ACTIVITY 10

Applying Models to Decisions

CARD-BASED INVESTIGATION

ACTIVITY 10

Applying Models to Decisions

ACTIVITY SUMMARY

Students revisit the fictional frog population of Menanda as they construct models of a frog population. Students apply their knowledge of orders of understanding to build their models. They use their models to construct a Fermi estimate and to inform a decision about which local site would best support the future frog population. The class discusses the role of models in decision-making.

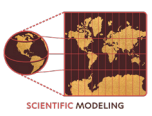
ACTIVITY TYPE
CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
2-3

KEY CONCEPTS & PROCESS SKILLS

1. 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.
2. Different questions about a single system may be best addressed by different scientific models, or one model may be used to answer multiple questions.
3. Models are developed based on observations of a system. When modeling a complex system, it is often useful to identify how a system's parts interact and to describe the limitations of the model based on the scientific question being investigated.
4. 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.*
5. One approach to mathematical modeling is estimation. Rough estimates based on limited information—known as a Fermi estimate—can be used to approximate unknown quantities that are difficult to measure.

CONCEPTUAL TOOLS



NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTION:
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: Developing and Using Models*)

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 10.1 "Scoring Guide: Developing and Using Models (MOD)"
- ITEM-SPECIFIC SCORING GUIDE: Activity 10, Build Understanding Item 1

FOR EACH GROUP OF FOUR STUDENTS

- SET OF MENANDA SITE CARDS (4 CARDS)

FOR EACH STUDENT

- STUDENT SHEET 10.1 "Evaluating Sites"
- STUDENT SHEET 10.2 "My Site Model"
- STUDENT SHEET 10.3 "Estimating Factor Impact on Population in 50 Years"
- STUDENT SHEET 10.4 "Writing Frame: Evidence and Trade-Offs" (OPTIONAL)
- SCORING GUIDE: Developing and Using Models (MOD) (OPTIONAL)

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 **Share a real-world example of the use of modeling presented in the Introduction in the Student Book.**

- The Introduction provides a real-world example of a scientific question and the application of a scientific model. You may choose to read it aloud to the class (using a storytelling approach), have individual students read a paragraph aloud to the class while others follow along with the text, have students read it cooperatively in their groups of four, or have students read it individually.
- Highlight the idea that scientists are now working to better understand how wildfires affect birds by developing models to investigate this question. You may want to have students brainstorm the kinds of models that could be constructed to investigate this question or the factors that might best be included in the model.

PROCEDURE SUPPORT (50 MIN)

2 **Present the fictional article found in Procedure Step 1.**

- The fictional scenario presented in Step 1 can be shared with the class in multiple ways. Read the scenario 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).
- 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.

3 **Hand out the Menanda Site cards and support students in rating factors according to their orders of understanding.**

- In Procedure Step 2, hand out a set of 4 Menanda Site cards to each group and Student Sheet 10.1, "Evaluating Sites," to each student. Each group member will analyze one of the sites, by completing Student Sheet 10.1. Facilitate the engagement of students with learning disabilities and neurodiverse learners by providing targeted support. Consider how to best adapt the activity to the needs of your particular student population. For example, students who need more time processing language (such as students with dyslexia) can be provided with a copy of the cards in advance of the activity.

- Students begin by reading their Site cards and rating the factors listed on Student Sheet 10.1 by their orders of understanding, from 1–3. The rating will vary by site, with cues embedded in the text about which factors have the most impact on the population at the site (with the use of terms such as *serious impact*, *small effect*, *significantly reduce*). There is no single correct answer, and students will share and discuss their ratings in their groups in Procedure Step 5.

- If your student population needs additional support, use the list of word cues associated with each rating you may have developed in Activity 4. For example, factors that have "serious impact/significantly reduce/primary impact" could be rated 1 (greatest impact), factors that are "constant/steady" rated 2 (medium impact), and factors that are "little/no impact" rated 3 (least impact).

4 **Students develop a model based on the two highest impact factors at their site.**

- On Student Sheet 10.1, students circle their site number and the two factors that have the greatest impact on the frog population at their site. They use this information to construct a model on Student Sheet 10.2, "My Site Model," using the same sample model introduced in Activities 2 and 9. Remind students that they will be using their models as part of their decision about which site to fund. Sample student responses are provided at the end of the activity.

5 **Students make estimates of the future frog population at their site and share them with their group.**

- In Procedure Step 7, hand out Student Sheet 10.2, "My Site Model," to each student. Students use data from Figure 10.2 to determine the present frog population at each site. Students are provided with information about another frog species that has doubled in size every 25 years. They use that information to predict the future population of the frogs at their sites. This prediction assumes that the population growth rate for the Menanda frogs is the same as the nearby species.

