Wild Bighorn Sheep: On the Edge?

Teacher's Guide and Student Pages

STEM Lesson Based on Wild Bighorn Sheep

By design, this lesson does not require teachers to know anything about wild bighorn sheep. Simply load the introductory slide show and begin!

This lesson has been aligned with Next Generation Science Standards, Common Core State Standards, NSES National Science Standards, ITEA National Technology Standards, ABET National Engineering Standards, and NCTM National Math Standards. For a complete description of standards, please see the end of this Teacher's Guide.

Synopsis

Students work individually, in small groups, and as a class to answer real-world questions using scientific data collected on wild bighorn sheep. After watching Part I of a slide show that provides background information about wild bighorn sheep, students are divided into six groups and each group is assigned data and a case study from one bighorn sheep herd in Montana. Individually, students use real-world

Grade Level: 7-8

Next Generation Science Standards: MS-LS2-1, MS-LS2-2, MS-LS2-4; **Common Core State Standards:** RST.6-8.1, RST.6-8.7, RST.6-8.8, RI.8.8, WHST.6-8.1, SL.8.1, SL.8.4, MP. 4, 6.SP.B.5; **NSES National Science Standards:** A 1-6, C 6, F 2, G 3; **ITEA National Technology Standards**: 2, 3, and 8; **ABET National Engineering Standards**: 1, 2, 3; **NCTM National Math Standards:** 4, 6, 8 and 10
A complete list of standards are available at the end of this Teacher's Guide

Subjects: Science and Math

Duration: Approximately 3 class periods

Materials for lesson:
Slide show "Wild Bighorn Sheep: On the Edge?", Student Pages, Calculator, Graphing paper or graphing software

Vocabulary: carrying capacity, endangered species, extirpation, gestation, habitat, livestock grazing allotment, minimum viable population, subspecies

Lesson author:
Dr. Melissa Reynolds-Hogland, Bear Trust International

data to calculate missing information from a table and graph the data. Working in small groups, students interpret the graphs and analyze the results, answer questions from their Student Pages, create a presentation about their case study, and present findings to their peers. Working as a class, students combine information and data from all six case studies to create a list of factors that are currently affecting the conservation of wild bighorn sheep. They also evaluate whether wild bighorn sheep are "on the edge". Then, students watch Part II of the slide show, which includes graphs relevant to each of the six case studies so students can compare their findings with findings presented by real bighorn sheep biologists. All data and results used in this lesson were generously provided by bighorn sheep scientists who work with the Montana Fish Wildlife and Parks. Additional information was provided by the Wild Sheep Working Group, which was formed by the Western Association of Fish and Wildlife Agencies and members are wildlife biologists from western states and Canadian Provinces.

Wild Bighorn Sheep: On the Edge?

Written by Dr. Melissa-Reynolds Hogland
Published by Bear Trust International, 2013
Photo image of wild sheep provided courtesy of Shutterstock

This lesson plan is provided at no charge to educators, youth, and the public thanks to the generosity of these sponsors:

Lesson Objectives

1. Students will actively participate in the process of scientific discovery, using real-world data and six case studies on wild bighorn sheep

2. Students will "discover" which factors are affecting the conservation of wild bighorn sheep throughout the US, and critically evaluate whether wild bighorn sheep are "on the edge"

3. Students will understand that effective conservation of wild bighorn sheep requires cooperation among scientists, wildlife managers, and owners of domestic sheep and goats

4. Students will use real-world data to calculate missing information in a table, graph the data, and analyze/interpret results

5. Students will be able to define and apply the terms carrying capacity and minimum viable population

6. Students will hone skills in communication as they engage in a range of collaborative discussions (in groups and teacher-led)

7. Students will present findings, emphasizing important facts with relevant evidence

8. Students will work individually and cooperatively as they problem solve, construct explanations, hone critical thinking skills, and participate in designing solutions

9. Students will learn that regulated hunting is an important conservation tool and that hunting organizations and state wildlife agencies have worked collaboratively to re-establish bighorn sheep herds throughout the west

10. Students will be able to define habitat and understand which resources are important for wild bighorn sheep survival and reproduction

11. Students will understand that there are three subspecies of bighorn sheep, one of which is federally endangered

Background Information for Teachers

It is estimated that over 2 million wild bighorn sheep roamed many parts of the west in the 1800s. With European settlement, the number of bighorn sheep plummeted to an estimated 15,000 sheep and bighorn sheep were extirpated throughout much of their historic range. The decline was due to ***unregulated*** hunting (which differs significantly from regulated hunting), habitat loss, predation, disease transfer from domestic sheep and goats to wild bighorns, and competition for food resources with domestic animals.

Thanks to efforts by conservation organizations like hunting groups and state wildlife agencies, the number of wild bighorn sheep has increased to about 70,000 sheep throughout the west. As part of this conservation effort, managers used transplant programs, where individual sheep from healthy herds are trapped and moved to different areas to re-establish formerly inhabited areas or to supplement small existing herds.

Currently, there are three subspecies of wild bighorn sheep: 1) Rocky Mountain bighorn sheep, 2) Desert bighorn sheep, and, 3) Sierra Nevada bighorn sheep. Of the three subspecies, the Sierra Nevada bighorn sheep is most limited in population size and range. In fact, the Sierra Nevada bighorn sheep subspecies was federally listed as an endangered species under the Endangered Species Act (ESA) in 1999. Predation by mountain lions was the primary factor that led to the severe decline of this subspecies. By 1995, there were only about 100 Sierra Nevada bighorn sheep anywhere in the world. Since it was listed as endangered and federally protected, this subspecies has grown to about 400 individuals today.

In the US, the Rocky Mountain bighorn sheep is the most widely distributed subspecies. This subspecies is the focus of the activities that are included in this lesson. Specifically, students will use real-world data and information from case studies on six different herds of Rocky Mountain bighorn sheep that live in Montana. These six herds and case studies were selected because when combined, they represent the range of bighorn sheep herd sizes that exist throughout the west and include most factors that currently affect the conservation of wild bighorn sheep.

CAVEAT ABOUT THE DATA: For their group activity, students will be using raw data collected by field biologists who documented the "number of bighorn sheep observed" during annual surveys conducted either by foot, on horseback or by air (helicopters or airplane). Please note that the data that students will be using represents the "number of bighorn sheep observed", which is NOT a population estimate. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, biologists who conducted the survey were likely not able to see every single sheep during the survey. There are ways to estimate the number of sheep "not observed" , which can then be included as a measure of uncertainty into population estimates. Based on the scope of this activity, your students will be evaluating the "number of sheep observed during surveys".

All data sets that students will use include data up through 2012 except for the data set for the Lost Creek bighorn sheep herd, which includes data through 2008.

Data were provided by the following bighorn sheep biologists who work for Montana Fish Wildlife and Parks: Tom Carlsen, Bruce Sterling, Brent Lonner, Scott Hemmer, and Vanna Boccadori. Additional information was provided by the Wild Sheep Working Group. Special thanks to Tom Carlsen who generously provided his expertise, time, and the conservation strategy for bighorn sheep in Montana.

Materials Needed

- Power point slide show: *Wild Bighorn Sheep: On the Edge?*
- Student Pages: Wild Bighorn Sheep: On the Edge? (at the end of this lesson)
  There are six sets of Student Pages, one set for members of each group
- Graphing paper or graphing software such as excel
- Calculator

Procedure

1. Show your students Part I of the power point slide show: "Wild Bighorn Sheep: On the Edge?"

To foster student participation during the slideshow, you may wish to have your students take turns reading the text for the slide show out loud.

