C. John Graves

# Elk Habitat:
## A Case Study of Scientific Inquiry
### *Determining the cause of shortened life span in Yellowstone National Park*

A case study is an excellent way to help students think like scientists as they work to solve a dilemma. With case studies, students are presented small bits of information through structured or guided inquiry, much the same way that scientific research data slowly add to the knowledge base of a given study. Students must think critically about the evidence provided and evaluate which factors are most relevant to the study's driving questions.

The National Science Education Standards (NRC 1996) clearly establish inquiry as a standard in which students use scientific reasoning and critical thinking. Inquiry instruction has been described as falling along the Inquiry Continuum (NRC 2000), which includes structured and guided inquiry. Case studies are one way to incorporate inquiry in the classroom (Bonnstetter 1998), as students analyze data, draw hypotheses, think scientifically, and test conclusions.

This article describes a case study of elk in Yellowstone National Park. Students read short narratives, based on scientific research data, about the puzzling question of why some elk live substantially longer than others in certain areas of Yellowstone. Each successive narrative provides more clues to solving this puzzle. Students are encouraged to model scientists' approach by asking questions, examining evidence, and designing possible research studies to find answers to the question of elk mortality.

## The case study

A *case study* is a story designed with the intent to engage learners in solving a problem and discovering its underlying principles (Miller, Moon, and Elko 2000). For the activity described in this article, which centers on elk habitat, I begin by presenting students with the following case study:

> Rocky Mountain elk *(Cervus elaphus)* living in Yellowstone National Park belong to the most abundant large-mammal population in the park. Their habitat includes high-elevation grasslands and Lodgepole pine forests. Rocky Mountain elk have the choice of living in one of two areas in Yellowstone—the Lamar Valley in the northeastern region of the park or the Madison River Valley, which lies between West Yellowstone, Montana, and Madison Junction, Wyoming, in the northwestern portion of Yellowstone. The elk herd population in the Lamar Valley is about 8,000–12,000; the average life span of elk in this area is 16 years, with some elk living 20–25 years. In the Madison River Valley, however, the average life span of elk is 10 years, and no adult elk live beyond 16 years. The herd size in this area is about 500–800.

Two overarching questions drive this activity:

1. Why do elk in the Madison River Valley have a shortened life span compared to elk in the Lamar Valley; and
2. What has caused the reduction of the Madison River Valley herd size?

The activity is based on the conclusions of a scientific study to determine the cause of the shortened life span of the Madison River Valley elk (Garrott et al. 2002) and is modeled after an activity on beluga whales (BSCS and NSTA 2001). Students are given an activity sheet that contains a reading passage with information about the elk population dilemma. After reading the passage, students receive discussion prompts to answer, and are encouraged to ask their own questions and draw conclusions before they are given the next activity sheet. As students work through the series of six sheets, they discover the cause of the shortened life span of the Madison River Valley elk.

The importance of student-generated questions in this activity cannot be overemphasized. As more information is presented, new questions emerge, which either shed light on an assumption or create more confusion. As a result, there is a need to constantly engage in a feedback loop of questioning. Students should keep a thorough record of questions and answers as they proceed through the case study.

## Beginning the investigation

Teachers are encouraged to combine sections of information and tailor the activity to best meet students' needs.

While the activity is designed to take one to two days to complete, it can be expanded into a weeklong investigation by having students focus on important ecological concepts related to the case study.

Begin by dividing students into groups of three to four. After presenting students with the case study (p. 24), have them identify the Madison River Valley and Lamar Valley on a map of Yellowstone National Park. Student groups can download maps of Yellowstone off of the internet or use Web 2.0 tools, such as Google Earth, to view these areas. As needed, students can research additional information about elk. An excellent resource is the "Wildlife" chapter in the *Yellowstone Resources and Issues 2009* guide (NPS 2009).

After students have researched the area, distribute the first of the six activity sheets (i.e., Elk habitat activity sheet 1). Ask students to read the narrative and answer the discussion prompts. Repeat this step with each of the activity sheets described in the following sections.