- In Procedure Step 12, hand out Student Sheet 10.3, "Estimating Factor Impact on Population in 50 Years," to each student. Students make a Fermi estimate to predict the effect of the two high-impact factors on the frog population at the site 50 years in the future. The factors selected and their general trend (increase, decrease, stay the same) are based on information from the Menanda Site cards. Students then make assumptions about how this factor may change in the future (for example, a 25% decrease in rain). Depending on your student population, you may want to model this process for a single site. Remind students to use their models to consider which factors would likely be affected

under future conditions and how it might affect their future estimates. These assumptions will vary and can generate new scientific questions and/or class discussions about what is predicted to happen in coming decades to temperature, rainfall, etc. Students record their population predictions in the last column of Table 2 on Student Sheet 10.1. A sample response to Student Sheet 10.2 (for Site 1) is provided at the end of the activity.

- For students who investigated the same site, you may want to have them compare Fermi estimates by recording their estimates on the board. Point out that it is expected that there will be a range of values. Evaluate the estimates based on scale by discussing the powers of 10 of the Fermi estimates for the same site. While exact estimates may vary based on assumptions, students should feel more confident in their estimates if they all arrived at estimates at the same scale (i.e., powers of 10). Have students share how they made their calculations and what assumptions they made. They can make revisions to their estimates as needed.

- Students share and discuss their population models and predictions for their sites in their groups. Students' responses will vary based on their models and their sites. A sample response to Student Sheet 10.3 (for each site) is provided at the end of the activity.

SYNTHESIS OF IDEAS (15 MIN)

6 **Students decide which site to recommend funding to protect and improve frog habitats.**

- Based on their models and future population estimates, students decide which site to fund. They do not need to agree, but they should be able to support their decisions with evidence from the activity, in particular their models and estimates.

- Highlight the idea that multiple models can offer different insights into the same question.

- Note that the use of models and the resulting Fermi estimates will strongly influence students' decision. Site 4 currently has the largest frog population. In the sample student response on Student Sheet 10.1 Table 2, the Fermi Estimate for Site 4 shows the greatest predicted population decline. Based on this estimate, students might choose to protect the frog habitat at Site 4.

- Encourage students to look at the difference in the scale of predicted population numbers and not simply to a particular value. For example, in the sample student response for Student Sheet 10.1, Sites 3 and 4 have different predicted populations that are at the same powers of 10.

- For students who need support organizing and writing their responses, you may wish to provide optional Student Sheet 10.4, "Writing Frame: Evidence and Trade-Offs," to compose their responses. Students could also use optional Student Sheet 10.4 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.

7 Facilitate a discussion by using a Walking Debate in Procedure Step 16.

- Use the literacy strategy of a Walking Debate in Procedure Step 16 to encourage students to discuss their opinions about which site to fund. You may want to post signs with each site number (Site 1, Site 2, etc.) and begin by having students walk to their recommended site. See Appendix 1: Literacy Strategies at the end of the Teacher's Edition for more guidance and information on using the Walking Debate with your students.

8 Assess student growth using the Developing and Using Models Scoring Guide for Build Understanding item 1.

- Build Understanding item 1 provides the opportunity for students to transfer their knowledge of modeling to a different context. Remind students of the Developing and Using Models Scoring Guide. You may wish to project Visual Aid 10.1, "Scoring Guide: Developing and Using Models (MOD)," for your students to review each level and clarify your expectations.
- Do not share the item-specific version of the Scoring Guide (Item-Specific Scoring Guide: Activity 10, Build Understanding Item 1) with students as it provides specific information on how to respond to the question prompt.
- Remind students that you expect to see them demonstrate growth in their development, use, and analysis of models, and they may want to review their responses to the assessment in Activity 3 (Build Understanding item 4) and/or Activity 5 (Build Understanding item 4).
- Sample responses for Levels 1–4 are provided in the Build Understanding section that follows. Review these responses to get an idea of what is expected for each level alongside the Item-Specific Scoring Guide. See Appendix 2, Assessment Resource, at the end of the Teacher's Guide for more guidance and information on using the Scoring Guides and assessment system with your students.
- Depending on your students, you may want to have them provide feedback on each other's work for revision prior to turning in the work to you for scoring. Alternatively, consider having students turn in a rough draft to you for feedback and revision.
- End the activity by revisiting the Guiding Question, *What role can models play in making a conservation decision?* Use this as a chance to revisit and summarize the key concepts and process skills of the unit.