2. At the conclusion of Part I, divide your students evenly into six groups. Assign each group one of the six data sets and case studies:

1. Thompson Falls Bighorn Sheep Herd
2. Lost Creek Bighorn Sheep Herd
3. Highland Bighorn Sheep Herd
4. Elkhorn Bighorn Sheep Herd
5. Southern Rocky Mountain Front Bighorn Sheep Herd
6. Missouri River Breaks Bighorn Sheep Herd

3. Hand out the appropriate "Student Pages" to members of each group (Group 1, Group 2, Group 3, Group 4, Group 5, Group 6) and allow students enough time to read the instructions, calculate their missing data, and create their graphs. As part of this activity, students in each group will then work together to answer questions specific to their case study (questions are located in their Student Pages).

4. Tell each group that they will be presenting their findings to the classroom (the presentation can be done by one member of each group, or by several members). As part of their presentation, each group should include:

1) Brief background information about their bighorn sheep herd
2) Information about where their bighorn sheep herd lives
3) The graph or graphs that they created from their data set
4) A list of factors affecting the conservation of their bighorn sheep herd

5. After all six groups have given their presentations, ask your students to work as a class to create a list of all the factors that affect the conservation of wild bighorn sheep (combine all the factors from all six case studies).

6. Next, show Part II of the power point slide show: "Wild Bighorn Sheep: On the Edge?". Part II includes graphs and results for each case study and asks students additional questions.

7. After you have watched Part II of the slideshow, have a class discussion using some of the following questions as guiding points:

A. At the end of the slide show, you learned about two ways that bighorn sheep managers, scientists, and owners of domestic sheep and goats are collaborating to ensure that bighorn sheep herds can persist while also making sure that owners of domestic animals can make a living. Can you think of other ways that bighorn sheep managers, scientists, and owners of domestic livestock and work together? Please send your ideas to: melissa@beartrust.org and we will pass your ideas along to wildlife managers.

B. Many of the six bighorn sheep herds you evaluated experienced decreases in the numbers of sheep observed. What were some of the reasons for these decreases?

C. How many of the six bighorn sheep herds experienced die-offs due to pneumonia transmitted by domestic sheep and goats?

D. To prevent disease transmission, scientists have determined that wild bighorn sheep should be at least **HOW** many miles away from domestic sheep and goats? If you were a bighorn sheep manager, how would you achieve this?

E. What does MVP mean?

F. How many of the six bighorn sheep herds you evaluated are currently below MVP? What does this indicate about the future of bighorn sheep? If you were a bighorn sheep manager, what would you do to minimize the chances that Rocky Mountain bighorn sheep and Desert bighorn sheep subspecies don't go down the same path as the federally endangered Sierra Nevada bighorn sheep subspecies?

G. For at least one bighorn sheep herd you evaluated, the management goal was to keep the population at or below carrying capacity. What does carrying capacity mean? How do managers keep bighorn sheep herds at or below carrying capacity?

H. Two of the six herds had high enough numbers of bighorn sheep to trap some individuals and transplant them to other bighorn sheep herds. Which two herds?

I. Noxious weeds are present in many areas where wild bighorn sheep herds live. Do you think it is a good idea to use domestic sheep to control weeds here? Why or why not?

J. All six of the bighorn sheep herds you evaluated were extirpated in the early 1900s. What does extirpated mean? How were these herds re-established?

K. What does habitat mean? What resources do bighorn sheep need?

L. For at least two of the bighorn sheep herds you evaluated, predators have been implicated as affecting bighorn sheep survival. However, this hypothesis (i.e., predators are affecting survival of bighorn sheep in these two herds) has not been tested. If you were a bighorn sheep scientist, how might you design a study to test this hypothesis?

M. How can fire suppression change habitat for bighorn sheep? What is prescribed burning and why do some managers of bighorn sheep use prescribed burning to help maintain high quality habitat for bighorn sheep?

N. How does human development affect habitat for bighorn sheep?

O. Wild bighorn sheep have a low rate of reproduction. What does this mean? How does a having a low rate of reproduction make bighorn sheep particularly susceptible to die-offs from diseases?

P. Do you think that bighorn sheep in the US are "on the edge"? Why or why not?

Vocabulary Words

Carrying Capacity: the maximum size of a biological population that the environment can sustain indefinitely without degrading the environment for future generations. When a biological population is at ecological carrying capacity, the number of births equals the number of deaths.

Endangered Species: a species of organisms facing a very high risk of extinction

Extirpation: a local extinction, when a species ceases to exist in a particular area but still exists somewhere else

Gestation Period: the time during which a fetus develops, beginning with fertilization and ending with birth

Livestock Grazing Allotments: an area of land that is designated and managed for grazing of livestock. It may include private, state, and public lands *under the jurisdiction of the Bureau of Land Management* (BLM) and/or other federal agencies.

The Bureau of Land Management administers about 245 million acres of public lands and manages livestock grazing on 155 million acres of those lands, as guided by federal law.

The BLM administers nearly 18,000 permits and leases held by ranchers who graze their livestock, mostly cattle and sheep, at least part of the year on more than 21,000 allotments under BLM management. Permits and leases generally cover a 10-year period and are renewable if the BLM determines that the terms and conditions of the expiring permit or lease are being met.

Habitat: the place an animal lives, which includes all the resources an animal needs to survive and reproduce

Minimum Viable Population: the smallest possible size that a biological population can exist without facing extinction

Subspecies: A taxonomic subdivision of a species consisting of an interbreeding, usually geographically isolated population of organisms

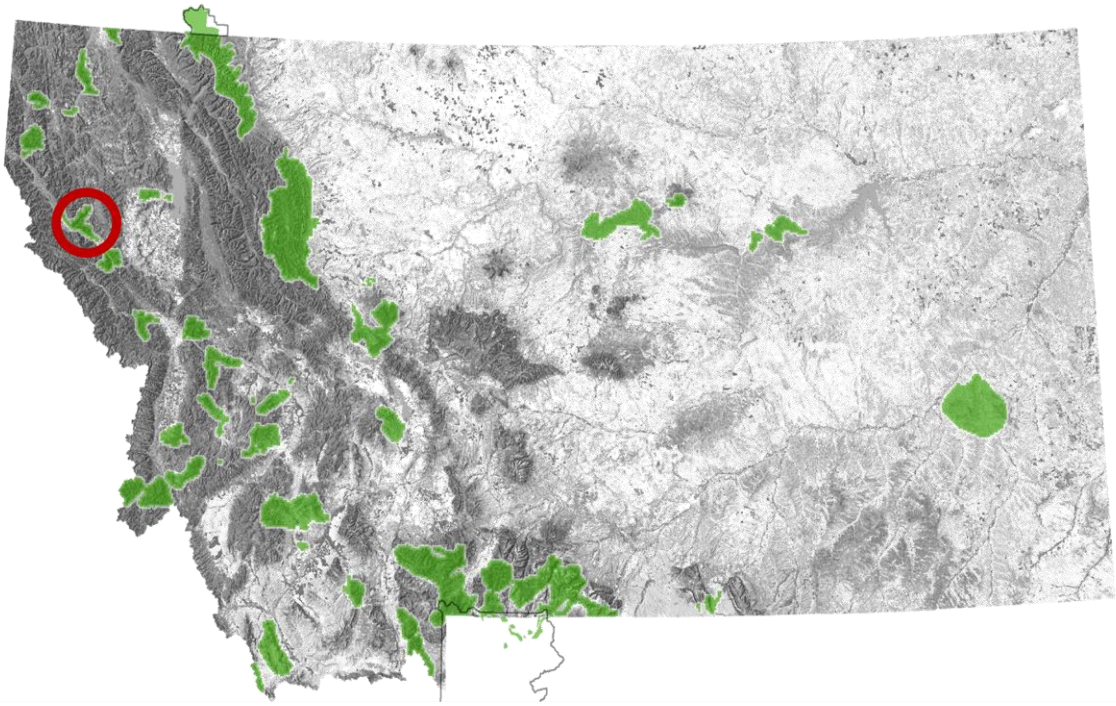
Student Pages: Wild Bighorn Sheep: On the Edge?

