ACTIVITY 9

Constructing Predictive Models

PRESENTATION

v 1.0

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Constructing Predictive Models

ACTIVITY SUMMARY

Students brainstorm factors that affect the size of a population. They then develop a scientific question about a local species and its future interactions, population size, or population range within their community. By identifying and selecting factors relevant to their question, they construct models. Students use their models to make Fermi estimates for the present and to predict the future. They then discuss the strengths and limitations of their models.

ACTIVITY TYPE
PRESENTATION

NUMBER OF
40–50 MINUTE
CLASS PERIODS
1–2

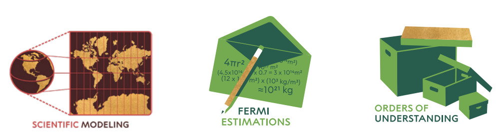
KEY CONCEPTS & PROCESS SKILLS

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 scientific 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.

CONCEPTUAL TOOLS



4 Models can be made more accurate through an iterative process that can involve testing it, refining it based on new evidence, adding or deleting relevant factors, or modifying the relationship between factors.

5 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*.

6 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.

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*)

TEACHER BACKGROUND INFORMATION

Scientific Optimism

Professional and amateur scientists continue to research the world scientifically, even when they are met with obstacles and errors. This approach of adopting a can-do attitude in light of challenges and believing that scientific problems are solvable are aspects of scientific optimism. Scientific optimism enables scientists to continue to focus on solving difficult problems over long periods of time. While this unit addresses some negative impacts of global changes, it has been developed to incorporate an approach of scientific optimism.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- FOOD WEB MODEL CONSTRUCTED IN ACTIVITY 3 (one student's model)
- VISUAL AID 1.1 "Interpreting Graphs" (OPTIONAL)
- VISUAL AID 2.1 "Developing Communication Skills" (OPTIONAL)

FOR EACH STUDENT

- STUDENT SHEET 9.1 "Developing Model Components"
- STUDENT SHEET 9.2 "Developing Fermi Estimates"
- STUDENT SHEET 9.3 "Developing Scientific Questions" (OPTIONAL)
- FOOD WEB MODELS CONSTRUCTED IN ACTIVITY 3 (OPTIONAL)

The Extension (Teaching Step 8) suggests using an online student-friendly computer modeling program to further explore cause-and-effect relationships and test ideas. The following are links to free online modeling programs:

- Concord Consortium's and the CREATE for STEM Institute at Michigan State University's SageModeler https://sagemodeler.concord.org/
- Howard Hughes Medical Institute's (HHMI) *Model Builder* https://www.biointeractive.org/classroom-resources/model-builder
- LOOPY https://ncase.me/loopy/
- Insight Maker https://insightmaker.com/

TEACHING NOTES

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

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

GETTING STARTED (5 MIN)

1 **Introduce the activity by using an example of a food web model from Activity 3.**

- In Activity 3, students constructed their own food web models. Remind students of these models by briefly displaying and reviewing one example from that activity. Ask the class, What determined what was included in your model? In this case, the model was based on prior knowledge, observations from the field trip, and research; both the prior knowledge and research also drew on observations, though from different times and from people. Ask, Did your model help you explain a phenomenon or make a prediction? Students may recognize that their food web models from Activity 3 were primarily an approach to explaining the feeding relationships in a location ecosystem, though the class discussed how to use the model to make predictions about changes to one population if another population increased or decreased.
- Point out that the model was students' first experience in this unit to construct a model. In this activity, students will construct a model to accomplish both the explanatory and predictive natures of scientific modeling, and they will use their models to inform a Fermi estimate. You may want to use the Introduction in the Student Book to explain the field of ecological forecasting; some students may wish to consider it as a future area of study.

PROCEDURE SUPPORT (45-60 MIN)

2 **Brainstorm factors that affect population size.**

- Hand out Student Sheet 9.1, "Developing Model Components." Pairs select and record a local species and develop a scientific question related to its future distribution within their community. 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, you may want to provide optional Student Sheet 9.3, "Developing Scientific Questions," for additional support.