9 **Revisit the Unit Driving Question, *How can scientific models be used to investigate changes in the distribution of species?***

- Over the course of the unit, students have been introduced to the role of scientific modeling in understanding, explaining, and predicting changes in species distribution over time, particularly in response to changes in climate. They have constructed and analyzed models to predict changes in population size and range, including different approaches to population estimation.

- Have a class discussion about what students have learned about scientific modeling, especially in terms of assumptions, limitations, and revisions of models. Scientific models simplify reality to explain complex systems and make testable predictions, and they must be refined as they are approximations of systems. Emphasize that errors, inaccuracies, and limitations of models do not mean that they are not useful or reliable. Rather, the process for designing models includes evaluating and improving them over time. Encourage students to recognize that they may need to interpret scientific models in their everyday lives, such as when voting on local issues, or they may even consider careers that incorporate modeling as an essential tool.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **MOD Scoring Guide**

In Procedure Step 7, you constructed a model and described it. Complete Student Sheet 10.2 by:

- **identifying the two most high-impact factors affecting the population at this site.**
- **explaining what your model predicts about the effect of the two factors on the frog population at your site.**
- **describing at least one source of uncertainty in your model.**

Sample Level 1–4 responses (for Site 1) for Student Sheet 10.2 can be found at the end of this activity.

② **Which site do you recommend for funding to protect and improve Menanda frog habitats? Support your answer with evidence from the activity and identify the trade-offs of your decision.**

Student answers will vary. A sample response is provided.

I recommend Site 4. It has the highest population of the 4 sites. But according to my group's models, it is likely to experience the greatest population decline due to changing temperatures and predation. Building a pond will also provide a habitat for other species. The trade-off is that one of the other sites will not get funded. Someone who disagrees with me will likely question my model.

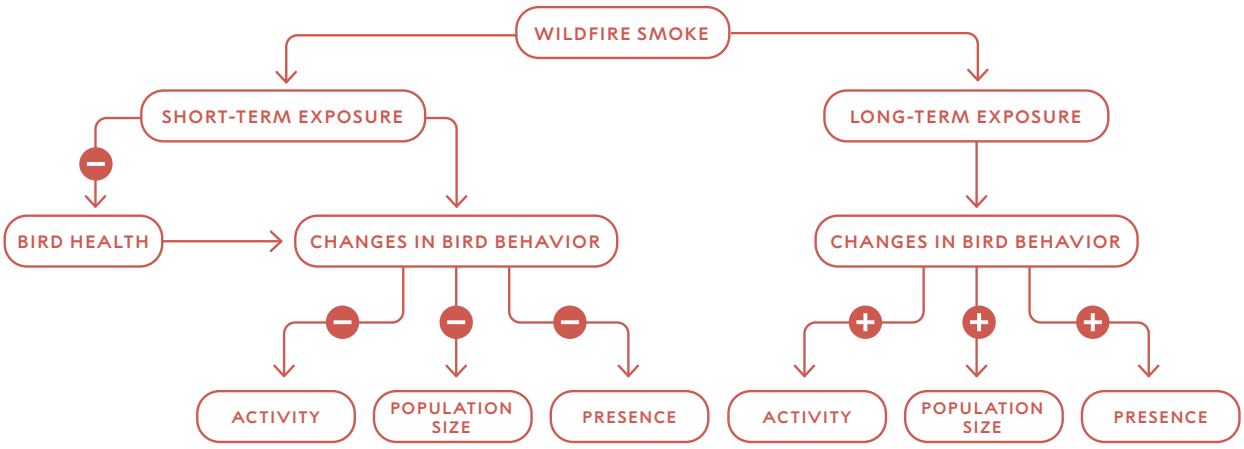
③ **A researcher creates a model to predict the local deer population over the next 5 years. At the end of the first year, the model's prediction for the population size was 40 deer, but the actual count was 25. Should the researcher revise the model? Explain what you think the researcher should do and why.**

Yes, the researcher should revise the model because it is very inaccurate. The researcher should make sure that the factors having the greatest impact on the deer population, such as predator population and disease, are included in the model. This will likely improve the model's accuracy.