Group 1 **Case Study: Thompson Falls Bighorn Sheep Herd**

Instructions for this Activity
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graphs. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:
1) brief background information about the history of this herd
2) information about where the herd lives
3) the two graphs you created
4) a list of factors affecting the conservation of this herd

Background Information
The Thompson Falls bighorn sheep herd occupies about 140 mi^2 along the Clark Fork River.



About 90% of the habitat is located on land managed by the US Forest Service. The remaining 10% is owned and managed by the state wildlife agency and small private landowners.

Sheep were **reintroduced** into this area in 1959 with **transplants** of 13 sheep from Wildhorse Island. By 1974, the herd had grown from 13 sheep to 240 sheep. Since 1981,

spring helicopter surveys have been conducted annually to estimate the number of sheep in this herd.

Beginning in late 2008, this herd started to drastically decline due to excessive vehicle collisions and mountain lion predation.

The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

For the Thompson Falls bighorn sheep herd, there are three main management challenges.

1. Sheep mortalities from vehicles traveling on Highway 200 is the number one challenge facing managers. Although roads are marked with warning signs, flashing lights, and reader boards letting drivers know that bighorns are in the area, some drivers continue to pay little attention.

Sheep are attracted to the highway in the winter because of a salt-based liquid de-icer that is applied to the road to clear the surface of ice and snow. During spring, sheep congregate adjacent to the highway because of freshly sprouted green vegetation.

2. Predators like mountain lions have recently become an important factor. Beginning in 2008, mountain lions have increasingly been killing bighorn sheep in this herd.

3. Habitat loss through wildfire suppression and conifer encroachment continues to be a problem. Compared to sheep habitats in other regions of the state, sheep ranges here are represented by lots of trees and shrub-dominated communities with <u>little grassland vegetation types available</u>. Historically, wildfire prevailed on the landscape and maintained fire-based vegetation communities of ponderosa pine and bunchgrasses. With the advent of fire suppression by the USFS over the past 50 years, sheep forage (food) such as bunchgrasses and certain shrubs are being replaced by Douglas fir trees through encroachment onto open forage sites. This has resulted in gradual habitat loss for bighorn sheep.

Notably, disease issues related to contact between wild bighorn sheep and domestic sheep is not an apparent problem for the Thompson Falls herd. There are no grazing allotments for domestic sheep or goats anywhere near this herd. However, bighorns from the Thompson Falls herd sometimes travel off the sheep range, especially during rut, and may come in contact with domestic sheep or goats on hobby farms scattered throughout the area.

Use the table on the next page to:

1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, rams and unclassified sheep for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".

2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.

Year	Ewes	Lambs	Rams	Unclassified	Total Number of Bighorn Sheep Observed
1981	109	55	75	90	
1982	155	79	66	61	
1983	114	45	60	207	
1984	76	57	99	200	
1985	106	55	135	47	
1986	145	80	105	22	
1987	106	63	97	48	
1988	91	53	91	35	
1989	110	46	70	0	
1990	120	48	63	10	
1991	85	32	54	35	
1992	110	49	30	0	
1993	126	50	50	35	
1994	141	52	68	0	
1995	117	38	55	2	
1996	99	44	56	24	
1997	107	36	49	12	
1998	117	36	55	2	
1999	89	34	54	0	
2000	75	28	63	0	
2001	83	41	56	0	
2002	83	40	38	0	
2003	110	62	40	0	
2004	99	37	42	20	
2005	112	41	36	2	
2006	83	32	39	25	
2007	106	47	63	47	
2008	106	31	80	53	
2009	84	27	58	0	
2010	68	29	33	0	
2011	65	21	37	0	
2012	29	12	8	0	

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep

observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed".

For this activity, we are evaluating only the "number of sheep observed during surveys".

Next, use the table below to create a graph showing the number of bighorn sheep that were killed by vehicles and trains each year.

Year	# of bighorn sheep killed by vehicles
1985	4
1986	1
1987	6
1988	4
1989	11
1990	14
1991	34
1992	25
1993	23
1994	24
1995	11
1996	13
1997	18
1998	24
1999	18
2000	20
2001	4
2002	13
2003	15
2004	20
2005	7
2006	27
2007	15
2008	38
2009	14
2010	23
2011	17
2012	18

QUESTIONS (answer these as a group)

1. In 1959, how many sheep were trapped FROM another herd and transplanted TO this area to re-establish the Thompson Falls herd?

2. How many bighorn sheep were killed by vehicles during 1985-2012?

3. What has been happening to this herd since 2008?

4. Why are sheep attracted to roads during winter?

5. Why are sheep attracted to roads during spring?

6. How has fire suppression changed the habitat for bighorn sheep?

7. What does MVP mean?

8. Is this herd currently above MVP for bighorn sheep in Montana?

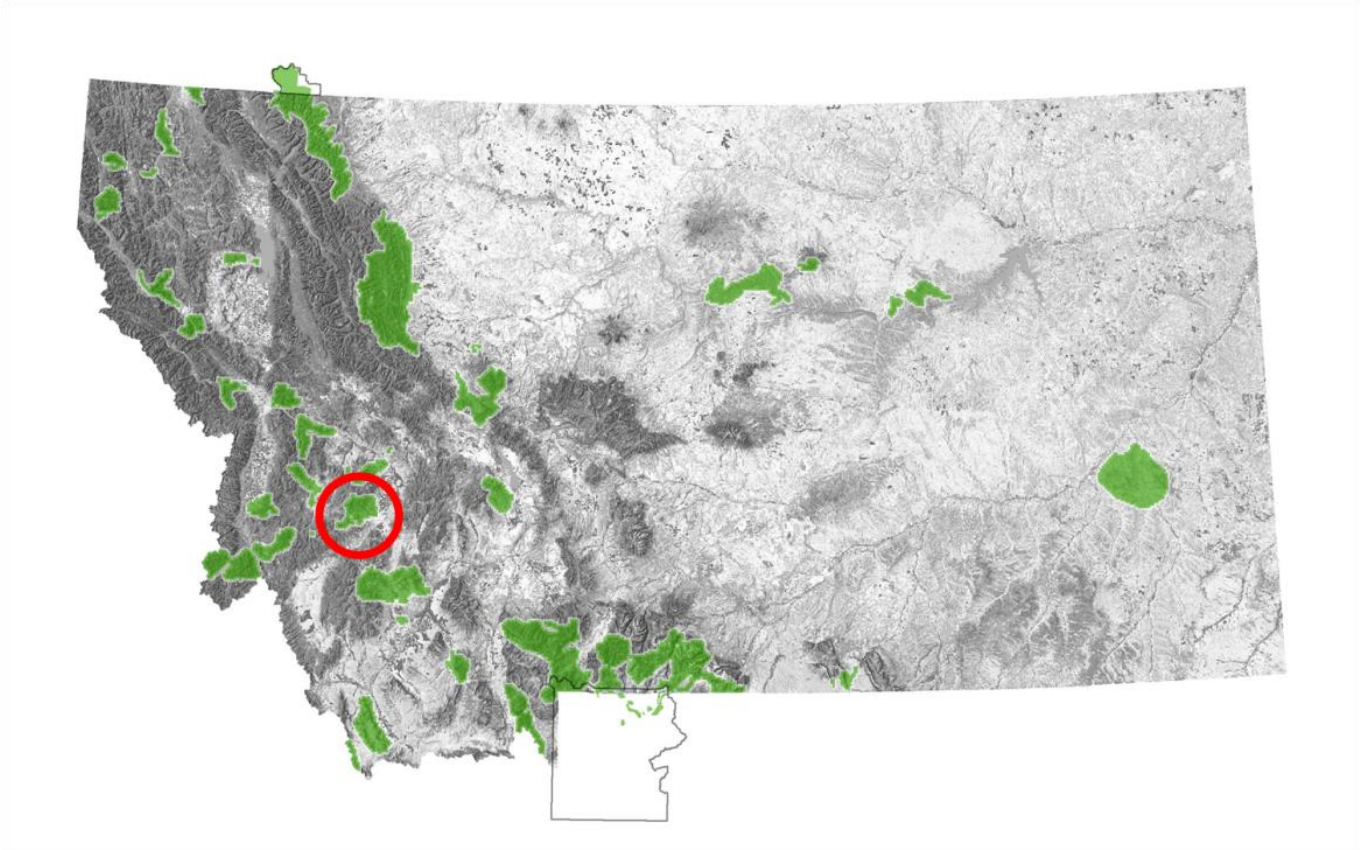
Student Pages: Wild Bighorn Sheep: On the Edge?