- In Procedure Step 3, partners brainstorm and list five factors that affect population size. This may feel familiar to students since they have been considering factors that affect population size throughout the unit. Guide students as needed. Students can add any additional factor(s) specifically relevant to their species. Possible responses include:
  - food availability
  - water availability
  - disease
  - competition
  - predation
  - temperature (and/or other environmental factors)
  - migration
  - urbanization (and/or other human effects)
  - natural hazards
- Pairs then further analyze their list of factors.
  - For each factor, they predict the present and likely future effects on their species' distribution.
  - For each factor, they rate it according to orders of understanding.
  - They decide which three factors to incorporate into their model.
- Remind students that they rate the orders of understanding by determining which factors are likely to have the greatest impact on the scientific question they are investigating, with 1 being the most important factor(s) related to their scientific question.
- 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).
- A sample response to Student Sheet 9.1 is provided at the end of the activity.

3 Students develop their models, using their selected factors.

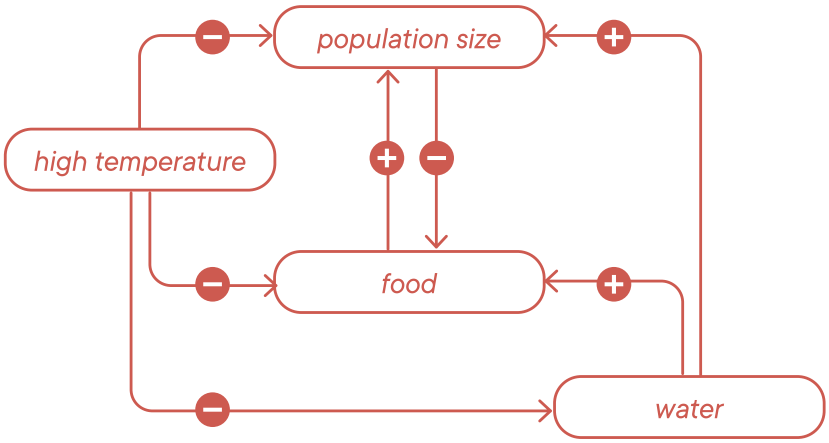
- To provide structure and guidance to the process of model construction, the Student Book provides a sample model that was first presented in Activity 2, Build Understanding item 2. Review the sample model as needed. Students can draw their individual models on the reverse side of Student Sheet 9.1.
- Depending on your student population, you may want to make the activity more open-ended by encouraging students to decide on their own approaches to constructing their models. For example, students could use optional Student Sheet 3.2, "An Ecological Relationship Model," as the framework for their model, or they can create their own approach and provide a key. Alternatively, provide additional support to those students who need more structure. For example, discuss the likely relationship between factors and population and then provide students with an empty framework to fill in. (A blank model is not provided because the framework depends on the relationship between the factors chosen to be included in the model. A factor may be connected to another factor or independently affect the population.)

- Students use the sample model first introduced in Activity 2 of the Student Book and their three identified factors to construct a model that would help address the scientific question they developed. A sample student response is provided.

Sample Student Response, Procedure Step 6

My Species: *Deer*

Scientific Question: *Will an increase in average local temperature reduce the number of deer in urban areas?*



An increase in food availability increases the population size, while a decrease in food availability decreases population size. Lots of water can result in more food and an increase in population, while a lack of water could reduce the size of the population. High temperatures could reduce the availability of food and water, resulting in a decrease in the population size. High average temperatures could also directly reduce the population due to migration or an increase in disease.

4 Pairs share their models with the other half of their groups.

- Support students in explaining their models to the other half of their groups. Students can address comments or suggestions by modifying their models. If needed, use Visual Aid 2.2, "Developing Communication Skills," to support student conversation.

5 Pairs make Fermi estimates of their species' population size now and in the future.

- Provide students with both pages of Student Sheet 9.2, "Developing Fermi Estimates." Remind students to use their models to consider which factors would likely be affected under future conditions and how it might affect their future estimate.
- You may want to list some local relevant information, such as the relative size of your town or neighborhood.

