Climate Change and the BWCA Investigation

Course Description: Climate change is a big topic, and is affecting many species in our state. The Boundary Waters is especially vulnerable to climate change as it lies in the Boreal Forest, our northernmost ecosystem and full of iconic Minnesota species such as the moose. In this interactive investigation, students will gather evidence on current trends in the Boundary Waters moose population, and investigate how these changes are tied to emissions predictions for the future. Following the investigation, students will create a Climate Action Plan to brainstorm changes they can make to influence our emissions future!

This curriculum was created as part of the No Boundaries to the Boundaries Program. No Boundaries to the Boundary Waters is an educational program of Friends of the Boundary Waters. No Boundaries to the Boundary Waters connects students to the wilderness through canoe trips, classroom visits, and curriculum resources. Our aim is to provide the means and opportunity for diverse and underserved students to access the Boundary Waters.

Have you used our curriculum? Please consider filling out our feedback survey. Survey responses help us to track curriculum use, improve curriculum, and do critical grant reporting to help keep access to curriculum free! You can fill out the survey HERE.

Guiding Question: What is the effect of climate change on moose populations in the BWCA?

Objectives:

- SWBAT compare and contrast Saint Paul, MN and Boundary Waters ecosystems
- SWBAT predict how moose populations will change in response to climate change using climate data and Minnesota flora/fauna data.
- SWBAT describe relationships between moose and deer populations.
- SWBAT write a scientific claim describing one effect of climate change on moose populations in the BWCA.
- SWBAT compare and contrast different climate change management plans.

Standards:

- 6E.1.1.1.3 Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. (P: 1, CC: 7, CI: ESS3)
- 7L.4.1.2.2 Evaluate competing design solutions for maintaining biodiversity or ecosystem services.* (P: 7, CC: 2, CI: LS2, ETS2)
- 9E.2.1.1.2 Analyze geoscience data to make a claim that one change to the Earth's surface can create feedbacks that cause changes to other Earth systems. (P: 4, CC: 7, CI: ESS2, ETS2)
- 9E.2.1.1.3 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems and human infrastructure.* (P: 4, CC: 7, ESS3, ETS1)
- 9E.3.2.2.1 Evaluate or refine a technological solution to reduce the human impacts on a natural system and base the evaluations or refinements on evidence and analysis of pertinent data.* (P: 6, CC: 7, CI: ESS3, ETS1, ETS2)
- 9E.4.2.2.1 Apply place-based evidence, including those from Minnesota American Indian Tribes and communities and other cultures, to construct an explanation of how a warming climate impacts the hydrosphere, geosphere, biosphere, or atmosphere. (P: 8, CC: 4, CI: ESS3)
- 9L.4.2.2.1 Obtain and communicate information about how Minnesota American Indian Tribes and communities and other cultures construct solutions to mitigate threats to biodiversity.* (P: 8, CC: 7, CI: LS2, ETS1)

Roadmap/How to Use this Resource: This curriculum is designed as a series of 5 lessons; however, it is flexible and can be adapted to fit different class schedules and student needs. Use the options below to help plan your lessons. After teaching the lesson, please fill out our feedback survey. This helps us track participant use and improve these lessons for future use! You can fill out the survey **here.**

Staff visit: The curriculum includes the opportunity for a field day with staff from Friends of the Boundary Waters, depending on location and availability. Please reach out to us at education@friends-bwca.org for support on how to implement and modify these lessons and for further information on a field day experience.

Option 1: One Class Period

- *Recommended Lesson*
    - Lesson 4: Climate Change Effects on Moose Data Dig *(this lesson is designed to work as a stand-alone activity, with the other lessons helping to prepare students and extend their thinking)*

Option 2: 1-2 Class Periods

- *Recommended Lessons without a Friends of the Boundary Waters Staff Visit:*
    - Day 1: Lesson 4- Climate Change Effects on Moose Data Dig
    - Day 2: Lesson 5- Addressing Climate Change in the BWCA
- *Recommended Lessons with a Friends of the Boundary Waters Staff Visit:*
    - Day 1: Lesson 2- Boundary Waters Biomes (Led by No Boundaries Staff)
    - Day 2: Lesson 4 - Climate Change Effects on Moose Data Dig

Option 3: 3-4 Class Periods

- *Recommended Lessons:*
    - Day 1: Lesson 3 - Moose and the Boreal Forest
    - Day 2: Lesson 4- Climate Change Effects on Moose Data Dig
    - Day 3: Lesson 5- Addressing Climate Change

Option 4: 4-5 Class Periods

- *Recommended Lessons:*
    - Day 1: Lesson 1- Getting your Feet Wet: An Introduction to the Boundary Waters
    - Day 2: Lesson 2 -Boundary Waters Biomes (optional: Friends of the Boundary Waters staff visit)
    - Day 3: Lesson 3 - Moose and the Boreal Forest
    - Day 4: Lesson 4- Climate Change Effects on Moose Data Dig
    - Day 5: Lesson 5- Addressing Climate Change

Grade Level Recommendations:

- *Grades 6-8*: Use the included fact sheets to support research components of the curriculum. Sentence stems are also included to support learners.

- *Grades 9-12:* Students should conduct their own research and complete the extension activities. During lesson 4 there is an additional “puzzle” for high school students.

Block-Scheduling Recommendations:

- For Classrooms with block scheduling (60 minutes or longer) OR faster learners, the curriculum could be readjusted as follows:
    - Day 1: Lesson 1 (Getting your Feet Wet) and 2 (Boundary Water Biomes)
    - Day 2: Lesson 3 (Moose and the Boreal Forest) and 4 (Climate Change Effects on Moose Data Dig)
    - Day 3: Lesson 5 (Addressing Climate Change)

Curriculum Overview:

Lesson Sequence and Outlines	*Lesson Overview/Guiding Question*	*Materials*
1 Intro to BWCA	In this lesson, students work through an online interactive session independently or in small groups. This is a good introductory activity students can do on their own, or you can pick and choose the sections to do in a shortened or full class time period. We recommend the Anishinaabe Land, Observations, and a Day in the Life sections.	• "Get your Feet Wet" Storyboard
2 Boundary Waters Biomes	This lesson introduces students to the biomes of the Boundary Waters, in order to provide context for the rest of the investigation. Students learn about Minnesota's biomes before researching differences between boreal and deciduous forests. **This lesson can be supplemented with a Field Day led by Friends of the Boundary Waters staff.** During this lesson, students will: 1) Make observations of different forest types. 2) Compare and Contrast Deciduous and Boreal forest using guided research prompts 3) Brainstorm and reflect on why differences exist between biomes, and the impact of climate change on biomes. This lesson includes an extension activity where students can conduct a field study in their community to compare their local biome with that of the Boundary Waters.	Boundary Waters Biomes: • Lesson Outline • Slides • Student Handouts • Biome FactSheets • Extension Activity
3 Moose and the Boreal Forest	This lesson introduces the primary investigation question Why are moose populations in the BWCA Changing? Students will: 1) Review key features of boreal forest ecosystems that make up the BWCA. 2) Conduct independent (or small group) research on Moose in order to create a fact-sheet. 3) Compare historical moose population data in order to identify patterns in moose population size 4) Brainstorm possible causes of moose population change in the BWCA.	Moose Investigation PreLab • Lesson Outline • Lesson Slides • Student Handout • Moose Evidence Sheets • Moose Fact Sheet (optional)
4 (Climate Change Effects on Moose - Data Dig)	In this lesson, students explore a series of data sets in order to answer the question: What is causing moose populations in the BWCA to decline? Students will: • Review the evidence that moose populations are declining as a whole class. • Explore various evidence/data sets to solve a series of puzzles. During this step, students will interpret and create graphs, read/listen to climate scientists, interpret maps, and analyze historical data. • Use the evidence from their puzzles to write a scientific claim supported by evidence to answer the question: What is causing the moose population in the BWCA to decline and how is it linked to climate change?	Climate Change and Moose Data Dig: • Lesson Outline • Lesson Slides • Student Handout • Evidence Sheets
5 (Addressing Climate Change in the BWCA)	This is the final lesson in the climate-moose investigation series. In this lesson, students review the effects of climate change on the boundary waters before exploring different proposed solutions. Students will: 1) Review the effects of climate change on Moose populations and BWCA ecosystems. 2) Compare and contrast different proposed solutions to address climate change. 3) Make a management recommendation and defend it to their peers. This lesson includes a species risk assessment project in which students look at the effects of climate change on other boundary waters species. This could be used as a summative assessment for the unit.	Addressing Climate Change in the BWCA • Lesson Outline • Lesson Slides • Student Handouts • Climate Change Solution Sheets • Species Risk Assessment Project

Additional Resources: The following provide more information about the topics covered in this curriculum.