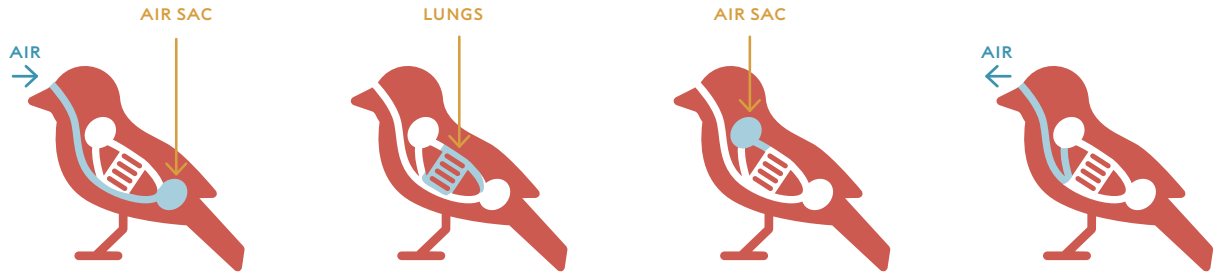
④ **In the Introduction, you learned that scientists are constructing models to explore the effects of wildfire smoke on house sparrows. Explain how each of the two models in Figure 10.3 might be used to begin to investigate this question.**

FIGURE 10.3
Two House Sparrow Models: Wildfire Effects (Model 1) and Respiration (Model 2)

MODEL 1



MODEL 2



1. **FIRST BREATH IN:** air (blue) moves into the air sac
2. **FIRST BREATH OUT:** air moves into lungs
3. **SECOND BREATH IN:** air moves into front air sac
4. **SECOND BREATH OUT:** air leaves the body

Model 1 has a lot of factors and predicts how a bird might respond to short-term and long-term exposure to smoke. It could be used to investigate how smoke exposure affects bird behavior.

Model 2 explains the biology of the bird and how it breathes. This model could be used to investigate how birds inhale wildfire smoke and how different organs in the bird might absorb smoke and lead to bird death.

CONNECTIONS TO EVERYDAY LIFE

5 This activity explored *population dynamics*—the study of how and why the size, structure, and distribution of a population change over time. Consider the ways in which people rely on and interact with different populations of organisms such as for food, recreation, conservation, and so on.

a Create a question about population dynamics that investigates a relationship between humans and an organism's population.

Student responses will vary. Sample questions include:

To what extent do loud repetitive sounds, such as cars honking, reduce the native bird population?

How does the use of weed killer affect the butterfly population?

Which bird species most benefits from birdhouses?

b List the factors that would be most relevant to creating a model to investigate this question.

Student responses will vary. The most relevant factors to the question *Which bird species most benefits from birdhouses?* include:

The present size of the bird population, the number of birdhouses, their locations, and the size of different bird species.

REFERENCES

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Nihei, A., Sanderfoot, O. V., LaBarbera, K., Tingley, M. W. (October 2024). Wildfire smoke impacts the body condition and capture rates of birds in California. *Ornithology*, *141*(4). ukae023. https://doi.org/10.1093/ornithology/ukae023

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Table 1: Orders of Understanding for Each Site

	SITE 1	SITE 2	SITE 3	SITE 4
Food availability				
Predation				
Yearly rainfall				
Average annual temperature				
Traffic				

Table 2: Present and Future Frog Populations for Each Site

	PRESENT FROG POPULATIONS	FUTURE FROG POPULATIONS BASED ON NEARBY SPECIES	FERMI ESTIMATE OF FUTURE FROG POPULATIONS
SITE 1			
SITE 2			
SITE 3			
SITE 4			

Table 1: Orders of Understanding for Each Site

	SITE 1	SITE 2	SITE 3	SITE 4
Food availability	*1*	*2*	*2*	*3*
Predation	*3*	*3*	*2*	*2*
Yearly rainfall	*1*	*3*	*1*	*3*
Average annual temperature	*2*	*3*	*1*	*1*
Traffic	*3*	*1*	*3*	*3*

Table 2: Present and Future Frog Populations for Each Site

	PRESENT FROG POPULATIONS	FUTURE FROG POPULATIONS BASED ON NEARBY SPECIES	FERMI ESTIMATE OF FUTURE FROG POPULATIONS
SITE 1	*50*	*200*	*50 (10^1)*
SITE 2	*500*	*2,000*	*1,250 (10^3)*
SITE 3	*200*	*800*	*250 (10^2)*
SITE 4	*1,000*	*4,000*	*300 (10^2)*

Site Number: 1 2 3 4

Construct your model:

Description of the relationships in the model:

Two of the most high-impact factors affecting the population at this site:

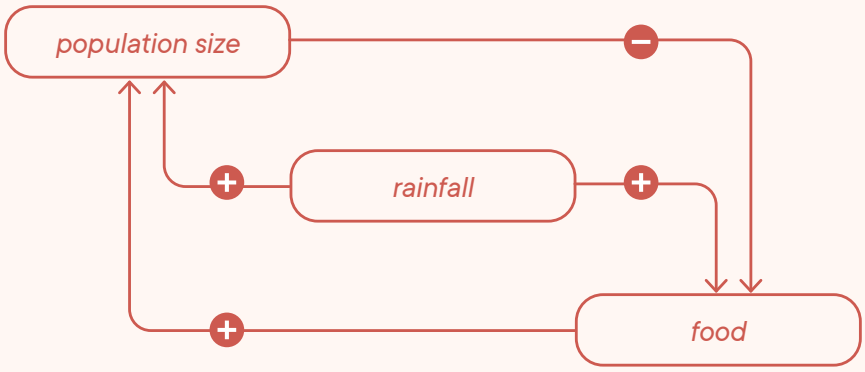
What does your model predict will happen to the frog population at this site? Explain how the factors will affect the population.

