: *Crystal Alpine*

Table 1: Butterfly Distribution, 1975–2025

Range	*Stayed within a much narrower area of the mountains over time, stayed half in and half out of the park over time*
Population Size	*Decreased a lot (maybe by 50%)*

Table 2: Factors Possibly Affecting Species Distribution

FACTOR	TREND OVER TIME	POSSIBLE CORRELATION BETWEEN FACTOR AND SPECIES DISTRIBUTION
Food availability	*Higher density of food is now available higher up the mountains, and the area of food availability has shrunk slightly.*	*Food density and food area appear to correspond to changes in the Crystal Alpine's distribution over time.*
Precipitation	*Highest levels of precipitation have moved from the coast eastward, lowest levels of precipitation moved westward.*	*Alpine's range remained mostly within the middle precipitation level (25–35 cm) over time. No clear correlation.*
River width	*Has decreased 10–25 meters in different areas.*	*Alpine's range over time does not overlap with the location of the river. No clear correlation.*
Temperature	*Area of highest mean temperature has greatly increased, moving northwest; shrinking band of coolest mean temperature in mountain area.*	*Alpine's range remained within the coolest mean temperature (17°C/63°F). Its distribution appears to correspond to changes in temperature over time.*

Butterfly Species: _____

POPULATION DATA

FACTOR	INITIAL POPULATION	FINAL POPULATION	CHANGE IN POPULATION	RELATIVE IMPACT ON POPULATION 1 = GREATEST IMPACT 3 = LEAST IMPACT
Disease				
Food availability				
Precipitation				
Predation				
River width				
Temperature				

Butterfly Species: *Indigo Longwing*

POPULATION DATA

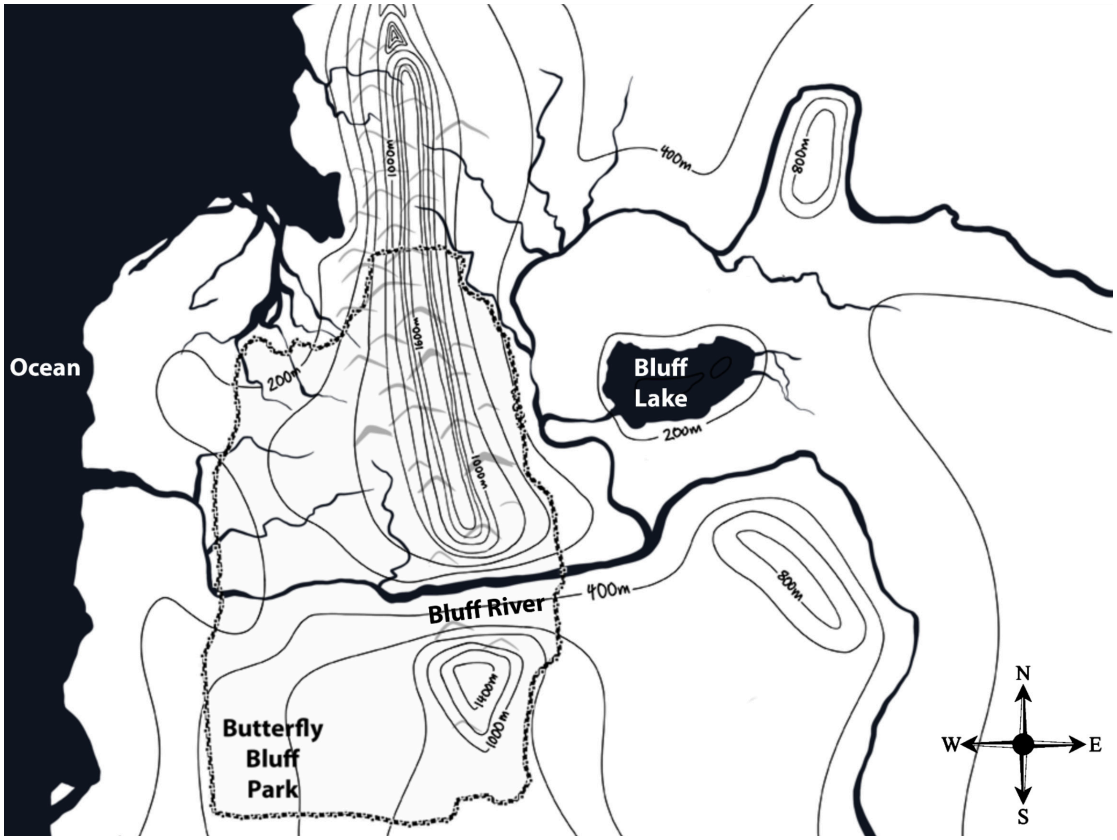
FACTOR	INITIAL POPULATION	FINAL POPULATION	CHANGE IN POPULATION	RELATIVE IMPACT ON POPULATION 1 = GREATEST IMPACT 3 = LEAST IMPACT
~~Disease~~	1,000	975	–25	3
Food availability	1,000	1,183	+183	1
Precipitation	1,000	805	–195	1
~~Predation~~	1,000	862	–138	2
~~River width~~	1,000	1,000	0	3
Temperature	1,000	838	–162	1