Video Resources:

- Climate Change and the Boundary Waters, presentation by Lee Frelich: https://www.youtube.com/watch?v=6GBNouPxpX0
- Brainworm and Moose: https://www.youtube.com/watch?v=QMEuvef7Lkw
- A Moose Mystery from the NYTimes: https://www.youtube.com/watch?v=rZ1YeBW8_EM&list=PLnC4yTjRBxQeDnfIW1Oxd2BlHnBKc4_bY&index=8

Moose and Climate Change Readings

- Researchers take a new approach to understanding a major source of Minnesota moose decline
- Minnesota Deer Management Plan
- Wilderness Conservation in an Era of Global Warming and Invasive Species: A Case Study from Minnesota's Boundary Waters Canoe Area Wilderness.

Climate Change and Boreal Forests Readings:

- Are Secondary Forests Ready for Climate Change? It Depends on Magnitude of Climate Change, Landscape Diversity and Ecosystem Legacies
- Forest adaptation strategies aimed at climate change: Assessing the performance of future climate-adapted tree species in a northern Minnesota pine ecosystem - ScienceDirect
- Climate Change and Minnesota's Forests: MN Senate Report
- Forest & Ecosystems | UMN Climate Adaptation Partnership.
- Climate Change Vulnerability Assessment Version 2 Great Lakes Indian Fish and Wildlife Commission
- An Ecosystem in Transition: The Boundary Waters in a Warming World

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Climate Change and the BWCA
Lesson 2: Boundary Waters Biomes
This is the 2nd lesson in the Climate Change and Moose Series; this lesson can either be teacher-led OR supported with a field experience led by Friends of the Boundary Waters Staff

Lesson Outline

Objectives:

- SWBAT define the term biome and list 2 examples
- SWBAT compare and contrast deciduous and boreal forests
- SWBAT identify 2 factors that affect biome formation

Materials:

- Lesson Slides
- Student Handout (print one copy for each student)
- Biome Fact-Sheets (Deciduous and Coniferous) (Optional resource: Students can conduct their own research in place of these resources if desired)
- Supplementary Materials:
    - Extension Activity: Community Biome Investigation
    - Biomes and the Boreal Forest Online Learning Module

Lesson Flow

1) *Complete this lesson after the "Getting Your Feet Wet" module*
2) *Lesson Introduction:*
    a) Remind students that they'll be learning about the Boundary Waters and how it is changing.
    b) Show students the map of the Boundary Waters and check-in on what they remember from the previous lesson
    c) Go over the lesson agenda:
        i) Make observations of Saint Paul (the capital of Minnesota) and Boundary Waters forests
        ii) Define Biomes and identify key features
        iii) Compare and Contrast Boundary Waters and Saint Paul Biomes
3) *Warm-up and Concept Introduction:*
    a) Show students 2 images of the Boundary Waters and Saint Paul forests, and have them work in small groups to compare and contrast the two images. Students will fill in responses on their own handouts before sharing out in small groups and then to the whole group. Possible guiding questions include:
        i) What type of trees do you notice?
        ii) Are there different colors in the two photos?
        iii) Which of these looks more familiar to you?

b) Provide students with the definition of a biome, and explain that the two forests from the previous slide represented different biomes. Biomes are determined by their physical environment. Have students brainstorm what this means. Be sure to clarify that physical environmental differences include climate and geology (abiotic factors).
c) Review the 4 major biomes found in Minnesota. In this lesson series, we'll explore differences between deciduous and coniferous (boreal) forests. After providing an overview of the 4 biomes, introduce the investigation.

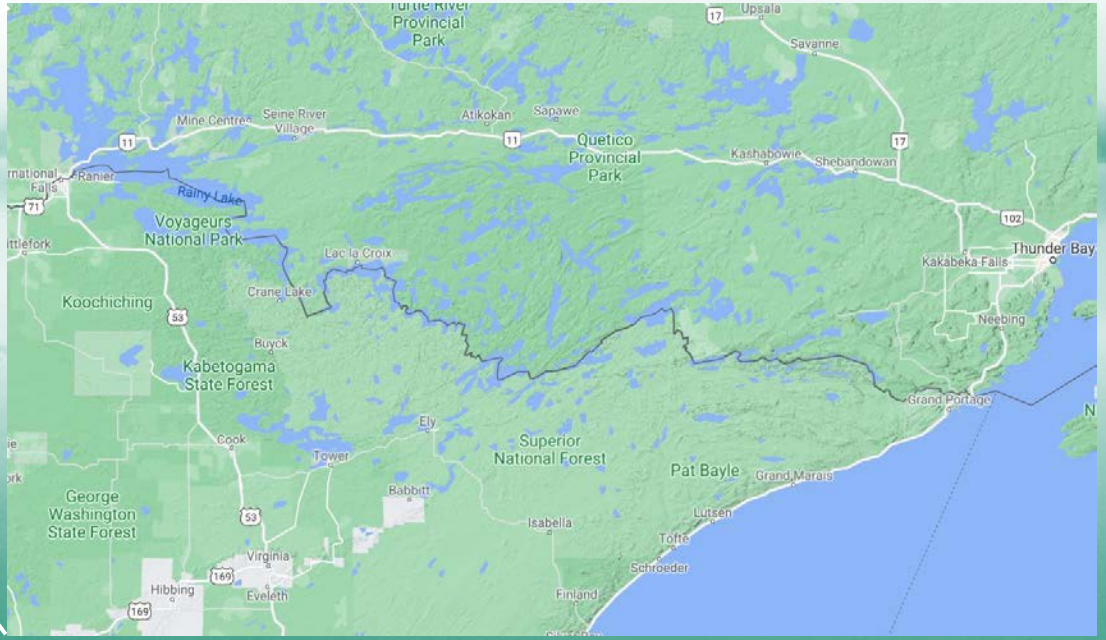
4) *Investigation: Comparing Deciduous and Coniferous (Boreal) Forests.*
   a) Clarify that the BWCA is primarily made up of Coniferous (Boreal) forests, and that today they'll compare that to deciduous forests found more commonly in central and southeastern Minnesota.
   b) Pass out "Biome Factsheets" to students
   c) Have students work in small groups to fill in the graphic organizer on their student handout (Optional: Have students conduct their own research in place of using the biome factsheets)
   d) Students brainstorm in small groups what physical characteristics might cause differences in the flora (plants) and fauna (animals) of these two biomes
   e) Have students share their findings from the investigation. Ask:
      i) What similarities and differences do you notice in the flora/fauna in these two biomes?
      ii) WHY do you think some species can survive in boreal forests but not in deciduous forests and vice-versa?
      iii) What factors do you think might be *most* important in determining what type of species are able to survive in a biome?
5) *Reflection and Closing*
   a) Remind students that biomes are determined by physical characteristics in their environments (climate and geology).
   b) Split students back into small groups to brainstorm and make predictions in their student handouts about what might happen if the physical characteristics of a biome change. Students talk in small groups and record their ideas on their student handout.
   c) Bring students back together to share out with the class, be sure to hear from a few students before wrapping-up the lesson.
   d) Remind students of the big takeaways from this lesson:
      i) Biomes are ecosystems formed in response to the physical environment.
      ii) Biomes are determined by their physical conditions (climate and geology)
      iii) Let students know that in the next lesson, we'll start exploring how changes to the physical environment (climate) can affect fauna like moose!
6) *Extension Activity: Community Biome Investigation*
   a) Students investigate the biome that makes up their local community.