Group 2 **Case Study: Lost Creek Bighorn Sheep Herd**

Instructions for this Activity
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graph. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:
1) brief background information about the history of this herd
2) information about where the herd lives
3) the graph you created
4) a list of factors affecting the conservation of this herd

Background Information
The Lost Creek bighorn sheep herd occupies about 411 mi^2 west of Anaconda, Montana.



About 55% of the habitat is owned by private landowners, 39% is owned by the federal government (USFS), and 6% is owned by the state.

The Lost Creek herd was re-established in 1967, with the help from the Anaconda Sportsmen's Club. In 1967, 25 bighorn sheep were trapped FROM a herd in the Southern Rocky Mountain front herd and transplanted TO this area. The population grew to 50 sheep by 1971. The herd continued to grow rapidly. In fact, this herd did so well that during 1986-1990, 150 sheep were trapped FROM the Lost Creek herd and transplanted TO other bighorn sheep habitat in Montana to re-establish other bighorn sheep herds or to supplement small herds. Even in late 1990, the herd continued to grow despite the fact that many sheep had been transplanted FROM this herd TO other herds.

On September 15, 1991, a hunter in Lost Creek found a sick ram. The ram died in transit to Anaconda and was taken to a veterinary lab for autopsy. It was determined that pneumonia was the cause of death. Subsequently, dead and sick sheep were found throughout the range of this herd. Lung samples from 19 bighorns from this herd were evaluated and it was determined that the sheep had died of pneumonia. The disease outbreak lasted for about 10 weeks and the population plummeted. Mortality from the die-off was over 50%.

The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

For the Lost Creek bighorn sheep herd, there are three main management challenges.

1. The number one management challenge is to maintain separation of wild bighorn sheep and domestic sheep and goats to avoid transmission of diseases (like pneumonia) to bighorns. The increasing use of domestic sheep to manage weeds, as well as sheep kept as pets or on hobby farms, is of concern to bighorn sheep managers. Several thousand domestic sheep are being used for weed control near the Lost Creek bighorn herd's habitat.

2. Loss of habitat due to human development is another challenge. The development of subdivisions within the core range of the Lost Creek herd presents numerous problems including potential stress to wintering and lambing sheep, direct mortality from dogs and fences, loss of landscape connectivity, and direct and indirect loss of habitat. Subdivision of key bighorn habitat is currently occurring at a rapid pace in Lost Creek.

3. Noxious weed infestation by species such as spotted knapweed are especially severe on private and public lands in Lost Creek. Efforts to enhance and maintain grassland foothills habitat would benefit bighorn sheep in Lost Creek.

Use the table below to:
1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, rams, and unclassified sheep for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".
2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.

Year	Ewes	Lambs	Rams	Unclassified	Total Number of Bighorn Sheep Observed
1978	45	33	47	13	
1980	70	31	42		
1981	67	23	41		
1982	73	27	49		
1983	62	31	70		
1984	3	0	88	104	
1985	90	39	99		
1986	101	36	106		
1988	150	58	123		
1989	147	65	149		
1991	64	32	161	54	
1992	72	28	44		
1994	55	7	54		
1995	6	3	49	68	
1996	24	11	49	39	
1997	51	18	45	16	
1998	48	22	20		
1999	53	31	53	22	
2000	38	22	61	44	
2001	64	33	62		
2006	125	53	72	53	
2007	56	8	80	153	
2008	62	39	70	143	

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed". For this activity, we are evaluating only the "number of sheep observed during surveys".

QUESTIONS (answer these as a group)

1. How many sheep were transplanted TO this herd in 1967 to re-establish it, and where did these transplanted sheep come from?

1. What happened during 1986-1990?

2. What happened during fall of 1991?

3. What percentage of this herd was affected by what happened in 1991?

4. How do you think sheep in this herd contracted pneumonia?

5. Based on the data you graphed, do you think this population recovered from what happened in fall of 1991?

6. Noxious weeds are present in this habitat. Do you think it is a good idea to use domestic sheep to control weeds in this area? Why or why not?

7. How does human development affect habitat for wild bighorn sheep in this herd?

8. What does MVP mean?

9. Has this herd ever fallen below the MVP estimate? If so, during which years?

Student Pages: Wild Bighorn Sheep: On the Edge?

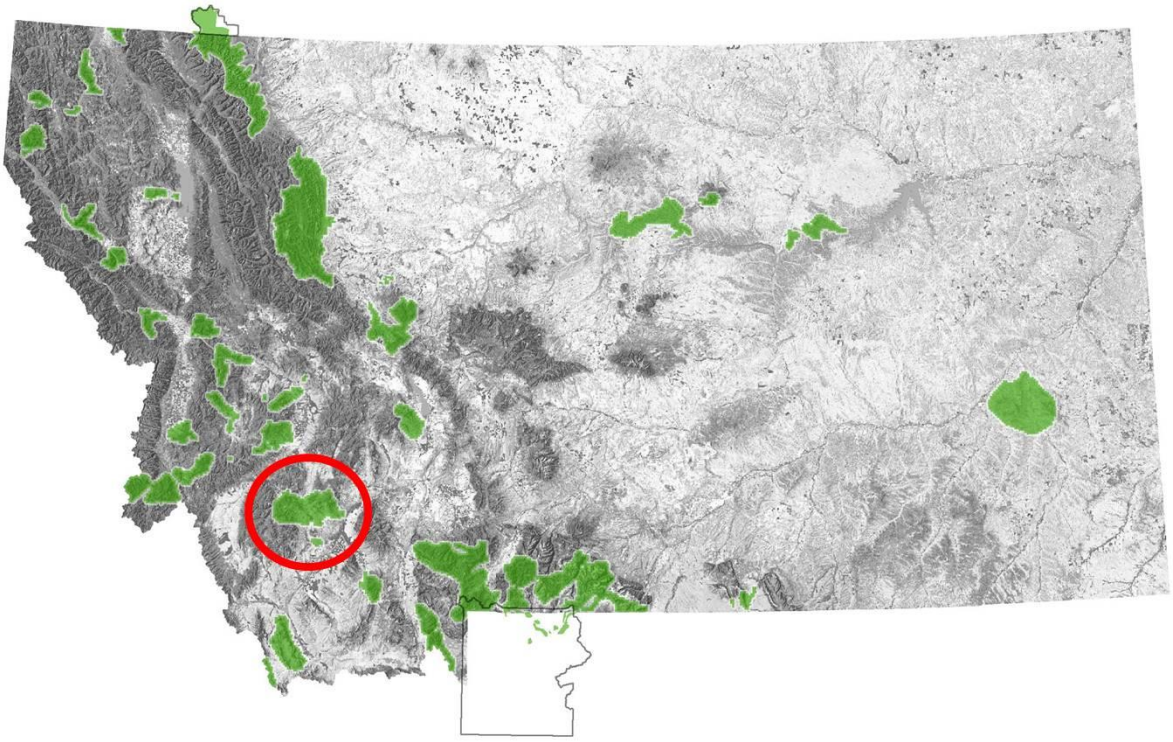
Group 3 **Case Study: Highland Bighorn Sheep Herd**

Instructions for this Activity
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graphs. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:
1) brief background information about the history of this herd
2) information about where the herd lives
3) the two graphs you created
4) a list of factors affecting the conservation of this herd

Background Information

The Highland bighorn sheep herd occupies about 1,141 mi^2 south of Butte, Montana.



About 42% of the habitat is owned by private landowners and 58% is managed by public land management agencies (BLM, USFS, and Montana Department of Natural Resources).