Butterfly Species: *Crystal Alpine*

POPULATION DATA

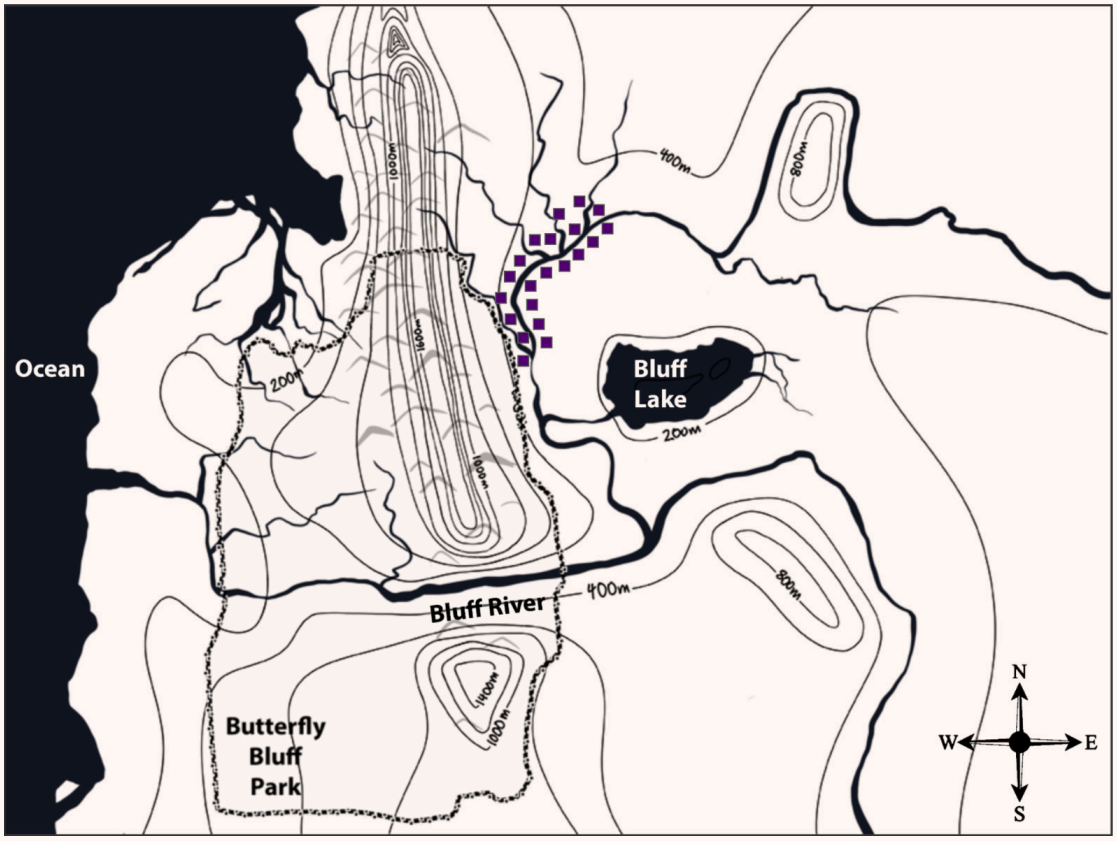
FACTOR	INITIAL POPULATION	FINAL POPULATION	CHANGE IN POPULATION	RELATIVE IMPACT ON POPULATION 1 = GREATEST IMPACT 3 = LEAST IMPACT
Disease	*1,000*	*773*	*–227*	*1*
Food availability	*1,000*	*1,173*	*+173*	*1*
~~**Precipitation**~~	*1,000*	*880*	*–120*	*2*
~~**Predation**~~	*1,000*	*967*	*–33*	*3*
~~**River width**~~	*1,000*	*1,000*	*0*	*3*
Temperature	*1,000*	*825*	*–175*	*1*

Draw your predictions of the species distribution for the Indigo Longwing and the Crystal Alpine in 2050.