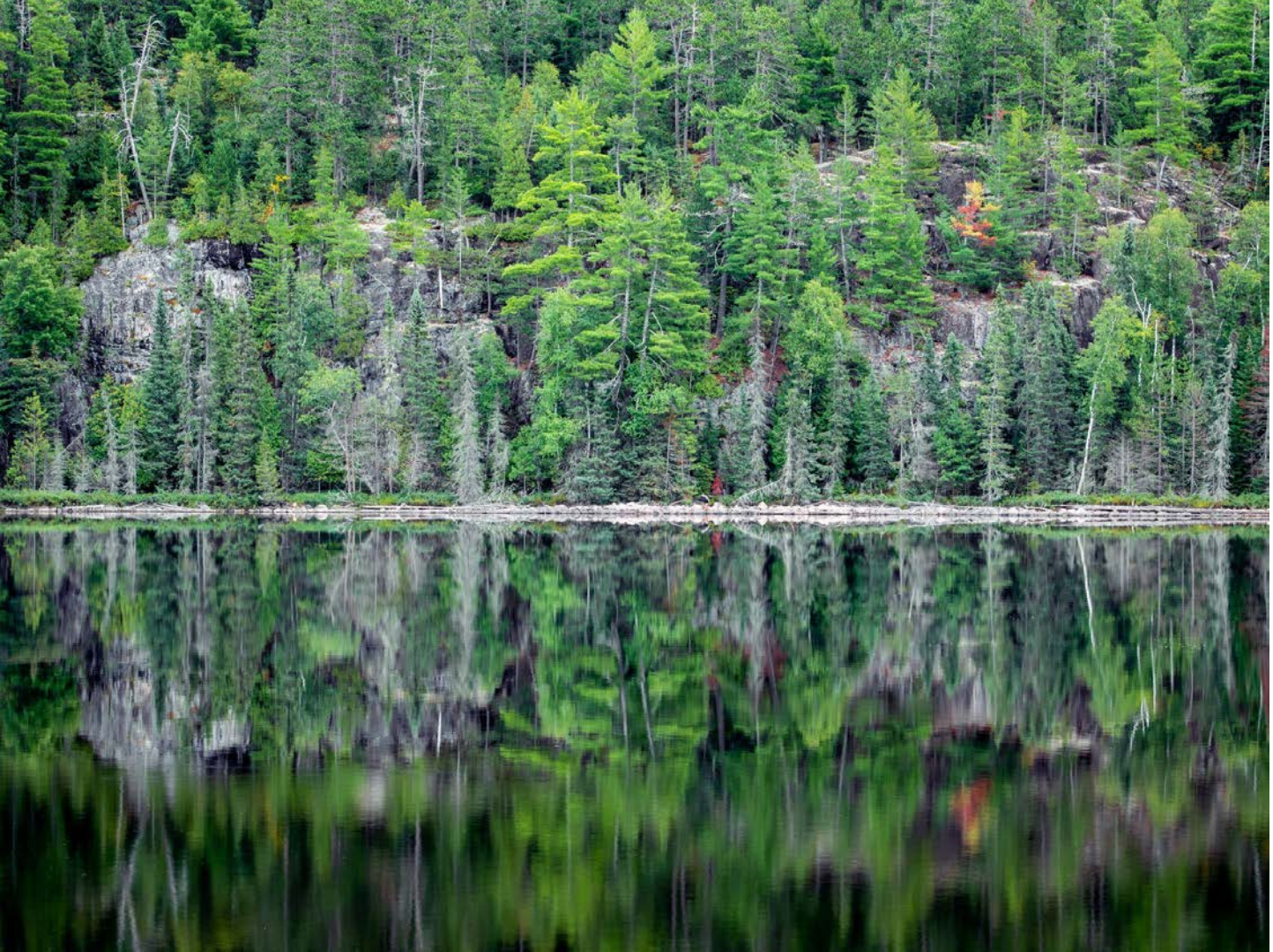
b) Students use a combination of observation and tree identification to determine what biome they live in.
c) Students end the investigation by comparing their local biome to that of the Boundary Waters and Saint Paul, MN.


FRIENDS OF THE
BOUNDARY
WATERS

The Boundary Waters is the region of wilderness separating Canada from the US between Ontario and Minnesota, west of Lake Superior.

The BWCA is 1.2 million acres, and 20% of it is water!





Check-in:

What do you remember about the BWCA? What might you see there?

Today we will:

1) Make observations of forests in the BWCA and Saint Paul, MN
2) Define the term Biome and identify key aspects of them
3) Compare/Contrast BWCA and Saint Paul Biomes

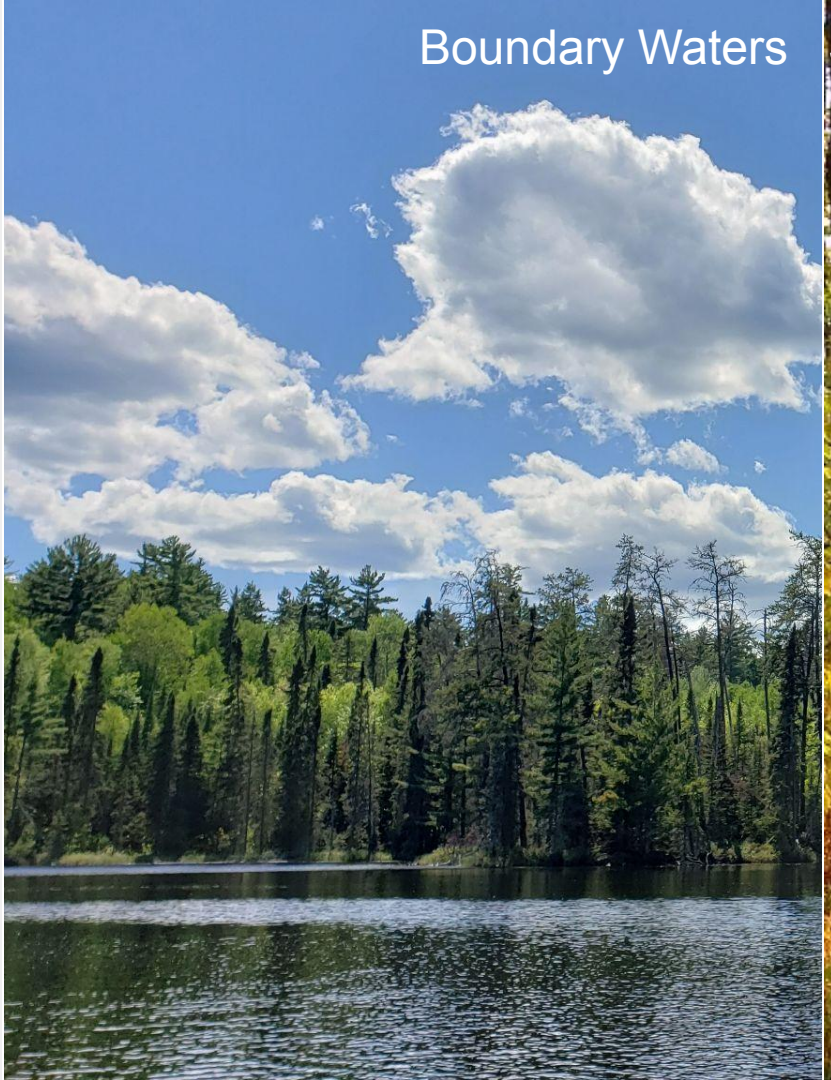
Both of these are forests in Minnesota. On the left is a photo from the BWCA, on the right is a photo from Saint Paul, MN.

As you look, record your observations in your handout:

1) What do you notice?

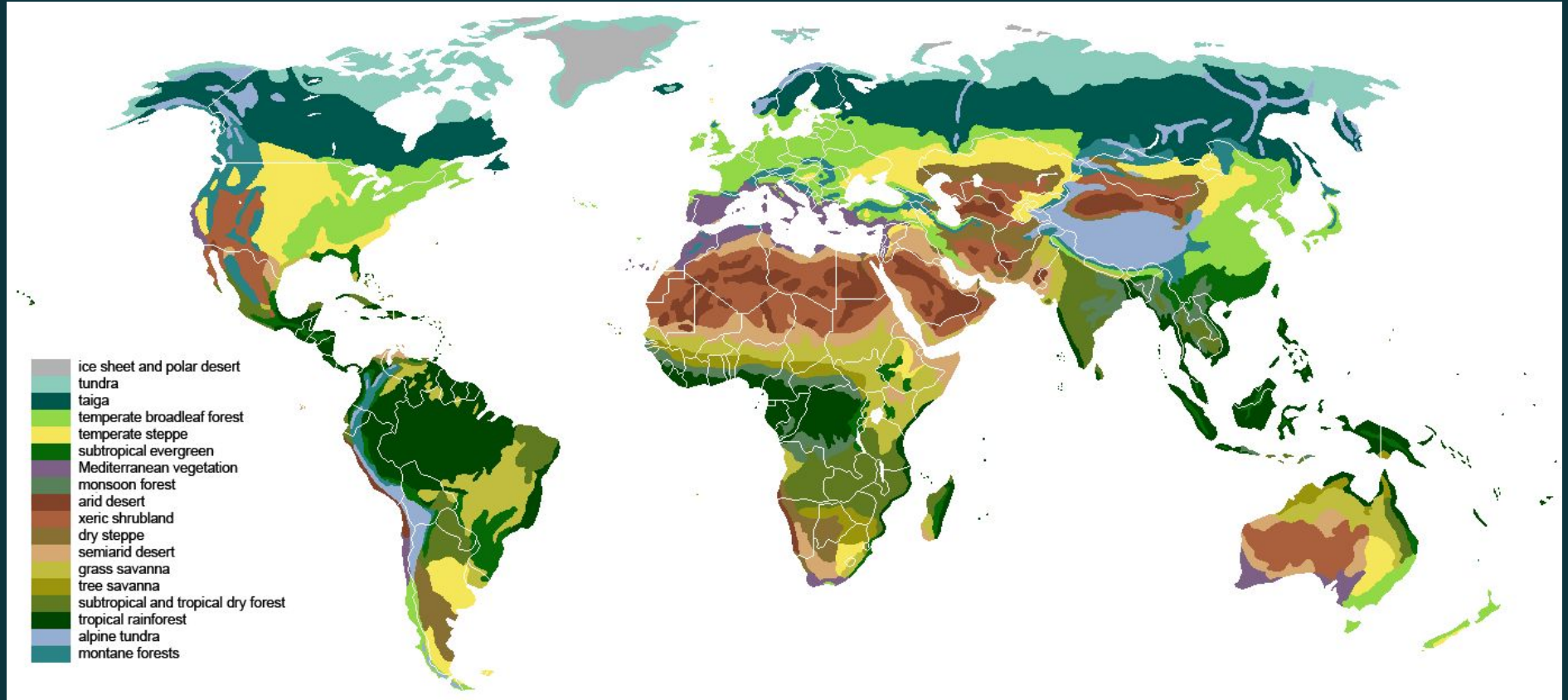
2) How are these forests similar? How are they different?