## Elk habitat activity sheet 1

### *Narrative*

Rocky Mountain elk are the most abundant large mammal in Yellowstone National Park, numbering up to 20,000 in the summer. Male elk, called bulls, have large antlers containing calcium, which are shed and regrown each year. Female elk, called cows, usually have one baby, or calf, per year.

Although widely distributed throughout Yellowstone, large concentrations of elk are found in the Lamar Valley in the northeast region of the park. The valley is approximately 25 km long and up to 3 km wide, void of trees, with the Lamar River cutting a channel through glacial deposit material. The edges of the valley rise up to forests of Douglas fir, Lodgepole pine, and Engelmann spruce. The predominant vegetation in the valley is mountain big sagebrush and several grass species, including Idaho fescue. The road to Cooke City, Montana, follows the northern edge of the valley and is maintained year-round.

In addition to elk, the area is home to wolves (reintroduced to Yellowstone in 1995), grizzly bears, bison, coyotes, and other small mammals. Snowfall is abundant, but foraging opportunities for the animals exist, so a winter population of 8,000–12,000 elk has historically been supported in the Lamar Valley.

By contrast, the Madison River Valley is only 10 km long and up to 2 km wide. The Madison River Valley is formed by the confluence of the Firehole and Gibbon Rivers at the head of the drainage. The underlying bedrock is volcanic. The West Entrance road cuts through the valley connecting West Yellowstone, Montana, and Madison Junction, Wyoming, in Yellowstone Park. The road is closed to wheeled traffic in the winter, but is used by over-snow vehicles. A resident herd of 500–800 elk has historically inhabited this area, along with mule deer, bison, coyotes, wolves, occasional grizzly bears, and other small mammals. Geothermal activity along the valley floor keeps winter snow melted, away from the river and hot spring areas. Some grasses are able to grow year-round in the hot springs area, and elk use this food source throughout the year.

### *Possible discussion prompts*

1. List questions posed by your group.
2. If you were an elk, in which habitat would you choose to live and why?
3. What major differences do you notice between the two habitats?
4. What effect do you think predation has on the elk herds in the two habitats?

### *Teacher note*

After groups of students have discussed these and other questions, debrief the information in this first activity sheet with a full-class discussion. As the class generates ideas, encourage students to continue individual or group investigations as appropriate. Note that many questions remain unanswered in each part of this activity, creating opportunities for students to conduct additional research, if time allows.

## Elk habitat activity sheet 2

### *Narrative*

In the mid 1990s, researchers began to notice changes in the population numbers of the two elk herds. The average age of Lamar Valley elk was approximately 16 years, with the oldest animals living 20–25 years. In the Madison River Valley, however, the average age of elk was approximately 10 years, with no elk living beyond 16 years.

### *Possible discussion prompts*

1. List questions posed by your group.
2. What are your initial reactions to the age difference in the two habitats? List and discuss as many causes as you can.
3. As student scientists, what investigations would you