- A sample response to Student Sheet 9.2 is provided. Procedure Step 9 lists three discussion questions. Sample responses are provided.

Sample Student Response, Procedure Step 9

What data would you want to collect to test your model?

We may want to test our model by using other methods of measuring/estimating population size now and in the future, as well as collecting data about other measurable factors in our model. For example, we may want more accurate data about the population of our selected species. We could gather this through population estimation methods such as mark and recapture or thorough research of scientific studies that have done this work. We might also want more complete information about the conditions that we are investigating, such as temperature or traffic.

If the data did not support your model, how would you revise it?

Models can be made more accurate by adding or deleting relevant factors or modifying the relationship between factors. For example, our model may be revised by changing the ways in which the interactions are presented, like adding or removing arrows, changing +/- projections.

How could this type of data help make your Fermi estimates more accurate?

It would reduce uncertainty in the assumptions and likely result in more accurate estimates.

SYNTHESIS OF IDEAS (30-45 MIN)

6 **Students present their models and estimates to the class.**

- In Procedure Step 10, have students present their models to the class. Their presentations should include the local species being investigated, their scientific questions, their models, an explanation of their models, and their Fermi estimates (including an explanation of how their model informed their estimates).
- For students who have chosen the same species, you may want to have them compare Fermi estimates with others in the class by putting their estimates on a whiteboard. Discuss the powers of 10 of the Fermi estimates for similar species in the present vs. the future. Ask, Does the predicted population size increase or decrease over time? In the sample student response for Procedure Step 6, the deer population declined by the powers of 10 from thousands to hundreds. Ask, Why (what factors are being addressed in the various models/what assumptions are being made)? In the sample student response, assumptions included the percentage of deer observed, the projected effect of changing environmental conditions on food availability, and the projected effect of changing environmental conditions on the deer population. Have students share how they made their calculations and what assumptions they made.

- Have students discuss the strengths and limitations of their models. Students may note that their models helped focus on key elements related to their scientific questions and identified interactions among those elements and population size. The models were limited in their focus to three factors, and students may have had uncertainty about the exact nature of relationships among the selected factors.

7 Introduce or review the concept of scientific optimism.

- Professional and amateur scientists continue to research the world scientifically, even when they are met with obstacles and errors. This approach of adopting a can-do attitude in light of challenges and believing that scientific problems are solvable are aspects of scientific optimism. Scientific optimism enables scientists to continue to focus on solving difficult problems over long periods of time.
- Ask, What examples of scientific optimism have you observed in this unit so far? Create a list of student responses on the whiteboard. Ask, In what ways can your model contribute to scientific optimism? Accept all responses. Encourage students to consider ways in which their models could contribute to scientific knowledge and/or inform decision-making about issues informed by science.
- Finish the activity by revisiting the Guiding Question, *How can a model be used to predict changes to the distribution of a population?* Using a model to describe how the most relevant parts of a system interact can provide the basis for explaining systems and making predictions.

EXTENSION (10 MIN)

8 Use the Extension as an opportunity for advanced learning.

On the Internet, students can find student-friendly computer programs to model complex systems that explore cause-and-effect relationships and test ideas. Students can find one of these tools to construct their population models and explore how the factors in their models interact.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **A local group wants to use your model to help determine land use, such as the location of housing vs. open space.**

a **What would you tell them about sources of uncertainty in your model?**

Student responses will vary based on their models and sources of uncertainty. A sample response is provided.

My model contains uncertainty about the relationship between high temperature and deer populations. I don't know for sure the direct effect of high temperatures on deer.