3) WHY might there be differences between these places?



Both of these forests are different **biomes**

Biome: An ecosystem formed in response to the physical environment. (Ex: Deciduous forest, rainforest, desert)



Minnesota has 4 unique Biomes

Deciduous Forest	Coniferous Forest	Prairie Grassland	Tallgrass Aspen
This biome is characterized by large deciduous forests or trees that lose their leaves at the end of a growing season. There is greater heat, humidity and moisture in this region.	This biome is characterized by coniferous trees, or trees with needles and cones. This biome is frequently affected by fire and storms.	This biome is characterized by large expanses of grasses. This biome features species well adapted to drier and warmer conditions.	This biome is characterized by deciduous trees intermixed with prairie land. The climate here is harsh - extreme winds, cold, and heat determine many of the species that survive here.
			

Where two biomes meet there is a **transitional zones** or **ecotone,** these areas have flora/fauna of more than one biome!

Dig-in: **Comparing Deciduous and Coniferous (Boreal) forests**

The BWCA is primarily made up of Coniferous (Boreal) forests! Use the fact sheets to compare how these forests are different from deciduous forests found in Saint Paul, Minnesota.

Directions:

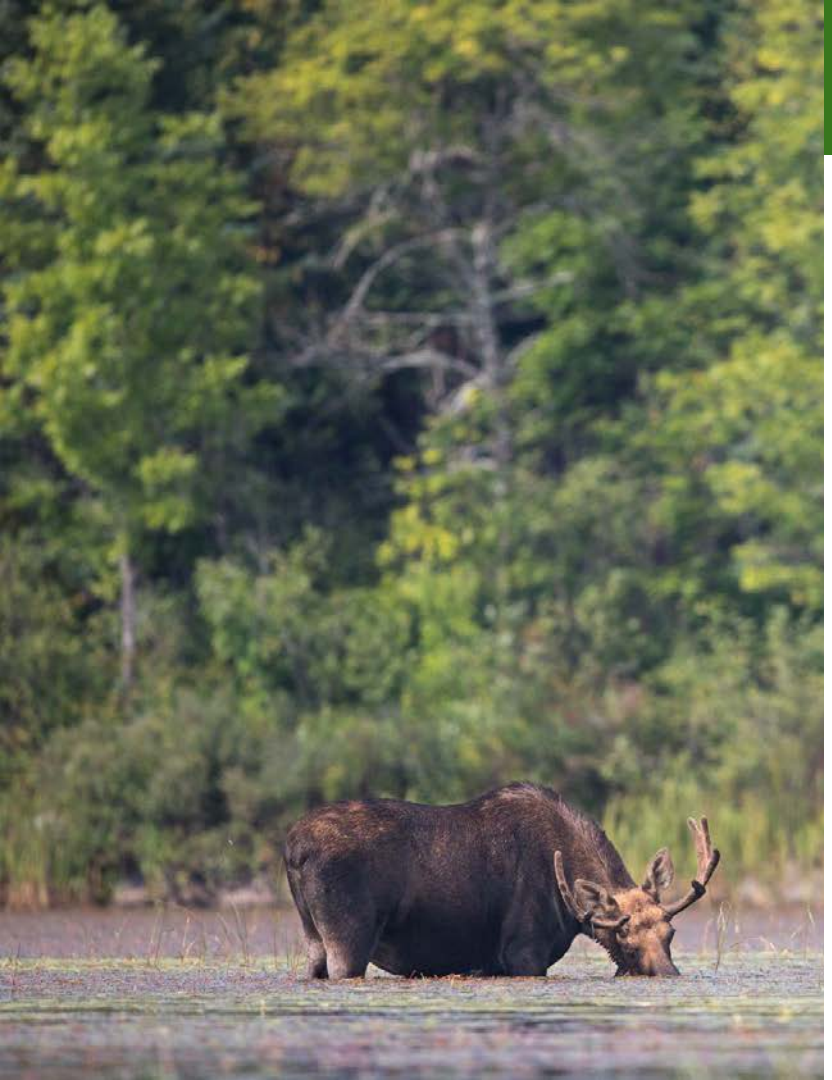
1) Collect a copy of the “Biome Factsheets”
2) Use the factsheets to fill in your graphic organizer
3) Work with a partner to brainstorm *why* these two biomes might have such different flora/fauna.

Share-out: **Comparing Deciduous and Coniferous (Boreal) forests**

1) What similarities and differences do you notice in the flora/fauna in these two biomes?

2) WHY do you think some species can survive in boreal forests but not in deciduous forests and vice-versa?

3) What factors do you think might be *most* important in determining what type of species are able to survive in a biome?



Reflect and Extend your Thinking

Biomes are determined by the ***physical*** features of an environment. These include:

1) Temperature patterns
2) Rain/Precipitation patterns
3) Geology: rock and soil types

Brainstorm: What happens if these physical features are changed?

- Work with your groups to make some predictions to the questions below. Record your answers on your student handout
  - How would changing climate (temperature and precipitation) affect a biome
  - Climate change is causing warmer annual temperatures in the BWCA: what type of changes would you expect to see?

Climate Change and BWCA

Lesson 2: Boundary Water Biomes Student Guide

Background Information: The BWCA is a region of wilderness in Northern Minnesota. It is 1.2 million acres, and 20% of the area is freshwater. The species that live in the boundary waters serve unique ecosystem functions and are also vulnerable to climate change. In this step of our investigation, you'll learn about who lives in the boundary waters and what makes this ecosystem so unique!

Warm-up: What do you remember about the BWCA (Boundary Waters)?

What do you remember about the BWCA? What might you see, hear, feel there? *Write or Draw your ideas in this box*

Observe: Look at the two photos. The one on the left is from the Boundary Waters, the one on the right is from Saint Paul. Record your observations in the table below

What do you notice about these two forests?	
Boundary Waters Forest Observations	*Saint Paul Forest Observations*
How are these forests similar? How are they different?	
WHY might there be differences between these two forests?	

FRIENDS OF THE BOUNDARY WATERS

Biome

Definition: _____

Examples of Biomes	**Factors that Determine Biomes**

Biomes Found in Minnesota

Transitional Zone/Ecotone: an area where two biomes meet. Much of Minnesota is made up of these! In a transitional zone you'll find flora/fauna from more than one biome

Dig-in: Use the fact sheets to complete the graphic organizer below, then brainstorm why you think deciduous and coniferous (boreal) forests might have such different flora and fauna

	Deciduous Forest	Coniferous (Boreal) Forest
Observations and Drawings		
Common Flora (Plants)		
Common Fauna (animals)		
Soil Depth and Type		
Average Summer Temperature		
Average Winter Temperature		
Average Summer Precipitation		
Average Winter Precipitation		

Reflect: Use the data from your graphic organizer to answer the reflection questions in the box below

1) What similarities and differences do you notice in the flora/fauna in these two biomes?

2) WHY do you think some species can survive in boreal forests but not in deciduous forests and vice-versa?

3) What factors do you think might be *most* important in determining what type of species are able to survive in a biome?

Reflect and Extend your thinking: In the box below, brainstorm what changes you would expect to see to a biome if the physical (abiotic) features are changed.

*Remember: Biomes are determined by the **physical** features of an environment. These include:*

1) *Temperature patterns*
2) *Rain/Precipitation patterns*
3) *Geology: rock and soil types*