Describe at least one source of uncertainty in your model.

LEVEL 4 RESPONSE

Site Number: (1) 2 3 4

Construct your model:



Description of the relationships in the model:

Frogs need food. More food means more frogs. Lots of frogs reduces the amount of food available. Increased rainfall has a positive effect on the size of the frog population and the availability of food.

Two of the most high-impact factors affecting the population at this site:

Food availability and rainfall.

What does your model predict will happen to the frog population at this site? Explain how the factors will affect the population.

My model predicts that when there is increased rainfall, there is more food and an increase in the size of the frog population. Large frog populations reduce the availability of food (because they eat it).

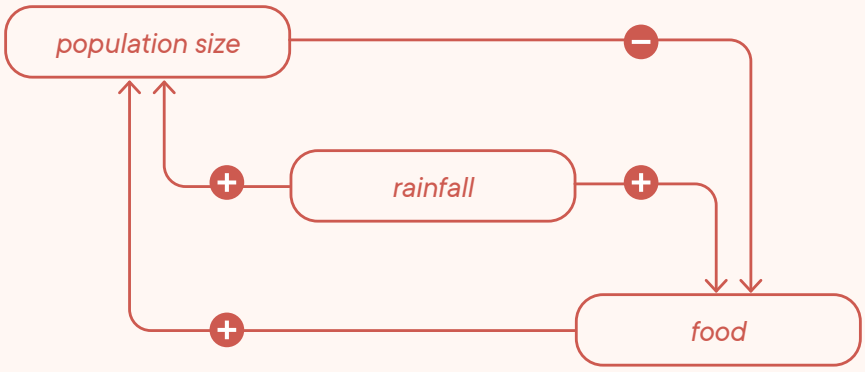
Describe at least one source of uncertainty in your model.

The effect of rainfall assumes a steady amount of rain over time. It does not take into account a severe thunderstorm or flooding, which could result in frog deaths and decreased population.

LEVEL 3 RESPONSE

Site Number: (1) 2 3 4

Construct your model:



Description of the relationships in the model:

If there is not enough food, frogs will die. Rain means there is more food and more frogs.

Two of the most high-impact factors affecting the population at this site:

Food availability and rainfall.

What does your model predict will happen to the frog population at this site? Explain how the factors will affect the population.

More rain and more food increases the frog population.

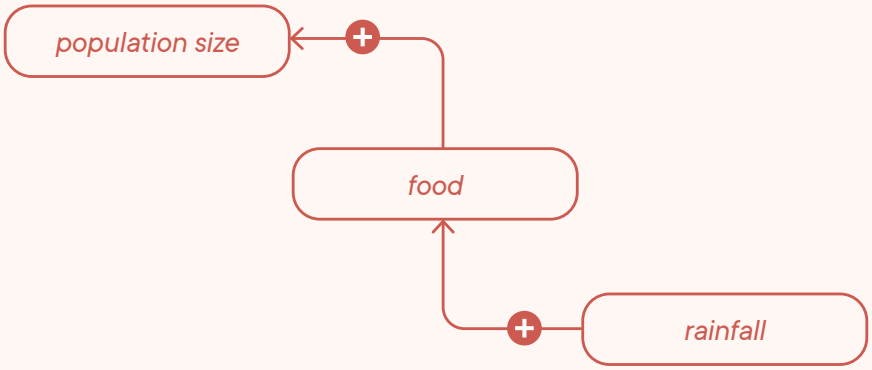
Describe at least one source of uncertainty in your model.

Rainfall varies.

LEVEL 2 RESPONSE

Site Number: (1) 2 3 4

Construct your model:



Description of the relationships in the model:

Rainfall increases food availability for the frogs.

Two of the most high-impact factors affecting the population at this site:

Food and rainfall.

What does your model predict will happen to the frog population at this site? Explain how the factors will affect the population.

The population will increase because of food and rain.