Describe your predictions, making sure to explain your reasoning and how each model informed your prediction.

Draw your predictions of the species distribution for the Indigo Longwing and the Crystal Alpine in 2050.



Describe your predictions, making sure to explain your reasoning and how each model informed your prediction.

Model 2 showed that the factors most affecting the Crystal Alpine population size are food availability, disease, and temperature. I predict that the Crystal Alpine will disappear from the park and the area altogether because they will run out of places to get food at the top of the bluff as it gets warmer and wetter with climate change. Model 1 showed these trends on the map over time, so my conclusions are based on that trend continuing.

The Indigo Longwing has already disappeared from the park because it is now only found outside its boundary, and I don't think it will come back. Model 2 showed that precipitation, food availability, and temperature had the greatest impact on its population size. Model 1 showed warming temperatures moving northward and the species moving northward along the river over time. I think that the Indigo Longwing will survive, but with a smaller population size and a range that is farther north.

There is a lot of discussion about the issue of

My decision is that

My decision is based on the following evidence:

First,

Second,

Third,

The trade-off(s)

People who disagree with my decision might say that

There is a lot of discussion about the issue of

butterfly populations declining in Bluff Park.

My decision is that

the boundary of the park should be expanded north and east.

My decision is based on the following evidence:

First,

the Indigo Longwing range has moved north and east over time and is no longer found within the park.

Second,

its food availability appears to be shrinking over time based on Model 1.

Third,

food is very important to its population based on Model 2.

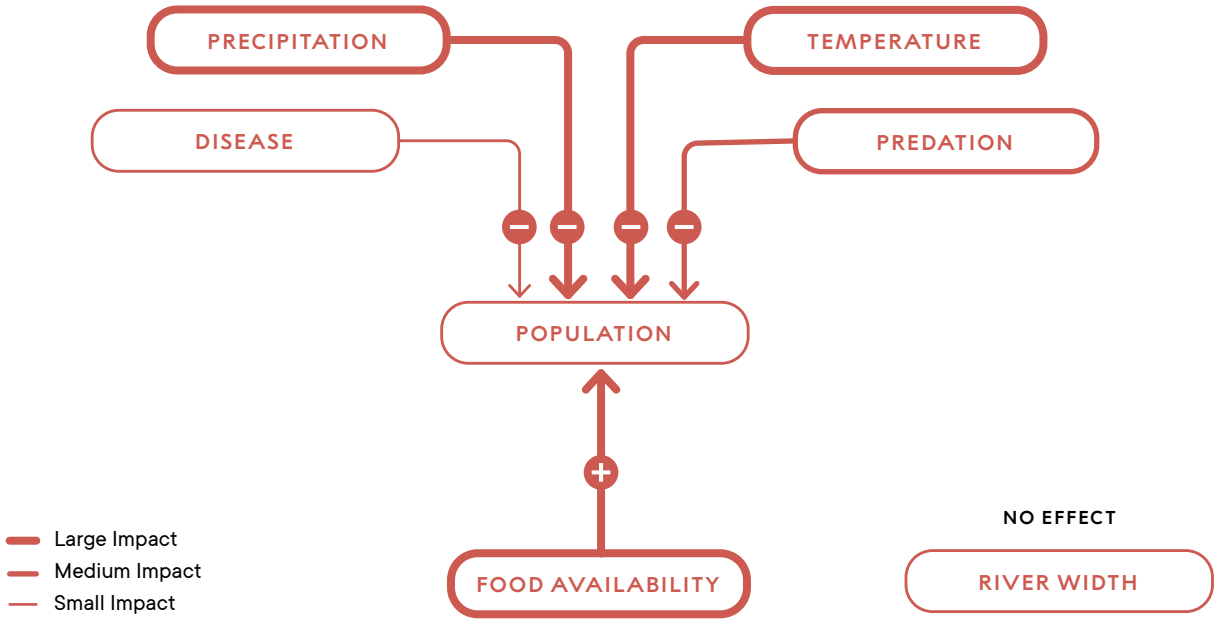
The trade-off(s)

is that expanding the boundary and protecting its food source may not be enough. Changes to temperature and precipitation may cause its population to continue to decline.

People who disagree with my decision might say that

nature changes over time, so people don't need to do anything.

INDIGO LONGWING



CRYSTAL ALPINE