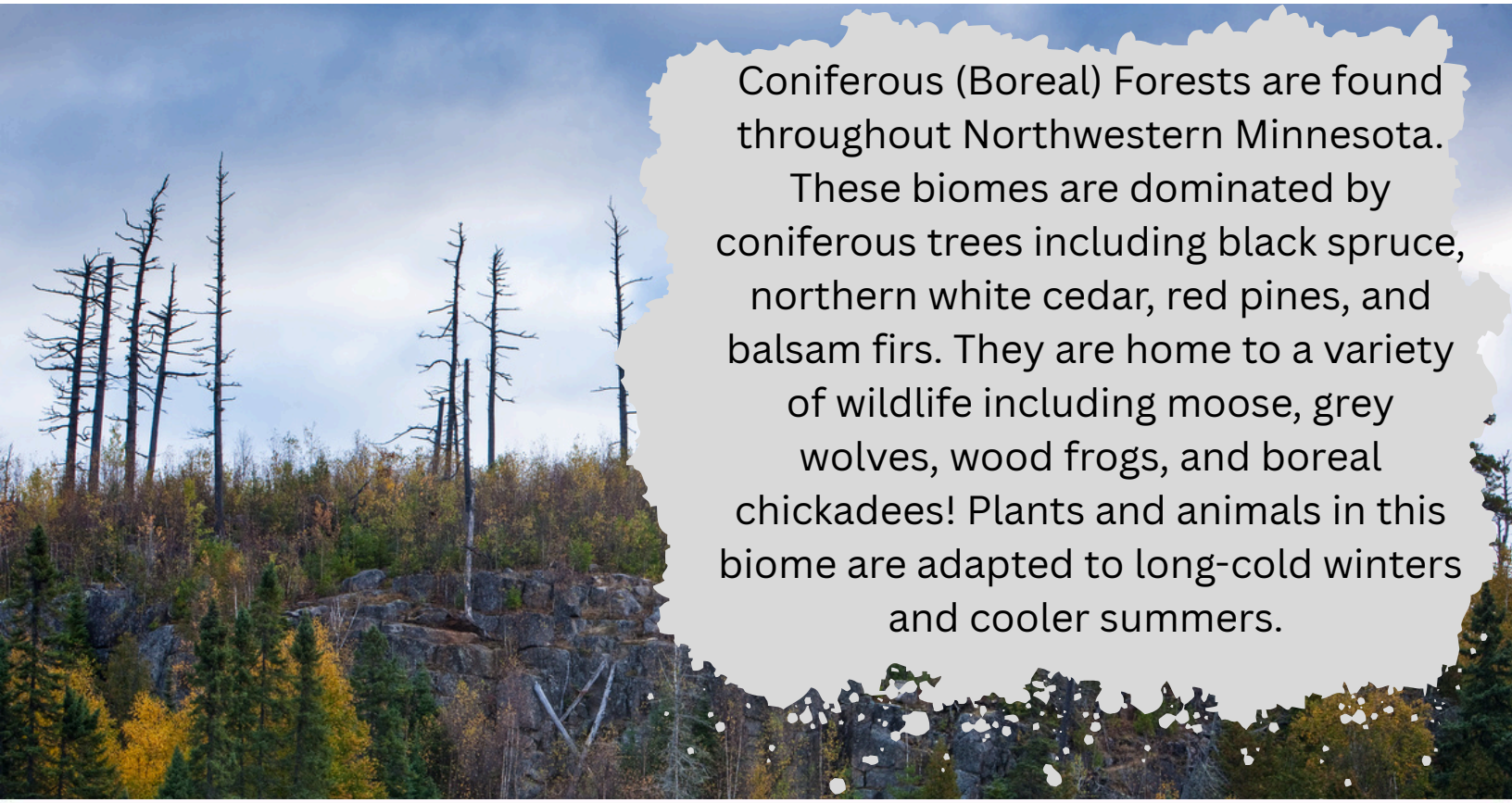
Brainstorm: What might happen to a biome if the physical features are changed?

- How would changing climate (temperature and precipitation) affect a biome

- Climate change is causing warmer annual temperatures in the BWCA: what type of changes would you expect to see?

BIOME FACTSHEET

BOREAL (CONIFEROUS) FOREST BIOME



Coniferous (Boreal) Forests are found throughout Northwestern Minnesota. These biomes are dominated by coniferous trees including black spruce, northern white cedar, red pines, and balsam firs. They are home to a variety of wildlife including moose, grey wolves, wood frogs, and boreal chickadees! Plants and animals in this biome are adapted to long-cold winters and cooler summers.

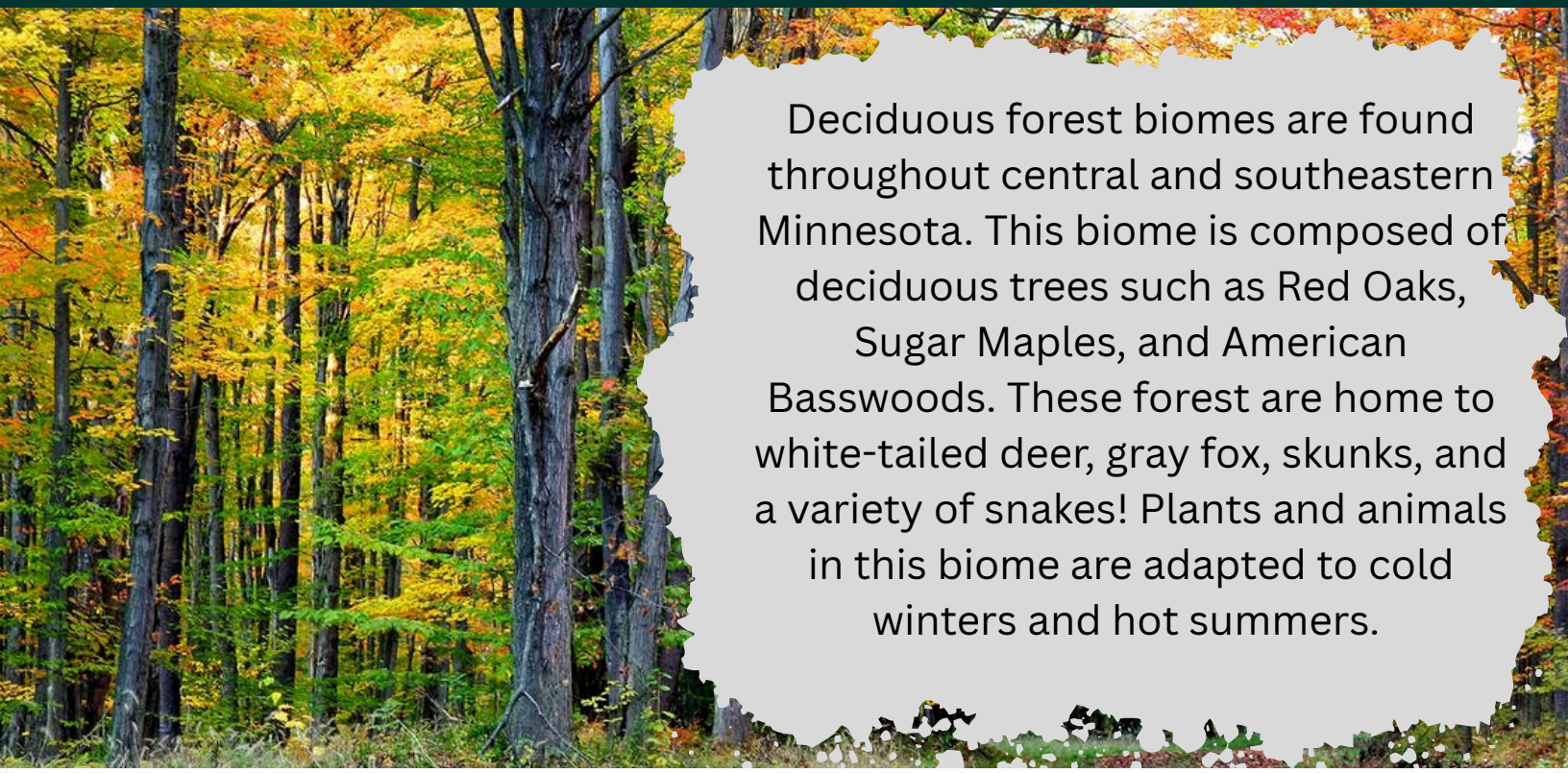
BOREAL (CONIFEROUS) BIOMES FAST FACTS

AVERAGE SUMMER TEMPERATURE (°F)	AVERAGE WINTER TEMPERATURE (°F)	AVERAGE SUMMER PRECIPITATION	AVERAGE WINTER PRECIPITATION	SOIL TYPE	GROWING SEASON LENGTH	VEGETATION EXAMPLES	ANIMAL EXAMPLES
50-68°F	-65 - 32°F	10-20 INCHES	20-40 INCHES	THIN, ACIDIC, AND NUTRIENT-POOR SOILS. TYPICALLY SOILS ARE AT LEAST 3 FEET DEEP	90-100 DAYS	• BLACK SPRUCE • NORTHERN WHITE CEDAR • BALSAM FIR • RED PINE • FLY HONEYSUCKLE	• WOOD FROG • BOREAL CHICKADEE • COMPTON'S TORTOISESHELL BUTTERFLY • GRAY WOLF • MOOSE

FRIENDS OF THE BOUNDARY WATERS

BIOME FACTSHEET

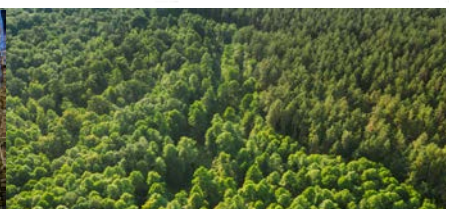
DECIDUOUS FOREST BIOME



Deciduous forest biomes are found throughout central and southeastern Minnesota. This biome is composed of deciduous trees such as Red Oaks, Sugar Maples, and American Basswoods. These forest are home to white-tailed deer, gray fox, skunks, and a variety of snakes! Plants and animals in this biome are adapted to cold winters and hot summers.