The original Highland bighorn sheep herd died out in the early 1900s, mainly due to unregulated hunting and disease transmission from domestic livestock. In the late 1960s, an effort was made to re-establish this herd through transplants of 53 bighorn sheep from a Southern Rocky Mountain front herd. The herd grew steadily, but then a die-off occurred during the winter of 1994-1995, causing about 90% mortality. The die-off was attributed to pneumonia. Following the die-off, several transplants were done in attempt to rebuild this population. In 2000-2001, 32 bighorn sheep were transplanted from a Southern Rocky Mountain front herd. In 2001, 3 more sheep were transplanted from the Bonner herd. In 2002, 14 sheep were transplanted from the Sula herd. In 2007, 17 sheep were transplanted from the Ruby Mountains.

A management goal for this herd is to restore its numbers to its former abundance. The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

For the Highland bighorn sheep herd, the number one management challenge is to maintain separation of wild bighorn sheep and domestic sheep and goats to avoid transmission of diseases (like pneumonia) to bighorns. Historically, the Highlands bighorn sheep range has overlapped with two small bands of domestic sheep located on private land. Biologists have observed bighorn sheep using agricultural areas that support domestic sheep throughout the year. Currently, several domestic sheep hobby farms operate within proximity of the Highlands bighorn sheep range. There are no domestic sheep grazing allotments in the Highland bighorn sheep range. Because of the pneumonia die-off, very few lambs have been surviving through their first year.

Use the table on the next page to:

1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, rams, and unclassified sheep for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".
2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.
3. Create a separate graph showing the number of lambs observed each year during aerial surveys. Put "Year" on the x-axis and "Number of lambs observed" on the y-axis.

Year	Ewes	Lambs	Rams	Unclassified	Total Number of Bighorns Observed
1972			4	50	
1973	20	10	4		
1974				35	
1975	14	7	3		
1976	12	7	5		
1977	25	13	8		
1978	11	4	3		
1979	35	28	8		
1980	41	17	12		
1981	71	29	14		
1982	42	19	22	32	
1983	62	31	34		
1984	101	15	42		
1985	59	39	41		
1986	98	26	50		
1987	75	35	48		
1988	116	29	33		
1989	98	37	58		
1990	74	27	97		
1991	154	61	46		
1992	182	58	76		
1993	91	49	37		
1994	161	41	118		
1995	23	6	14	3	
1996	18	0	0		
1997	27	4	1		
1998	25	6	4		
2005	6	2	19		
2006	6	0			
2007	6	0	6		
2008	4	1	1		
2009	19	1	5		
2010	37	2	1		
2011	23	0	8		
2012	7	1	18	10	

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed". For this activity, we are evaluating the "number of sheep observed during surveys".

QUESTIONS (answer as a group):

1. How many sheep were transplanted TO this herd in 1960 to re-establish it, and where did these transplanted sheep come from?

2. What happened in 1994?

3. Since 2001, how many sheep were transplanted TO the Highland herd? Why were they transplanted to this herd?

4. Based on the population data you graphed, do you think the transplanting efforts **since 2001** have been successful? Why or why not?

5. How do you think wild bighorn sheep in this herd contracted pneumonia?

6. What can you say about bighorn sheep lamb survival since 1994?

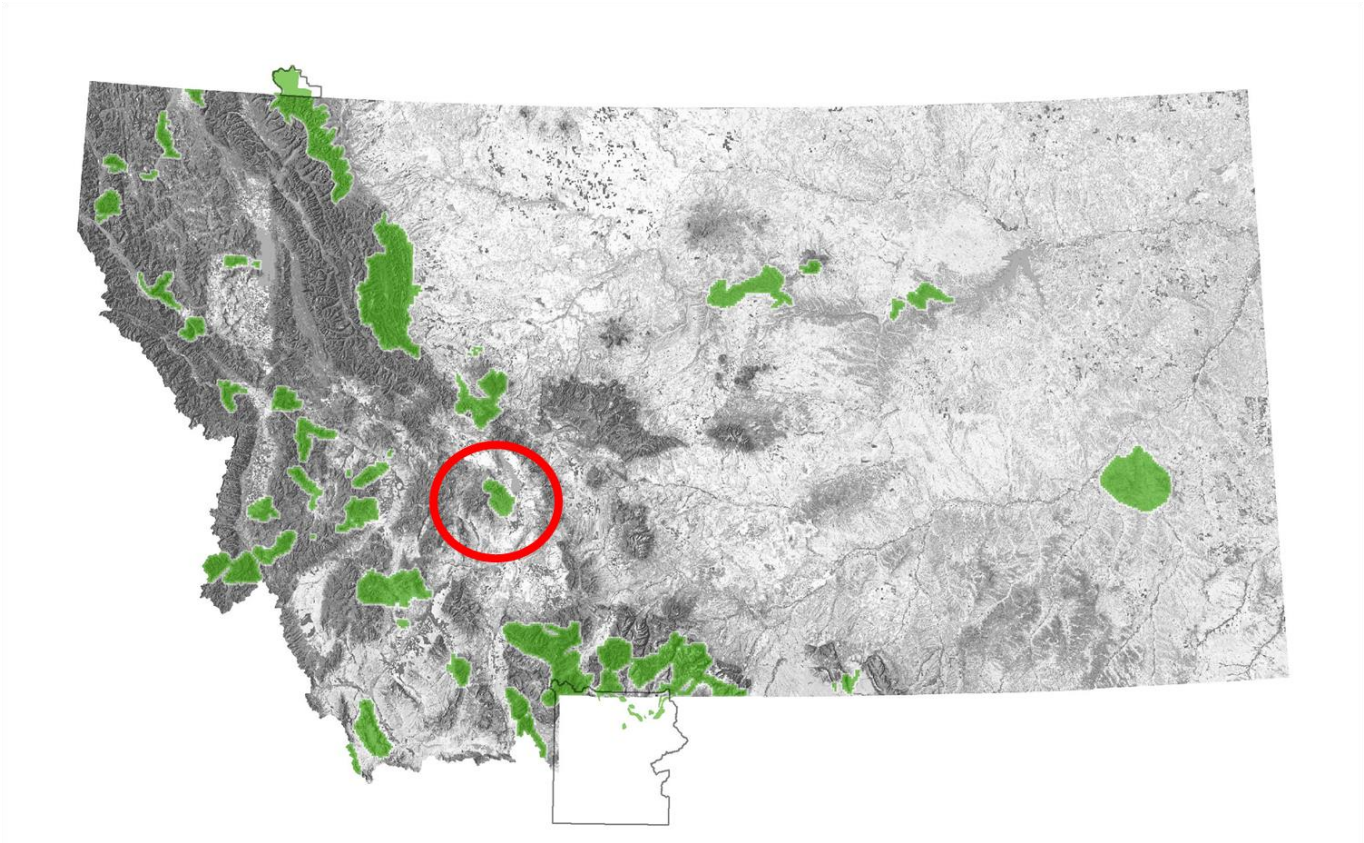
Student Pages: Wild Bighorn Sheep: On the Edge?

Group 4 **Case Study: Elkhorn Bighorn Sheep Herd**

Instructions for this Activity
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graphs. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:
1) brief background information about the history of this herd
2) information about where the herd lives
3) the two graphs you created
4) a list of factors affecting the conservation of this herd

Background Information
The Elkhorn bighorn sheep herd occupies about 1,241 mi^2 southeast of Helena, Montana.



About 59% of the habitat is owned by private landowners and 41% is managed by public land management agencies (Bureau of Land Management (BLM) and USDA Forest Service).

The Elkhorn bighorn sheep herd was re-established by trapping bighorn sheep FROM another herd and transplanting them TO the Elkhorn area, which began in winter of 1995-1996. 25 bighorn sheep were transplanted TO the Elkhorn herd FROM the Rock Creek herd in 1995. 30 bighorn sheep were transplanted TO the Elkhorn herd FROM the Milltown herd in 1997. 20 bighorn sheep were transplanted TO the Elkhorn herd FROM the Missouri River Breaks herd during 2000. Since 1996, the number of bighorn sheep in the Elkhorn herd had been steadily increasing.