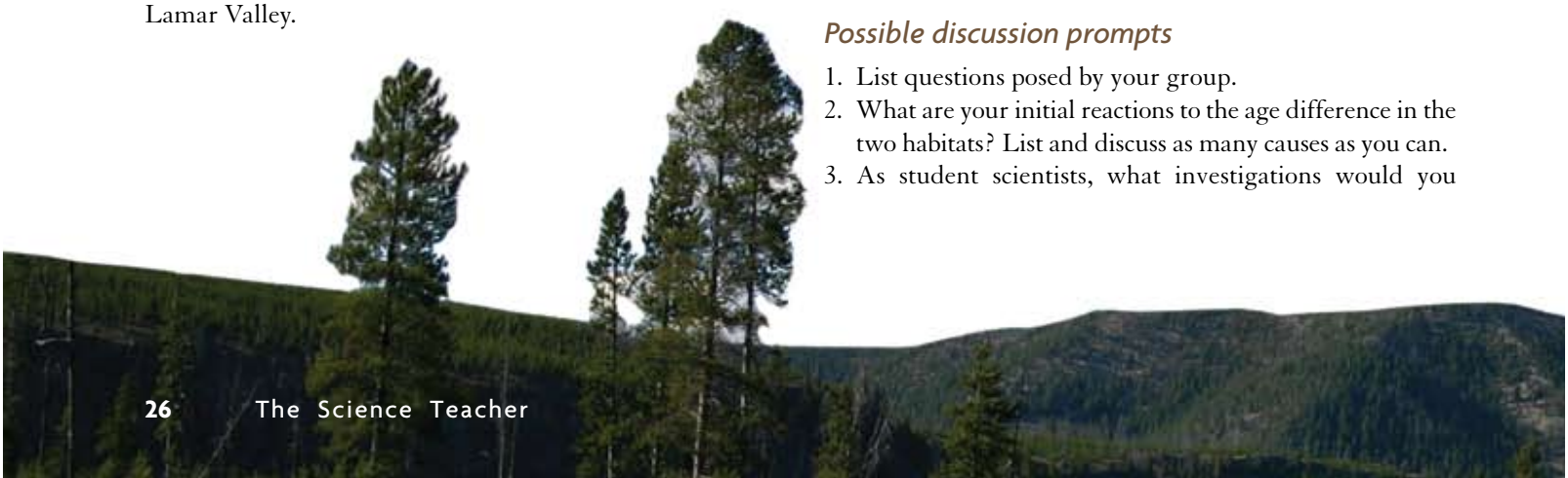

**FIGURE 1A**

**Elk jaw from Lamar Valley.**

PHOTOS COURTESY OF THE AUTHOR AND ROBERT GARROTT

**FIGURE 1B**

**Elk jaw from Madison River Valley.**


conduct to determine the cause of the difference in life span between elk in their two habitats?
4. What additional information do you need to know?

### *Teacher note*

Debrief this activity sheet with a full-class discussion, encouraging each group to share their insights, questions, and possible directions for further investigation.

## Elk habitat activity sheet 3

### *Narrative*

In mid-January 1995, 14 wolves were reintroduced to Yellowstone National Park in an attempt to re-establish the predator in a historical ecosystem after its removal in the early 1900s. Pro-reintroduction advocates argued that the absence of wolves had created an artificial predator–prey food chain and that reintroduction would return the ecosystem to a more realistic historical balance. These wolves were captured in Canada and placed in three 1-acre holding pens. One of these pens was located near the Lamar Valley. The wolves were released into the wild a few months later, and began to establish territories and prey on large mammals, especially elk, which make up 90% of the wolves' winter diet. In winter, a wolf pack will kill up to 14 elk per month. In January 2008, 443 wolves lived in 51 packs in the Greater Yellowstone ecosystem. Out of the 51 packs, 11 packs (171 wolves total) lived within the borders of Yellowstone National Park.

### *Possible discussion prompts*

1. List questions posed by your group.
2. What impact did reintroducing the wolves have on elk in Yellowstone National Park?
3. Is this information adequate to explain the life span difference in the Lamar Valley and Madison River Valley elk?
4. What additional information is needed to adequately explain the difference in life span?
5. As student scientists, what investigations would you conduct to determine the effect of wolves' predation on the elk herds in these two habitats?

### *Teacher note*

This is an excellent chance to encourage students to investigate the reintroduction of wolves to the Greater Yellowstone ecosystem and the wolves' impact on other wildlife (Montana Fish, Wildlife, and Parks 2009). Conclude with full-class discussions on the prompts.

## Elk habitat activity sheet 4

### *Narrative*

In the mid-1990s, researchers discovered stark differences between the jaws of Lamar Valley elk and the jaws of Madison River Valley elk. Lamar Valley elk jaws showed typical wear of teeth at the time of death (Figure 1A). Madison River Valley elk jaws, however, showed accelerated and malformed wear patterns of teeth and abnormalities in jaw development (Figure 1B). Because of these abnormalities, many Madison River Valley elk died of starvation. By 2004–2005, researchers also began to observe a decrease in the population of the Madison River Valley elk herd size. The historical numbers of up to 800 elk living in the valley were now reduced to 150–200.