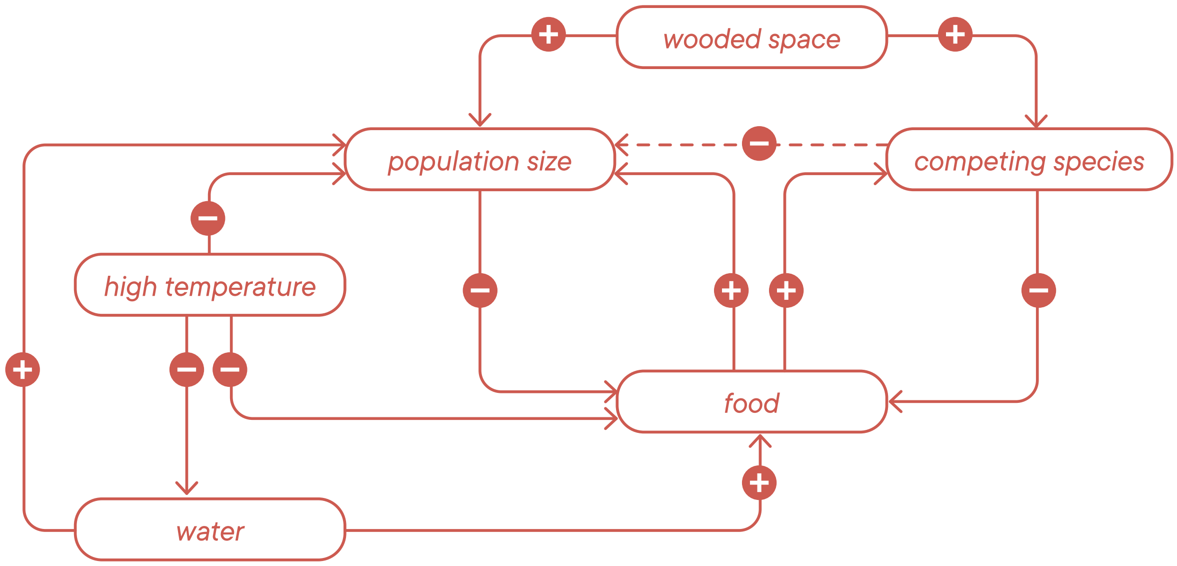
b **How could you test your model to evaluate its accuracy?**

Student responses will vary based on their models. A sample response is provided.

I could gather historical data on the annual deer population and average temperatures to determine if there was a relationship. If high temperatures corresponded to years where there were fewer deer, I would know my model is accurate.

② **Imagine that a new species is accidentally introduced into your community. It can successfully outcompete your local species in wooded areas but not in other spaces. Explain how you would modify your model (in words or in a drawing) to account for this new species.**

I investigated an urban deer population. The competing species would affect the population size of the deer in wooded areas where more of the deer live. The new species would be competing for space and food. I'm not sure how it would be affected by higher temperatures nor if there would be competition for water since there is a large lake nearby. My modified model is:



CONNECTIONS TO EVERYDAY LIFE

③ **A high school soccer coach wants to create a simple predictive model to guess the probability of winning the next game.**

Model 1: This model uses the team's number of game wins over the last five seasons.

Model 2: This model uses the number of goals scored per game, plus three other factors: the number of rained-out games, the number of games played on the weekend, and the number of injuries in the previous season.

Which model would you use and why?

I would use Model 1 because it is common to use historical data to predict the future. Model 2 also uses historical data, but the number of goals scored only matters in comparison to the other team's goals, so it is not likely to be predictive of wins, only the number of goals. The other factors in Model 2 do not have a big impact on the game outcomes (low orders of understanding), so they do not add much accuracy to the model. So while Model 2 is more sophisticated, it is not likely to give a more accurate prediction.

STUDENT SHEET 9.1 | DEVELOPING MODEL COMPONENTS | NAME

Local Species: ____________

Scientific Question:

FACTORS	PRESENT AND LIKELY FUTURE EFFECTS ON POPULATION DISTRIBUTION	RELATIVE IMPACT ON POPULATION 1 = GREATEST IMPACT 3 = LEAST IMPACT	3 FACTORS TO INCLUDE IN YOUR MODEL