On January 10, 2008, Montana Fish Wildlife and Parks (the state wildlife agency responsible for managing wild sheep in Montana) received a report of a dead bighorn in the Elkhorn Mountains. Field observations confirmed bighorn sheep were dying and a helicopter survey was flown on January 16, 2008 to determine the extent of the die-off.

Based on the results of the 2007 survey, there SHOULD have been about 220 sheep in January 2008. Montana bighorn field biologists flew the entire Elkhorn habitat and counted only 35 sheep. Some sheep could be seen coughing from the helicopter. The die-off represented about 90% of the population. During their aerial survey, biologists documented 75 domestic goats running loose on BLM and private lands near this herd. Since 2008, survival of lambs has been essentially zero.

The management goal is to restore this population back to its former abundance. The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

For the Elkhorn bighorn sheep herd, there are several management challenges. Below you'll find two of them:

1. The number one management challenge is to maintain separation of wild bighorn sheep and domestic sheep and goats to avoid transmission of diseases (like pneumonia) to bighorns. When bighorn sheep were first introduced into the Elkhorn range during 1995, the BLM guidelines for minimum distance between wild bighorns and domestic sheep and goats were used. This guideline suggested that wild bighorn sheep habitat should have a 6 mile buffer around it, away from domestic sheep and goats to prevent co-mingling and the possibility of disease transmission FROM domestic sheep and goats TO wild bighorn sheep. This guideline was based on the best information available at the time, but turned out to be incorrect. It is now recommended that wild bighorn habitat has a 17.5 mile (28km) buffer around it (and away from domestic sheep and goats) to help ensure wild bighorns do not come in contact with domestic sheep and goats.

2. Loss of habitat due to human development and mining on winter bighorn sheep range continues to be a conservation issue. There is also a National Guard training area in this bighorn range. While the National Guard has shown sensitivity to wildlife and wildlife conservation issues on their training area, the cumulative impacts of mining and military training will likely have long-term negative effects on all wildlife that use this area.

Use the table below to:
1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, and rams for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".
2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.
3. Create a separate graph showing the number of lambs observed each year during aerial surveys. Put "Year" on the x-axis and "Number of lambs observed" on the y-axis.

Year	Ewes	Lambs	Rams	Number of Bighorn Sheep Observed
2001	62	19	25	
2002	45	31	6	
2003	77	32	35	
2004	78	29	25	
2005	87	28	48	
2006	84	24	54	
2007	96	27	75	
2008	15	0	4	
2009	20	0	6	
2010	5	0	6	
2011	0	0	6	
2012	12	2	2	

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed". For this activity, we are evaluating only the "number of sheep observed during surveys".

QUESTIONS (answer these as a group)

1. How many bighorn sheep were transplanted TO this herd to establish it during 1995-2000, and where did these transplanted sheep come from?

2. What happened in 2008?

3. In January, 2008 field biologists conducted a survey to determine the extent of the die-off. What did they see during these aerial surveys?

4. What percentage of this herd was affected by what happened during 2008?

5. How do you think wild bighorn sheep in this herd contracted pneumonia? What evidence leads you to this hypothesis?

6. What can you say about bighorn sheep lamb survival since 2008?

7. Based on the data you graphed for the number of total sheep observed, would you say that this herd has recovered from what happened in 2008?

8. Scientists have determined that wild bighorn sheep should be ____ miles away from domestic sheep and goats to minimize disease transfer from domestic sheep and goats to wild bighorn sheep.

Student Pages: Wild Bighorn Sheep: On the Edge?

Group 5 **Case Study: Southern Rocky Mountain Front Bighorn Sheep Herd**

Instructions for this Activity

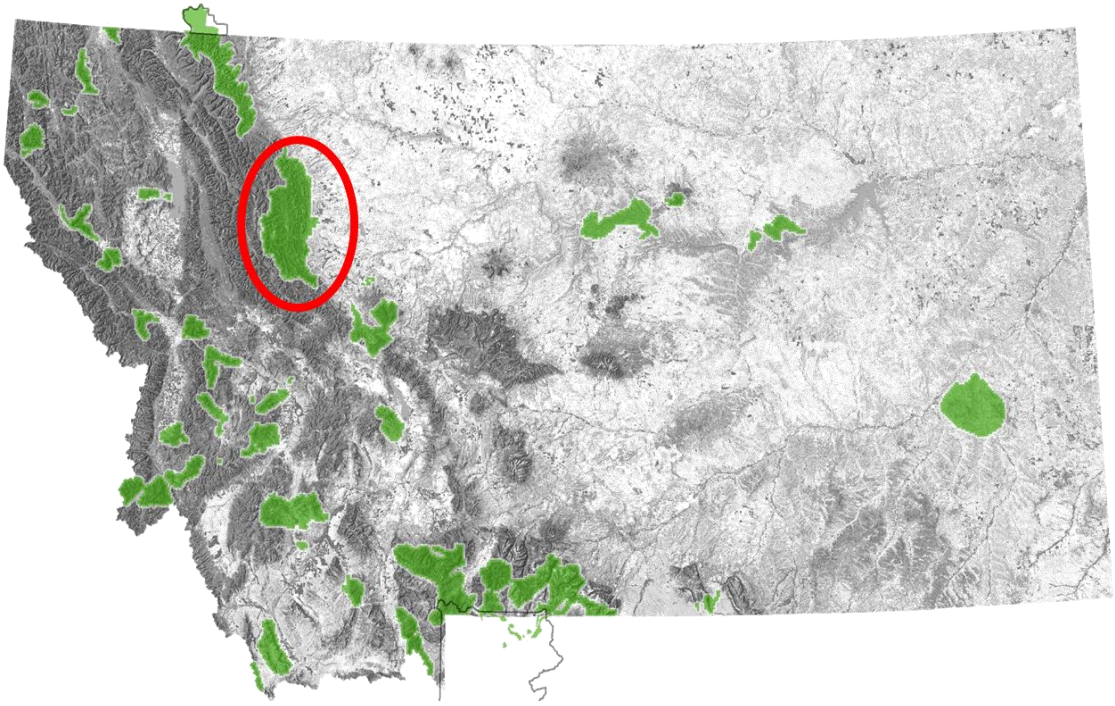
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graph. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:

1) brief background information about the history of this herd
2) information about where the herd lives
3) the graph you created
4) a list of factors affecting the conservation of this herd
5) include information about prescribed burns and how they are sometimes used to help increase habitat quality for wild bighorn sheep herds

Background Information

The Southern Rocky Mountain front bighorn sheep herd includes 4 hunting districts which includes about 1,105 mi^2.



About 42% of the habitat is owned by private landowners and 58% is owned by several public land management agencies, including the Bureau of Land Management (BLM) and the USDA Forest Service. For this case study, your group will be focusing on the herd in district 422.

District 422 has traditionally been an area demonstrating relatively high sheep numbers. Because of this, the area has been one of the main focal points for sheep trapping for the purpose of transplanting in other areas throughout Montana and other western states. Since 1941, there have been 52 trapping and transplanting efforts in this district!

In 1983, this herd experienced a die-off. In summer 2010, this herd experienced another die-off that had affected 50% of the herd by year 2011. The symptoms that bighorn sheep had indicated that pneumonia was the cause of death for the 2010 die-off, but identifying how this herd contracted this disease is not known. The cause of the 2010 die-off is currently under scientific investigation.

To sustainably manage this herd, one management goal is to maintain the number of bighorn sheep observed to be 200 individuals. The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

1. Maintaining high quality habitat: Up until 2010, this herd had done relatively well and so managers had been focusing on maintaining high quality habitat. Most of the sheep habitat in this district is on public lands so the bighorn sheep managers work in cooperation with the US Forest Service on things like habitat manipulation, <u>such as prescribed burns</u>.