### *Possible discussion prompts*

1. List questions posed by your group.
2. What new evidence is presented and how does it factor into the difference in average age of the two elk habitats?
3. What do you believe could be the cause of accelerated and malformed wear of teeth and jaws in Madison River Valley elk herds?

4. As scientists, what investigations would you conduct to determine the cause of the accelerated and malformed wear patterns?
5. What possible explanations are there for the reduced population size? List all explanations that come to mind.
6. What additional questions does this information raise?

### *Teacher note*

Ask student groups to share their ideas in a full-class discussion. Encourage individual and group research into possible explanations for the information revealed in this activity sheet.

## Elk habitat activity sheet 5
### *Narrative*

Researchers discovered that as the heavy snows of the Madison River Valley accumulated over the season, elk tended to congregate in the river valley, especially around areas of hot spring activity, to forage on the plants that grow year-round in the geothermal areas. Plants gathered from these areas contained extensively high concentrations of fluorine (F) and silicon dioxide ($SiO_2$).

Silicon dioxide is created when silicon-rich volcanic rock dissolves and comes in contact with geothermal water. As the geothermal water comes to the surface and cools, the dissolved silicon dioxide falls out of the solution, forming deposits. Silicon dioxide is found in streams and can be deposited on trees, boardwalks, and so on. It is also found in the water absorbed by the roots of plants that live in the hot spring areas. It is hard like rock and very abrasive.

When ingested by elk, fluorine concentrates in mineral tissues such as teeth and bone. The jaws of elk living in the Madison River Valley contained more than six times the levels of fluorine found in the jaws of elk from the Lamar Valley. These levels of fluorine become toxic to the developing teeth and jaws of young elk, resulting in uneven or excessively rapid teeth wear and jaw formation. Of the 74 jaws researchers collected in the Madison River Valley, 78% showed the classic signs of fluoride poisoning.

### *Possible discussion prompts*

1. List questions posed by your group.
2. What new evidence is presented and how does it factor in to the difference in average age of the two elk habitats?
3. Does this new information cause you to reject any early hypotheses? Explain.
4. Does this new information adequately explain the decrease in herd population?
5. Are there any new hypotheses to explain the decrease in herd size?

### *Teacher note*

Although students may think they have the "answer" based on the information provided in this activity sheet—that fluoride poisoning and ingestion of silicon dioxide accounted for the elk population decline in Madison River Valley—there are other complex issues involved. Encourage students to continue to think about and discuss other possible connections. For example, would toxic fluoride affect deer, bison, or other species? What about the plants themselves—are they affected? Is this a health concern for humans, aquatic plants, and animals? Rich sources for further investigation abound.

## Elk habitat activity sheet 6
### *Narrative*

Wolves primarily prey on the young and weak members of a population. Because the average age of the Madison River Valley elk herd has been reduced due to the toxic levels of fluorine and the ingestion of silicon dioxide, higher numbers of adult elk are susceptible to predation by wolves due to the reduced number of younger elk. In addition, the snow pack on the slopes adjacent to the Madison River Valley is deep. Wolves have learned to force the elk away from the geothermal areas in the river drainage and into the surrounding slopes where the elk get stuck in the deep snow and become easy prey.

### *Possible discussion prompts*

1. What additional evidence is presented and how does it further explain the reduced population in the Madison River Valley elk herd?
2. As a group, discuss the complexities involved in explaining the differences between the elk in the Lamar Valley and the elk in the Madison River Valley.
3. Explain how habitat plays a role in the differences between the two elk herds.

### *Teacher note*

The impact of wolves on Yellowstone elk is complex. Encourage students to investigate the predator–prey relationship of wolves and elk, bison, and other animals. One interesting side note is the impact of wolves on Yellowstone's coyote population. This might serve as an interesting research project for students.

## Expanding the activity

There are numerous extensions to the elk inquiry case study. The following ideas may lead to interesting student investigations.