STUDENT SHEET 9.1 | DEVELOPING MODEL COMPONENTS | NAME SAMPLE STUDENT RESPONSE

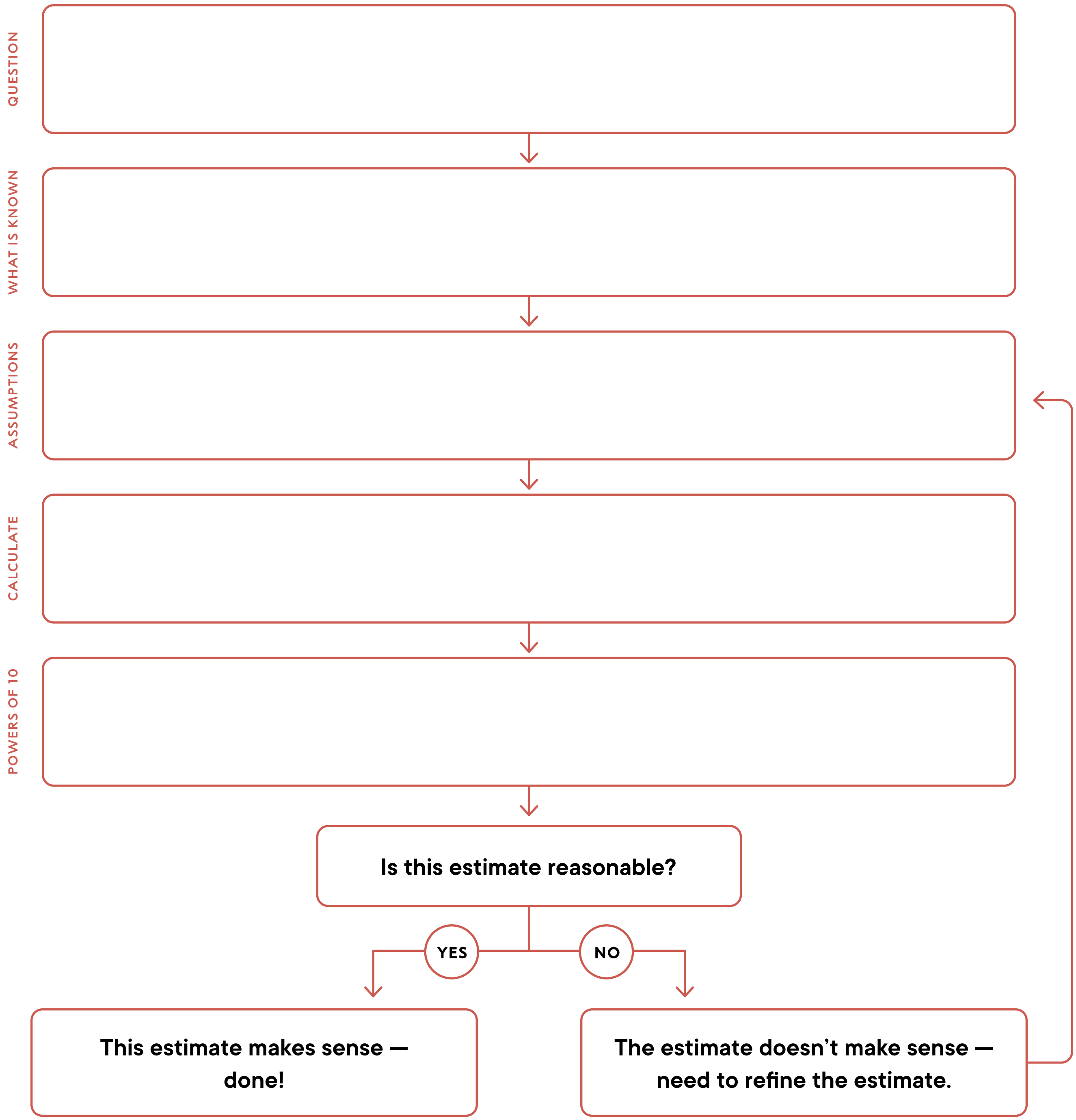
Local Species: *Deer*

Scientific Question:

Will an increase in average local temperature reduce the number of deer in urban areas?