Historically, wildfire prevailed on the landscape in this area and therefore fire-based vegetation communities such as ponderosa pine and bunchgrasses were maintained by fire. With the advent of fire suppression by the USFS over the past 50 years, sheep forage such as bunchgrasses and certain shrubs have been and are currently being replaced by Douglas fir trees through encroachment of these trees onto open areas that have supported grasses and shrubs. This has resulted in gradual habitat loss for bighorn sheep. Using prescribed burns, land managers can **reduce Douglas fir encroachment and help maintain fire-based vegetation like bunchgrasses and some shrubs.** This helps minimize habitat loss for wild bighorn sheep due to Douglas fir encroachment.

Another habitat quality issue that was recently resolved: Oil and gas exploration was a possibility in this area, which could have affected wild bighorn sheep habitat. Recently, this situation was settled so that all public lands on the Rocky Mountain Front will not be exposed to oil and gas explorations in the future, which will benefit bighorn sheep habitat.

2. Minimizing disease transmission from domestic sheep and goats: Given that the die-off in 2010 may have been caused by pneumonia, managers are also working to minimize the possibility of domestic sheep and goat interactions with wild bighorns to reduce the threat of disease transmission.

3. Possible predation factor: This region also has a strong predator presence including grizzly bears, black bears, mountain lions, wolverines, lynx, coyotes and wolves. It is likely that bighorn survival is or could be affected by predation, but no research has tested this hypothesis yet.

Use the table on the next page to:

1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, rams, and unclassified sheep for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".
2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed". For this activity, we are evaluating only the "number of sheep observed during surveys".

Although many bighorn sheep herds are surveyed by helicopters or airplanes, this herd has been surveyed by biologists who were hiking or riding horses.

Year	Ewes	Lambs	Rams	Unclassified	Number of Bighorn Sheep Observed
1970	106	57	38		
1972	99	52	27		
1973	85	34	41		
1974	120	67	59		
1975	102	59	51	2	
1976	77	63	24	1	
1978	79	37	11	52	
1979	82	44	31		
1980	88	59	55		
1981	113	54	68		
1982	103	64	66		
1983	38	16	24		
1984	87	20	45		
1985				231	
1986	97	59	58		
1988	96	56	62	15	
1989	143	71	74		
1990	82	52	63		
1991	58	24	49	27	
1992			27	195	
1995	51	37	45	51	
1996	93	23	63		
1997	62	32	33	6	
1998	93	38	68	7	
1999	91	33	65	73	
2000	70	37	47	51	
2001	79	24	48	53	
2002	60	30	19	49	
2003	87	40	50	77	
2004	103	35	32	125	
2005	131	56	81	72	
2006	125	21	96	28	
2007	75	40	61	39	
2008	128	34	97	35	
2009	97	25	79	72	
2010	92	4	72	28	
2011	57	3	65	31	
2012	55	9	58	39	

QUESTIONS (answer these as a group)

1. What is a prescribed burn? Why would bighorn sheep managers use prescribed burns to manage habitat for bighorn sheep?

1. Oil and gas exploration was a possibility in this area, but was recently stopped. How do you think that oil and gas exploration might affect habitat for wild bighorn sheep?

2. What happened in 2010?

3. Why are managers concerned about keeping wild bighorn sheep away from domestic sheep and goats?

4. It is likely that predators in this area are affecting bighorn sheep survival, but this hypothesis has not yet been tested. If you were a bighorn sheep scientist, how would you design a study to test this hypothesis?

5. Most of the habitat in this herd is owned by the public. How might the land ownership affect the ability of managers to maintain healthy bighorn sheep habitat? (hint: is it easier or more difficult to maintain large tracts of land for habitat when it is owned by lots of private individuals or when it is owned by a natural resource land agency like the forest service?)

Student Pages: Wild Bighorn Sheep: On the Edge?

Group 6 **Case Study: Missouri River Breaks Bighorn Sheep Herd**

Instructions for this Activity

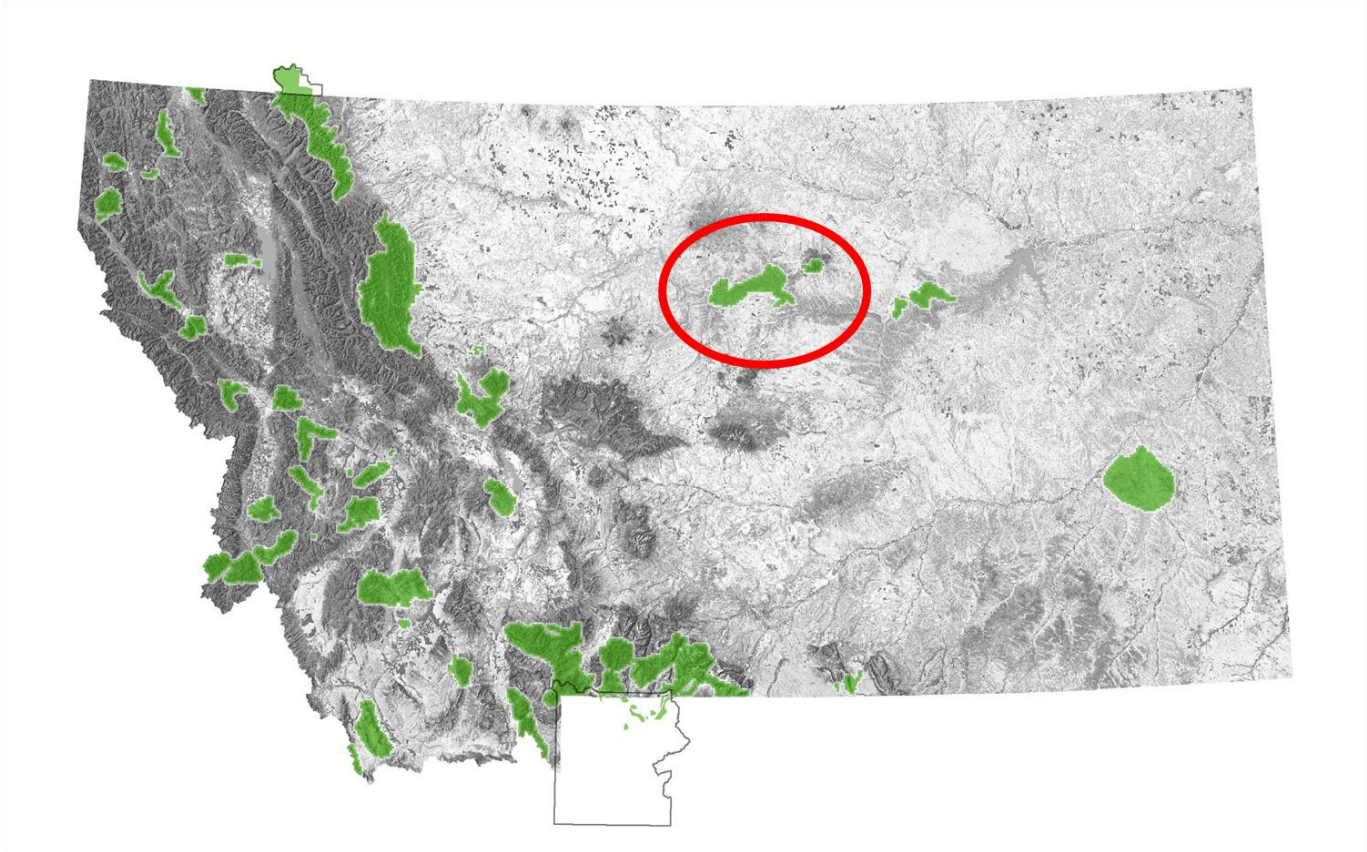
You should be in one of 6 groups. Individually, read through this page of background information thoroughly before calculating the missing data and creating your graph. After you have graphed the data individually, work as a group to answer the questions and then compile a list of factors that are affecting this herd of wild bighorn sheep.