### *Overgrazing by Yellowstone elk*

There has been continual debate on the effect of elk overgrazing in Yellowstone National Park. Some researchers believe there are more elk foraging than the habitat can accommodate, which leads to overgrazing. Other researchers think this is not an issue. Students can research the topic and debate the issue, write position papers, or present their findings through a multimedia presentation.

### *Impact of wolves outside of Yellowstone*

No fences surround Yellowstone, so animals are free to move beyond the park's boundaries. Wolves have established themselves in the states surrounding the park—Montana, Idaho, and Wyoming. The presence of wolves has impacted the hunting of large mammals, such as elk. Currently, the issue of whether or not wolves should be included on the Endangered Species List is hotly debated. In recent months, wolves have been removed from the list, only to be placed back on it. This cycle of delisting and listing continues. Encourage students to research this topic and present their findings. Again, the *Yellowstone Resources and Issues 2009* guide (NPS 2009) is an excellent resource.

## Designing case studies

I was first introduced to case studies through the beluga whale activity mentioned earlier in this article (BSCS and NSTA 2001). While I found the activity engaging, with rich discussion and new information in each passage installment, I felt disconnected from the content because I had no personal reference to beluga whales or the St. Lawrence River, the site of the activity. As a result, I created the Yellowstone elk case study, which is more relevant to me and my students because we live close to the park.

I would encourage teachers to use both the beluga whale and the Yellowstone elk activities as models to create relevant, place-based case studies for their own students. It may even be possible to engage students as cowriters. An excellent resource is the National Center for Case Study Teaching in Science (see "On the web").

Case studies are an excellent way to encourage students to examine evidence, ask questions, propose investigations, and discover new information through discovery as they work collaboratively to solve a dilemma. This guided inquiry approach uses scientific research data of elk herds in Yellowstone to critically engage students with real-life scenarios and invites them to think and learn in ways not typically presented in the classroom. ■

*C. John Graves* (graves@montana.edu) *is an adjunct instructor at Montana State University in Bozeman, Montana.*

### On the web

Interactive Yellowstone National Park Map and Itinerary Collection: *www.yellowstonepark.com/PlanYourTrip/Map.aspx*

Montana Fish, Wildlife, and Parks: *http://fwp.mt.gov/default.html*

National Center for Case Study Teaching in Science: *http://ublib.buffalo.edu/libraries/projects/cases/case.html*

Yellowstone Maps from Harpers Ferry Center: *http://home.nps.gov/applications/hafe/hfc/carto-detail.cfm?Alpha=YELL#*

Yellowstone Map from the University of Texas Libraries: *www.lib.utexas.edu/maps/national_parks/yellowstone_map.jpg*

Yellowstone National Park (official site): *www.nps.gov/yell*

### References

Biological Sciences Curriculum Study and National Science Teachers Association (BSCS and NSTA). 2001. *Building a presence for science, professional development toolkit*. Colorado Springs, CO: BSCS.

Bonnstetter, R. 1998. Inquiry: Learning from the past with an eye on the future. *Electronic Journal of Science Education* 3 (1). *http://wolfweb.unr.edu/homepage/jcannon/ejse/bonnstetter.html*

Garrott, R., L. Eberhardt, J. Otton, P. White, and M. Chaffee. 2002. *Ecosystems* 5 (7): 659–666.

Miller, B., J. Moon, and S. Elko. 2000. *Teacher leadership in mathematics and science: Casebook and facilitators guide*. Portsmouth, NH: Heinemann.

Montana Fish, Wildlife, and Parks. 2009. Wolves and big game. *http://fwp.mt.gov/default.html*

National Park Service (NPS). 2009. Wildlife. In *Yellowstone resources and issues 2009,* eds. C. Duckworth and L. Young, 103–154. Mammoth Hot Springs, WY: NPS Division of Interpretation. *http://home.nps.gov/yell/planyourvisit/upload/ri09ch7.pdf*

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

NRC. 2000. *Inquiry and the national science education standards.* Washington, DC: National Academy Press.