DECIDUOUS BIOMES FAST FACTS

AVERAGE SUMMER TEMPERATURE (°F)	AVERAGE WINTER TEMPERATURE (°F)	AVERAGE SUMMER PRECIPITATION	AVERAGE WINTER PRECIPITATION	SOIL TYPE	GROWING SEASON LENGTH	VEGETATION EXAMPLES	ANIMAL EXAMPLES
77-86 °F	14-32 °F	30-60 INCHES	30-60 INCHES	RICH, LOAMY, DARK SOILS WITH LOTS OF ORGANIC MATTER. TYPICALLY 12-40 INCHES IN DEPTH	100-130 DAYS	• NORTHERN RED OAK • AMERICAN BASSWOOD • SUGAR MAPLE • PRICKLY GOOSEBERRY • RUE ANEMONE	• EASTERN HOGNOSE SNAKE • CERULEAN WARBLER • EASTERN PIPISTRELLE BAT • GRAY FOX • EASTERN SPOTTED SKUNK • WHITE-TAILED DEER



FRIENDS OF THE BOUNDARY WATERS

Climate Change and BWCA
Lesson 2: Boundary Waters Biomes Extension Activity: Community Biome Investigation

Background Information: Biomes are ecosystems that form in response to their physical environment. This means that temperature patterns, precipitation patterns, soil type, and rocks all play a huge role in determining what type of plants and animals can live in an area. Saint Paul, Minnesota (Minnesota's state capital) is predominantly Deciduous Forest. In contrast, the Boundary Waters is coniferous (boreal) forest. This means the two areas have very different plant and animal life. *In this investigation, you'll compare your community to these two areas to better understand how the physical environment is related to the flora and fauna in a region.*

Your Task: Follow the steps below to investigate your local biome, then compare your biome to the Boundary Waters and Saint Paul, MN.

Step 1: Community Observations

Directions: Choose a spot in your community (near your home or school) that you can sit quietly outside. Sit and observe the space for at least 5 minutes. Record your observations in the box below. Record: plants and animals that you see, observations about the weather, what the ground looks like, what type of building or other landmarks are around you.

Write/Draw your observations in this box

Step 2: Tree ID

Identifying the flora (plants) in an area is one way that we can determine the biome that we are in. To do this, you need to:

1) Watch the BWCA Tree Identification Video to learn about how to identify coniferous trees
2) Use the dichotomous key to identify at least 5 trees in your community.
3) Record your results in the data table below.

Sample #	Location of Tree	Observations and Sketch	Type of Tree
1			
2			
3			
4			
5			

Step 3: Community Biome Research

Directions: We classify a region as a particular biome based on the plants and animals that live there *and* the physical characteristics. In this step, you'll research the physical characteristics of your community.

1) Use the websites listed below and any additional resources you like to fill out the table below.
    a) Climate Related Data: https://www.usclimatedata.com/
    b) Regional Flora (plant) Database: https://tinyurl.com/f6zb7wed
    c) Regional Fauna (animals) Database: https://mol.org/dashboard/regions
    d) Overview of North American Biomes: https://tinyurl.com/bdd6jy37
2) Use your table, tree identification, and observations to write a claim describing the biome you live in.

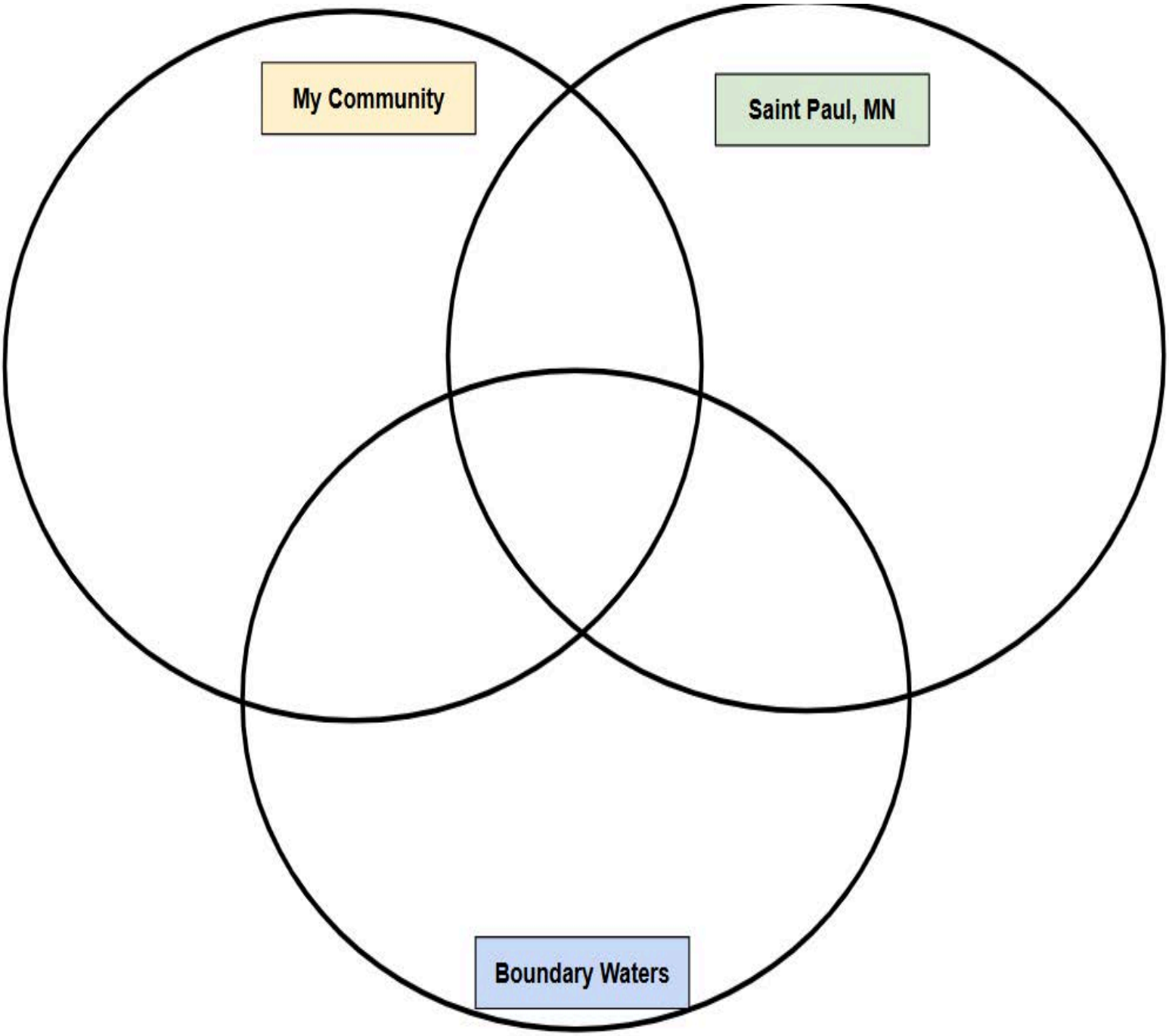
Characteristics of my Local Biome	
Location (where do you live?)	
Common Flora (Plants)	
Common Fauna (animals)	
Average Soil Depth and Type	
Average Summer Temperature	
Average Winter Temperature	
Average Summer Precipitation	
Average Winter Precipitation	

Draw a Conclusion: Based on your table, tree identification, and observations write a claim describing the biome you live in. Support your claim with at least 2 pieces of evidence!

Write your claim and evidence in this box

Step 5: Compare your Biome

Directions: Use your research from above and your biome investigation to fill out the venn diagram. Use the venn diagram to answer the reflection questions on the next page.



Reflection Questions:

1) What differences do you notice between these three regions? *Why* do you think these differences exist?

2) What similarities do you notice between these three regions? *Why* do you think those similarities might exist?

3) Based on your research, what factors determine the biome that makes up a region?

4) Draw a conclusion: based on your research, how is the physical environment (climate/geology) related to the flora and fauna in a region?

Climate Change and BWCA
Lesson 3: Moose and the Boreal Forest
This is the 3rd lesson in the Climate Change and Moose Series, this lesson is intended to be teacher-led in the classroom

Lesson Outline

Objectives:

- SWBAT identify 2 species found in boreal forests
- SWBAT describe 3 adaptations of moose to boreal forests
- SWBAT describe changes to moose populations in the BWCA
- SWBAT make predictions about the cause of moose population change in the BWCA

Materials:

- Lesson Slides
- Student Handouts (print one copy for each student)
- Evidence A and B Sheets (print one copy for each student group)
- Moose Fact Sheet (optional) (print one copy for each student group if using)

Lesson Flow

1) *Complete this lesson after the "Boundary Water Biomes" module*
2) *Lesson Introduction and Set-up*
    a) Review with students what the BWCA is and where it is found
    b) Have students brainstorm/reflect on what they remember from the last lesson:
        i) Guiding question: What is a biome? What type of biome makes up the BWCA? What type of flora/fauna would you expect to find there?
    c) Go over schedule for the day:
        i) Review Biomes
        ii) Research Moose
        iii) Look at Moose population Data
        iv) Write hypotheses/predictions about cause of moose population decline
3) *Biome Review:*
    a) Review the definition of a biome with students – emphasize that biomes are determined by their physical (abiotic) features: temperature, soil type, elevation, precipitation
    b) Review the 4 biomes found in Minnesota, let students know that today we will be focusing on coniferous (boreal) forests.
    c) Review key characteristics of Boreal (coniferous) forest biomes. This is the type of biome that makes up the BWCA
4) *Introduce Case Study:*
    a) Review some of the major flora and fauna found in boreal forests with students, before telling them that today we will be focusing in on moose

b) Let students know that moose are considered a keystone species in boreal forests. Have them brainstorm out ideas about what that might mean before introducing the activity