Then, as a group create a presentation that you will give to your other class mates. Your presentation should include the following:

1) brief background information about the history of this herd
2) information about where the herd lives
3) the graph you created
4) a list of factors affecting the conservation of this herd

Background Information

The Missouri River Breaks herd includes 4 hunting districts which includes about 3,863 mi^2. The highest quality bighorn sheep habitat here includes the steep-walled canyons and ridges adjacent to the Missouri River between the mouth of the Judith River to Timber Creek.



About 21% of the habitat is owned by private landowners and 72% is federally owned by the Bureau of Land Management (BLM) and the USDA Forest Service. There are 6 wilderness study areas on the BLM land and 2 proposed Wilderness Areas. For this case study, your group will be focusing on the herd in district 680.

In the 1800s, early explorers commonly observed bighorn sheep along the Missouri River. By the early 20th century, bighorn sheep were extirpated from the Missouri River Breaks. By 1940, plans were underway to restore wild bighorn sheep to this area. In hunting district 680, 28 bighorn sheep were trapped FROM another herd and transplanted TO the Missouri River Breaks habitat in 1980 and the population began to increase.

The number of observed bighorn sheep in this herd has been declining since around 2009. Managers don't know exactly why, but the winters of 2009-2010 and 2010-2011 were exceptionally harsh, which likely contributed to a decline in observed bighorn sheep over the last few years. There was also lower lamb survival and some winter mortality during that period. No bighorn sheep have been trapped in this herd and transplanted to other herds. There was no confirmed evidence of pneumonia or coughing sheep during winters of 2009-2010 or 2010-2011, although anytime there is a drop in the number of sheep observed and lower lamb survival, managers worry about pneumonia. There is also a different population of bighorn sheep that live across the Missouri River and some sheep from this herd **could have potentially** emigrated into that herd (which would explain why the number of observed sheep has been declining).

To sustainably manage this herd, one management goal is to maintain the number of bighorn sheep observed to be between 400-450 individuals. The **minimum viable population** estimate for bighorn sheep in Montana is 125 animals. Minimum Viable Population is the smallest possible size that a biological population can exist without facing extinction.

Management Challenges (Factors affecting conservation of bighorn sheep)

For the Missouri River Breaks bighorn sheep herd, there is one main management challenge.
1. Keeping this herd at or below carrying capacity to reduce the risk of die-offs from disease transmission and to minimize habitat degradation is important. To help keep the population at or below carrying capacity, managers use at least 2 management strategies: 1) regulated hunting (where the number of sheep allowed to be hunted is calculated based on scientific information), and, 2) trapping some individuals from the Missouri River Breaks herd and transplanting them to other historic wild bighorn sheep habitat. Regulated hunting is an important conservation tool for wildlife managers.

Carrying capacity is the maximum size of a biological population that the environment can sustain indefinitely without degrading the environment for future generation

Use the table below to:
1. Calculate the total number of bighorn sheep observed each year during aerial surveys (add the number of ewes, lambs, rams, and unclassified sheep for each year) and put answers in the column marked "Number of Bighorn Sheep Observed".
2. Create a graph showing the total number of bighorn sheep observed each year during aerial surveys. Put "Year" on the x-axis and "Number of Bighorn Sheep Observed" on the y-axis.

Year	Ewes	Lambs	Rams	Unclassified	Number of Bighorn Sheep
1990	24	8	16		
1992	37	6	30		
1994	40	15	28		
1995	88	40	99		
1996	44	19	54		
1997	117	22	77		
1998	139	59	32		
1999	119	66	47		
2000	126	86	65	20	
2001	161	102	110		
2002	154	80	95		
2003*	80	31	80		
2004	172	80	134		
2005	201	111	122		
2006	260	130	142		
2007	235	96	119		
2008	173	72	137		
2009	208	85	138		
2010	168	54	95		
2011	139	56	67	3	
2012	104	45	76		

***In 2003:** the aerial survey only covered a portion of this area because of mechanical problems with the helicopter

Important information about your data set: The "number of observed bighorn sheep" is not a population estimate. It represents raw data that were collected during the surveys. Population estimates include measures of uncertainty, like estimates of "sheep observability". For example, do you think biologists who were conducting the survey were able to see every single sheep during the survey? There are ways to estimate the number of sheep "not observed". For this activity, we are evaluating only the "number of sheep observed during surveys".

QUESTIONS (answer these as a group)

1. How many sheep were transplanted to this area in 1980?

2. What does carrying capacity mean?

3. Why is it important to keep a wild population at or below carrying capacity? How do managers keep this population below or at carrying capacity?

4. How does regulated hunting differ from unregulated hunting? (Hint: which one includes hunting limits based on science?)

5. How many bighorn sheep do managers strive to maintain in this herd each year? Do you think that the number of sheep that managers strive to maintain each year represents carrying capacity for this herd? Why or why not?

6. What happened in 2003 during the survey work? Given this incident, do you think the number of observed bighorn sheep that biologists saw during 2003 accurately depicts how many sheep were in this population at that time? Why or why not?

7. During the last several years, the number of observed bighorn sheep in this herd has dropped. What are some of the possible reasons to explain this decline? If you were a bighorn sheep scientist working on this herd, how would you test some of these "possible reasons" (or hypotheses)?

Next Generation Science Standards: Middle School

Performance Expectations:

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems

MS-LS2-4: Construct an argument supported by empirical evidence that changes in the physical or biological components of an ecosystem affects populations

Foundations:

Analyzing and interpreting data

Constructing Explanations and designing solutions

Engaging in argument from evidence

Connections to Nature of Science:

Scientific knowledge is based on empirical evidence

Common Core State Standard Connections: Literacy

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text

RI.8.8: Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims.

WHST.6-8.1: Write arguments to support claims with clear reasons and relevant evidence

SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues building on others' ideas and expressing their own clearly

SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well -chosen details

Common Core State Standards Connections: Math

MP. 4: Model with mathematics

6.SP.B.5: Summarize numerical data sets in relation to their context

NSES National Science Standards

Standard A: Science as Inquiry 1-6

1. Identify questions and concepts that guide scientific investigations (STEM)
2. Design and conduct scientific investigations (STEM)
3. Use technology and mathematics to improve investigations and communications (STEM)
4. Formulate and revise scientific explanations and models using logic and evidence (STEM)
5. Recognize and analyze alternative explanations and models (STEM)
6. Communicate and defend a scientific argument (STEM)

Standard C: Life Science 6; Students will understand the behavior of organisms (STEM)

Standard G: History and Nature of Science 3; Students will understand connection to historical perspectives (STEM)

National Technology Standards ITEA

Standard 2: Students will develop an understanding of the core concepts of technology

a. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems (benchmark W and STEM)
b. Management is the process of planning organizing and controlling work (benchmark EE and STEM)

Standard 8: Students will develop an understanding of the attributes of design (STEM)

a. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach d, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communication processes and results. (benchmark H)

National Engineering Standards ABET

1. Students will have an ability to design and conduct experiments as well as interpret data (STEM)
2. Students will have an ability to function on multi-disciplinary teams (STEM)
3. Students will have an ability to communicate effectively (STEM)

National Math Standards NCTM

Standard 4: Measurement (STEM)

a. Understand measurable attributes of objects and the units, systems and the processes of measurement (STEM)

Standard 6: Problem Solving

a. Build new mathematical knowledge through problem solving (STEM)
b. Solve problems that arise in mathematics and in other contexts (STEM)
c. Apply and adapt a variety of appropriate strategies to solve problems (STEM)
d. Monitor and reflect on the process of mathematical problem solving (STEM)

Standard 8: Communications

a. Communicate their mathematical thinking coherently and clearly to peers, teachers and others (STEM)

Standard 10: Representation

a. Create and use representations to organize record, and communicate mathematical ideas (STEM)
b. Select, apply, and translate among mathematical representations to solve problems (STEM)