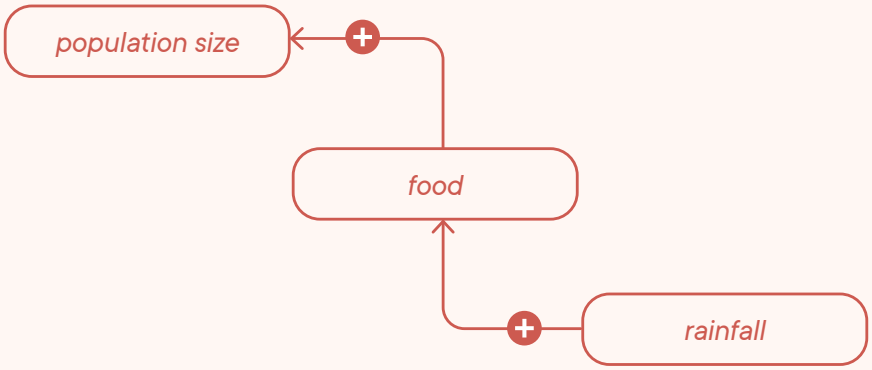
Describe at least one source of uncertainty in your model.

Frogs.

LEVEL 1 RESPONSE

Site Number: (1) 2 3 4

Construct your model:



Description of the relationships in the model:

Food and rainfall affect frogs.

Two of the most high-impact factors affecting the population at this site:

Food and frogs.

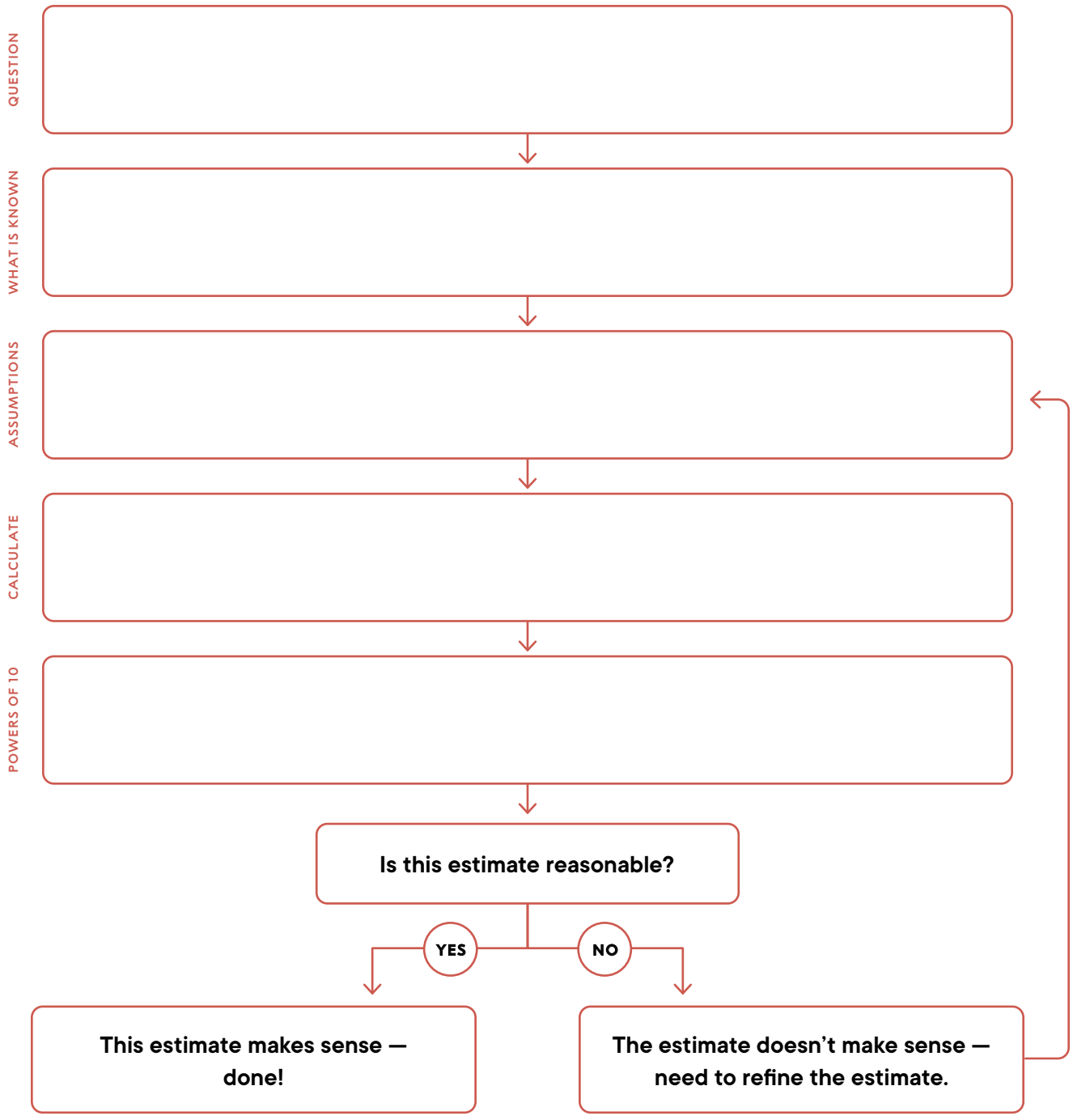
What does your model predict will happen to the frog population at this site? Explain how the factors will affect the population.