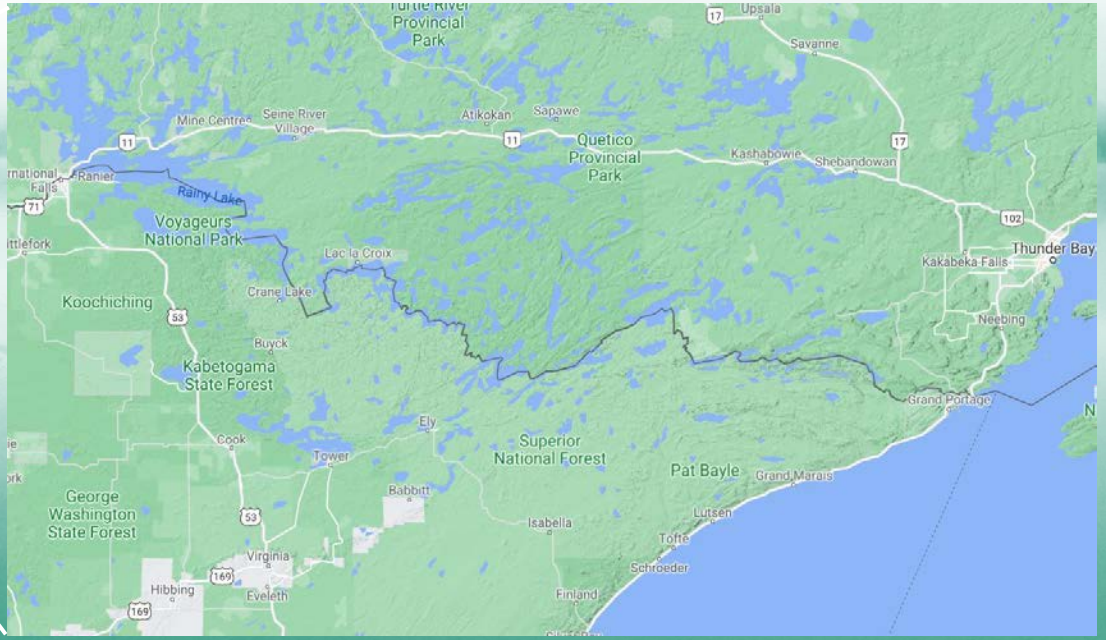
5) *Student Investigation:*
   a) Pass out copies of the "moose investigation student handout" and "moose fact-sheet"[1] to students.
   b) Students use the fact sheet, or conduct independent research, in order to fill in their moose fact sheet
   c) After students have filled in their fact sheet pass out copies of "Evidence A" and "Evidence B"
   d) Students look at the evidence sheets in order to determine how we calculate moose populations. Then, they graph population estimates of moose over time to identify changes in population size. Finally, they look at distribution maps to identify how the distribution of moose is changing.
   e) Students end their investigation by using population data and their research to identify 3 possible causes of moose population decline.
   f) Have students share their ideas before wrapping up the class period. In the next lesson, students will look at evidence to support or refute their predictions.

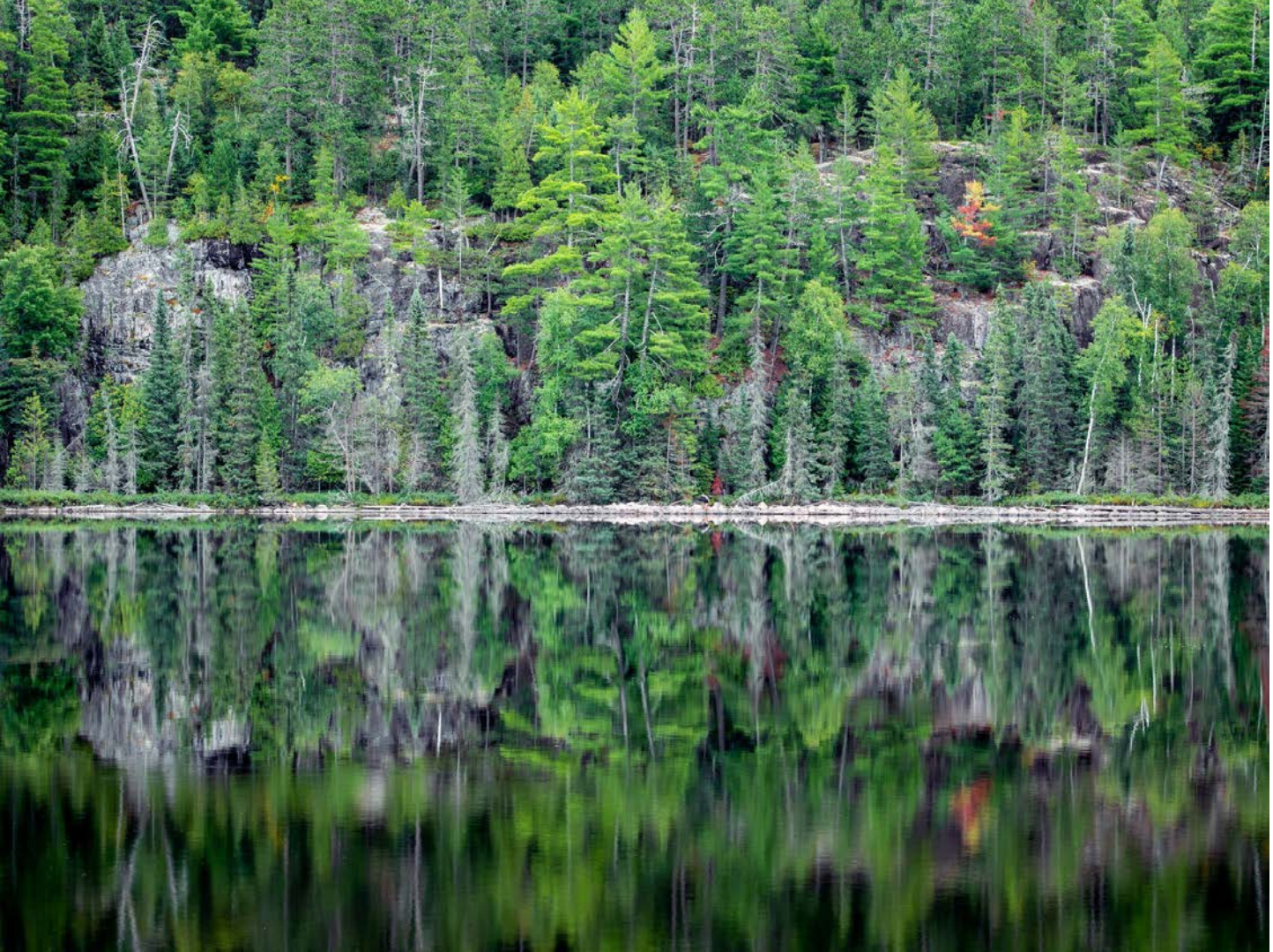
[1] Optional: for high school/more advanced students have them conduct their own research in place of using the fact sheets. Be sure to have students cite their sources if conducting their own research. DNR Moose Page is a great resource.


FRIENDS OF THE
BOUNDARY
WATERS

The Boundary Waters is the region of wilderness separating Canada from the US between Ontario and Minnesota, west of Lake Superior.

The BWCA is 1.2 million acres, and 20% of it is water!





Check-in:

What type of *biome* is the Boundary Waters?