FACTORS	PRESENT AND LIKELY FUTURE EFFECTS ON POPULATION DISTRIBUTION	RELATIVE IMPACT ON POPULATION 1 = GREATEST IMPACT 3 = LEAST IMPACT	3 FACTORS TO INCLUDE IN YOUR MODEL
Food availability	*More food, more deer.* *Deer can move to where food is, food availability could be reduced by high temperatures.*	*1*	*X*
High temperatures	*No known effect.* *Change in average temperature could affect food availability.*	*1*	*X*
Traffic	*Reduces population size.* *Increase in traffic will likely reduce population.*	*3*	
Predation	*Reduces population size.* *Increase in urban coyotes may decrease population or cause them to move to different range.*	*2*	
Water availability	*No water, fewer deer.* *Deer can move to where water is, water availability could be reduced by high temperatures.*	*1*	*X*

Fermi Estimate: Present Population



STUDENT SHEET 9.2 | DEVELOPING FERMI ESTIMATES | NAME

CONTINUED

Fermi Estimate: Population 50 Years in the Future

QUESTION

WHAT IS KNOWN

ASSUMPTIONS

CALCULATE

POWERS OF 10

Is this estimate reasonable?

YES

This estimate makes sense — done!

NO

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

 SAMPLE STUDENT RESPONSE

Fermi Estimate: Present Population

QUESTION

What is the population size of deer in my community now?

WHAT IS KNOWN

I observe 3-5 deer in my community every month.
My neighborhood is about ¼ square miles.
My town is about 25 square miles.

ASSUMPTIONS

I observe about 25% of the deer in my town.

CALCULATE

Observe 3 deer in ¼ mi^2 = 300 deer in 25 mi^2 x 4 (only see 25%) = 1,200
Observe 5 deer in ¼ mi^2 = 500 deer in 25 mi^2 x 4 (only see 25%) = 2,000

POWERS OF 10

1,000-2,000 deer in my town, or 10^3

Is this estimate reasonable?

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

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

Fermi Estimate: Population 50 Years in the Future

QUESTION

What will the population of deer in my commnity be in 50 years?

WHAT IS KNOWN

My neighborhod is about $\frac{1}{4}$ square miles.
My town is about 25 square miles.

ASSUMPTIONS

Higher temperatures and decreased food availability will decrease deer population.
I will observe 2-3 deer in my community every month.
I observe about 50% of the deer in my town.

CALCULATE

Observe 2 deer in $\frac{1}{4}$ mi^2 = 200 deer in 25 mi^2 x 2 (only see 50%) = 200
Observe 3 deer in $\frac{1}{4}$ mi^2 = 300 deer in 25 mi^2 x 2 (only see 50%) = 600

POWERS OF 10

200-600 deer in my town, or 10^2

Is this estimate reasonable?

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

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

Local Species: ______________

Scientific Questions

1. **Read the following list of scientific questions. Use the list to either brainstorm a new question, choose one of the questions, or modify an existing question.**

   - How will the predicted changes in local temperature affect the population distribution of this local species?
   - Will the population of a new competing species grow large enough to affect the distribution of this local species?
   - If the regional park is made larger, will the distribution of this local species change?
   - Will an increase in stormwater runoff during heavy rains affect the distribution of this local species?
   - How will the future availability of its primary food source change the distribution of this local species?
   - If a species that this local species relies on for food disappears, will the local population be able to adapt to another food source?
   - Will the building of a new major road affect the distribution of this local species?

2. **Record the scientific question you have about your local species.**

Local Species: *Deer*

Scientific Questions

1. **Read the following list of scientific questions. Use the list to either brainstorm a new question, choose one of the questions, or modify an existing question.**
   - How will the predicted changes in local temperature affect the population distribution of this local species?
   - Will the population of a new competing species grow large enough to affect the distribution of this local species?
   - If the regional park is made larger, will the distribution of this local species change?
   - Will an increase in stormwater runoff during heavy rains affect the distribution of this local species?
   - How will the future availability of its primary food source change the distribution of this local species?
   - If a species that this local species relies on for food disappears, will the local population be able to adapt to another food source?
   - Will the building of a new major road affect the distribution of this local species?

2. **Record the scientific question you have about your local species.**

   Will an increase in average local temperature reduce the number of deer in urban areas?