Goes up.

Describe at least one source of uncertainty in your model.

Factors.

Site Number: 1 2 3 4



Site Number: (1) 2 3 4

QUESTION

What is the likely effect of changing food availability and yearly rainfall on the future frog population at Site 1?

WHAT IS KNOWN

Current frog population of 50 frogs.
If population doubles every 25 years, there will be 200 frogs in 50 years.
The 2 factors most likely to impact the population are food and rainfall.

ASSUMPTIONS

I predict future droughts, so 50% less rainfall.
This will decrease food availability by 50%.

CALCULATE

200 frogs x ½ due to less rain = 100 frogs
100 frogs x ½ due to less food = 50 frogs

POWERS OF 10

50 frogs, or 10^1, in 50 years.

Is this estimate reasonable?

YES

This estimate makes sense — done!

NO

The estimate doesn't make sense — need to refine the estimate.

Site Number: 1 (2) 3 4

QUESTION

What is the likely effect of changing traffic patterns and food availability on the future frog population at Site 2?

WHAT IS KNOWN

Current frog population of 500 frogs.
If population doubles every 25 years, there will be 2,000 frogs in 50 years.
The 2 factors most likely to impact the population are traffic and food.

ASSUMPTIONS

I predict more traffic, which will kill about 50% of the frogs.
I predict 25% more frogs because of more food from backyard ponds.

CALCULATE

2,000 frogs x ½ due to less rain = 1,000 frogs
1,000 frogs x 1¼ due to less food = 1,250 frogs

POWERS OF 10

1,250 frogs, or 10^3, in 50 years

Is this estimate reasonable?

YES

This estimate makes sense — done!

NO

The estimate doesn't make sense — need to refine the estimate.

Site Number: 1 2 **3** 4

QUESTION

What is the likely effect of changing temperature and rainfall on the future frog population at Site 3?

WHAT IS KNOWN

Current frog population of 200 frogs.
If population doubles every 25 years, there will be 800 frogs in 50 years.
The 2 factors most likely to impact the population are temperature and rainfall.

ASSUMPTIONS

I predict more warmer temperatures will kill 75% of the frogs.
I predict 25% more frogs due to increased rainfall.

CALCULATE

800 frogs x ¼ due to high temperatures = 200 frogs
200 frogs x 1¼ due to more food = 250 frogs

POWERS OF 10

250 frogs, or 10^2, in 50 years

Is this estimate reasonable?

YES → **This estimate makes sense — done!**

NO → **The estimate doesn't make sense — need to refine the estimate.** → (return to ASSUMPTIONS)

Site Number: 1 2 3 (4)

QUESTION

What is the likely effect of changing temperature and predation on the future frog population at Site 4?

WHAT IS KNOWN

Current frog population of 1,000 frogs.
If population doubles every 25 years, there will be 4,000 frogs in 50 years.
The 2 factors most likely to impact the population are temperature and predation.

ASSUMPTIONS

I predict warmer temperatures will kill 90% of the frogs.
I predict that predation will kill another 25% of the remaining frogs.

CALCULATE

4,000 frogs x 0.1 due to high temperatures = 400 frogs
400 frogs x 0.75 due to predation = 300 frogs

POWERS OF 10

300 frogs, or 10^2, in 50 years

Is this estimate reasonable?

YES → **This estimate makes sense — done!**

NO → **The estimate doesn't make sense — need to refine the estimate.** → back to ASSUMPTIONS

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

which site to fund to protect and improve Menanda frog habitats.

My decision is that

Site 1 should be funded.

My decision is based on the following evidence:

First,

Site 1 has the smallest frog population of 50. This makes it vulnerable to completely disappearing.

Second,

our group's Fermi estimates predict that this site will continue to have the smallest frog population.

Third,

the population at this site is very affected by rainfall, and some years there is little or no rainfall, which means the population declines.

The trade-off(s)

is that the other sites will not get funded, and their frog populations may also decline.

People who disagree with my decision might say that

their group's estimates predicted a different population outcome, and they recommended a different site.

VISUAL AID 10.1 | SCORING GUIDE: DEVELOPING AND USING MODELS (MOD)

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about phenomena and/or systems.

WHAT TO LOOK FOR:

- Response accurately represents the phenomenon and/or system.
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model.

LEVEL	GENERAL DESCRIPTION
Level 4 **Complete and correct**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system, AND the student uses it to develop a complete and correct explanation or prediction.
Level 3 **Almost there**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system AND includes a mostly correct use of the model to create an explanation or prediction.
Level 2 **On the way**	The student's model* represents components of the phenomenon/system AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.
Level 1 **Getting started**	The student's model* represents components of the phenomenon/system BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon/system.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION
Level 0 **Missing or off task**	The student's response is missing, illegible, or irrelevant.
X	The student had no opportunity to respond.

WHEN TO USE THIS SCORING GUIDE:

This Scoring Guide is used when students develop their own models or use established models to describe relationships and/or make predictions about phenomena and/or systems.

WHAT TO LOOK FOR:

- Response accurately represents the phenomenon and/or system.
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 4 **Complete and correct**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system, AND the student uses it to develop a complete and correct explanation or prediction.	The student response: • contains a complete model and includes a detailed description of it. • identifies the two most impactful factors and logically predicts their likely effect on population. • provides a thorough, logical explanation of a source of uncertainty in the model.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 3 **Almost there**	The student's model* completely and accurately represents the components, relationships, and mechanisms of the phenomenon/system AND includes a mostly correct use of the model to create an explanation or prediction.	The student response: • contains a complete model and includes a description of it. • identifies the two most impactful factors and predicts their likely effect on population. • identifies a source of uncertainty in the model.
Level 2 **On the way**	The student's model* represents components of the phenomenon/ system AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.	The student response: • contains a model with some description of it. • identifies the two most impactful factors BUT may not logically predict their likely effect on population.

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

LEVEL	GENERAL DESCRIPTION	ITEM-SPECIFIC DESCRIPTION
Level 1 **Getting started**	The student's model* represents components of the phenomenon/system BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon/system.	The student response: • contains an incomplete model AND/OR it has little or no description. • identifies the two most impactful factors BUT predicted effects on population are vague, illogical, or missing. • identifies a source of uncertainty in the model, BUT it is vague, illogical, or missing.
Level 0 **Missing or off task**	The student's analysis is missing, illegible, or irrelevant to the goal of the investigation.	
X	The student had no opportunity to respond.	

* A model can be a diagram, drawing, physical replica, diorama, dramatization, storyboard, or any other graphical, verbal, or mathematical representation. It may include labels or other written text as required by the prompt.

MENANDA SITE 1

This frog population lives in a seasonal pond, which is now mostly dependent on yearly rainfall. Years when there is little or no rainfall results in very few frogs. Yearly rainfall affects the food availability, which is also having a serious impact on the population. In years with less rainfall, higher than average annual temperatures can also contribute to a declining population. Predation remains constant over time. There is little traffic nearby.

Local residents would like to re-establish natural water flows that will better support seasonal ponds and wetland areas.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
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MENANDA SITE 2

New homes are being built near this site. Increased traffic is significantly reducing the local frog population. It is also reducing the predator population, so predators are only having a small effect on the frog population. Residents would like to build a tunnel under the busiest local road to provide a wildlife crossing between the site and a nature area on the other side of the road.

Many local residents have built backyard ponds, increasing food availability and helping to measurably increase the population. Changes in average local temperature and yearly rainfall amounts do not appear to be having an impact on the frog population.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling, Activity 10: Menanda Site Cards

MENANDA SITE 3

This site is on the sheltered side of a mountain, resulting in much less yearly rainfall than the surrounding areas. This is the primary cause of a much smaller frog population in this area. The average annual temperature is also much warmer than the surrounding areas, further reducing the frog population. Food availability and predation are constant over time. There is only one road and little traffic in this area.

A nearby hiking trail attracts people who sometimes accidentally damage the habitat. Local residents would like to place wildlife-friendly fencing and signs around the site to protect the area.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling, Activity 10: Menanda Site Cards

MENANDA SITE 4

As the average annual temperature increases, the size of the frog population at this site is significantly declining. Yearly rainfall amounts are staying steady, resulting in a steady amount of food availability, which is helping keep the population steady. These factors have also resulted in an increase in the predator population, causing declines in the frog population. There is no traffic nearby.

Residents would like to create a more frog-friendly habitat by building a pond at this site with native plants.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT
UNIT 2: Scientific Modeling, Activity 10: Menanda Site Cards