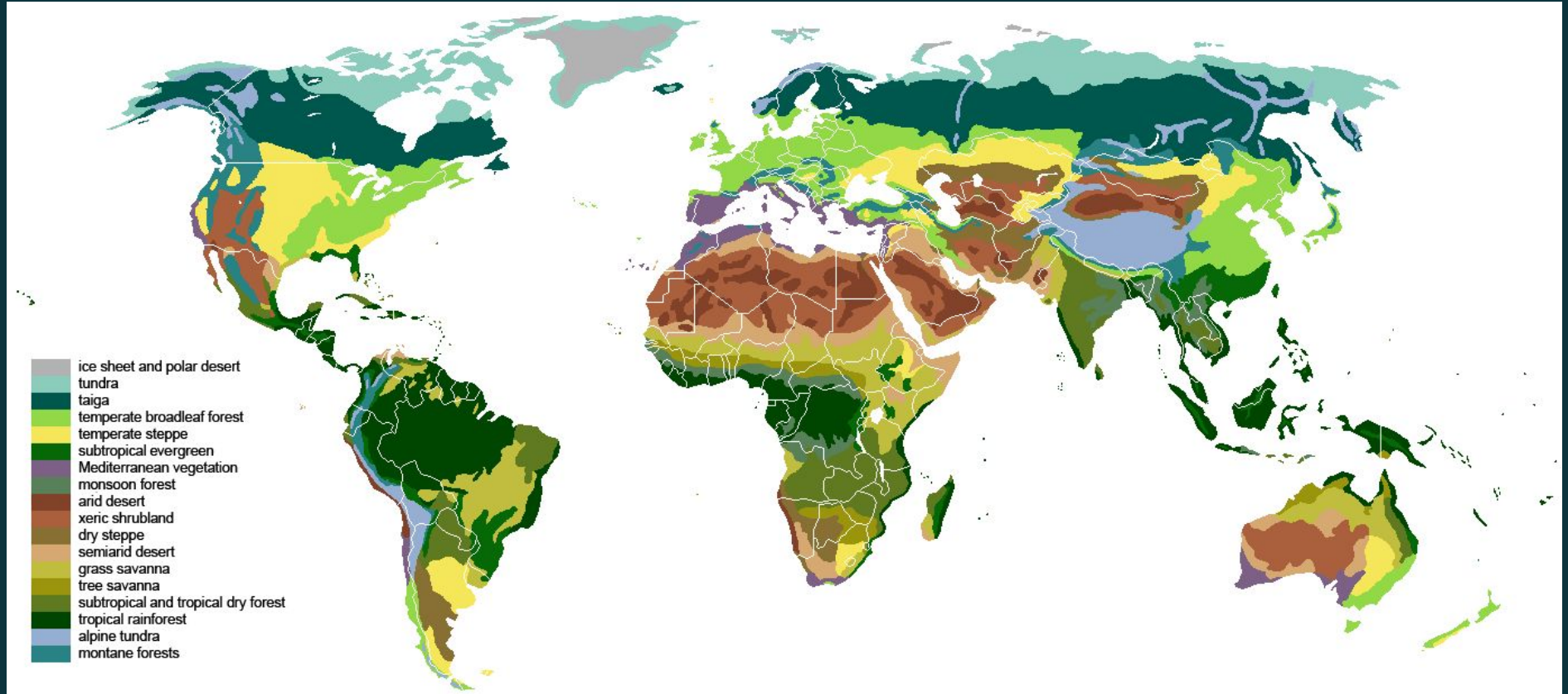
What does that mean in terms of its climate and flora/fauna?

Today we will:

1) Review Biomes
2) Conduct research on Moose
3) Look at moose population data
4) Brainstorm possible causes of moose population change

Biome: an ecosystem formed in response to the physical environment

Temperature, Precipitation, Soil Type, and Elevation can all affect the type of biome in an area!



Minnesota has 4 unique Biomes

- **Deciduous Forest:** This biome is characterized by large deciduous forests (trees that lose their leaves at the end of a growing season). There is greater heat, humidity and moisture in this region.
- **Coniferous Forest:** This biome is characterized by coniferous trees (trees with needles and cones). This biome is frequently affected by fire and storms.
- **Prairie Grasslands :** This biome is characterized by large expanses of grasses. This biome features species well adapted to drier and warmer conditions.
- **Tallgrass Aspen:**This biome is characterized by deciduous trees intermixed with prairie land. The climate here is harsh - extreme winds, cold, and heat determine many of the species that survive here.

The BWCA is primarily **Boreal (Coniferous) Forest** biome

- Short, moist summers, long dry winters
- Temperature Range: -65 - 86F
- Thin, Acidic Soils (nutrient poor)
- Dominated by coniferous trees (spruce, fir, pine, and larch)

Photo: Thomas Spence

The Boreal (Coniferous) forest is home to a variety of plants and animals, and has complex species interactions

Coniferous (Boreal) forests are home to a large variety of animals. Including:

- Moose
- Grey Wolves
- Black Bears
- Lynx
- River Otters
- Squirrels
- Chipmunks

Coniferous trees dominate these forests! Common flora include:

- Red pine
- Eastern White Pine
- Jack pine
- Birch
- Balsam Fir
- Wild raspberries, blueberries, and strawberries!

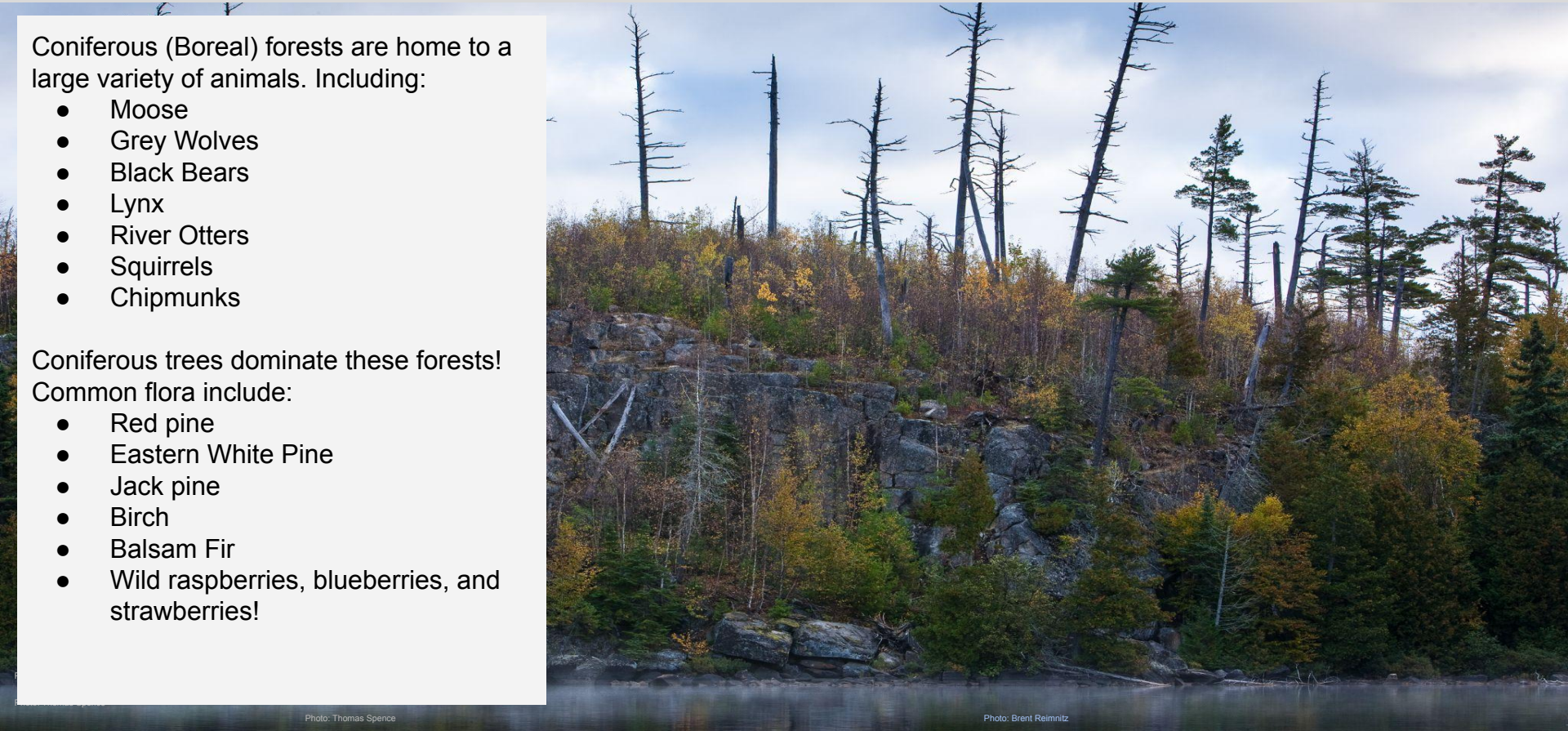


Photo: Thomas Spence

Photo: Brent Reimnitz

Dig-in: **Moose Investigation**

Moose are considered a keystone species in the Boundary Waters. This means that they play an important role in keeping the ecosystem stable, and can be an indicator for the overall health of the Boundary Waters. Since the mid-2000s we've been seeing changes to the moose population, today you'll start investigating why!

Directions:

1) Collect a copy of "Moose Fact Sheet"
2) Use the factsheet to fill in your graphic organizer
3) Look at Evidence A and B to learn more about how moose populations are changing, and create a graph of changing population sizes
4) Work with your group to brainstorm 3 possible reasons for the changes to Minnesota's moose population.

Climate Change and BWCA

Lesson 3: Moose and the Boreal Forest Student Guide

Background Information: Minnesota's moose population has declined about 60% since the mid-2000s[1] and researchers want to know *why*! In this investigation, you'll use data from the MN DNR (Department of Natural Resources) and citizen scientists to figure out why Minnesota's moose population is decreasing, and what we can do about it. In this lesson, you will:

1) Conduct research on Moose to identify possible threats
2) Look at the data to see how we know the populations are declining and look for patterns
3) Brainstorm possible causes of the moose decline

Step 1: Research Moose basics

Directions: Use the fact sheet to complete the graphic organizer below.

Common Name: Moose *Anishinaabemowin Name: mooz* *Scientific Name: Alces alces*	
Physical Description and Photo/Drawing	
Diet (What do they eat)	
Typical Life Span (How long do they live)	
Habitat Information (*Where* do they live)	

[1] https://www.mprnews.org/story/2025/03/03/minnesoas-2025-moose-population-stable-but-theyre-not-out-of-the-woods

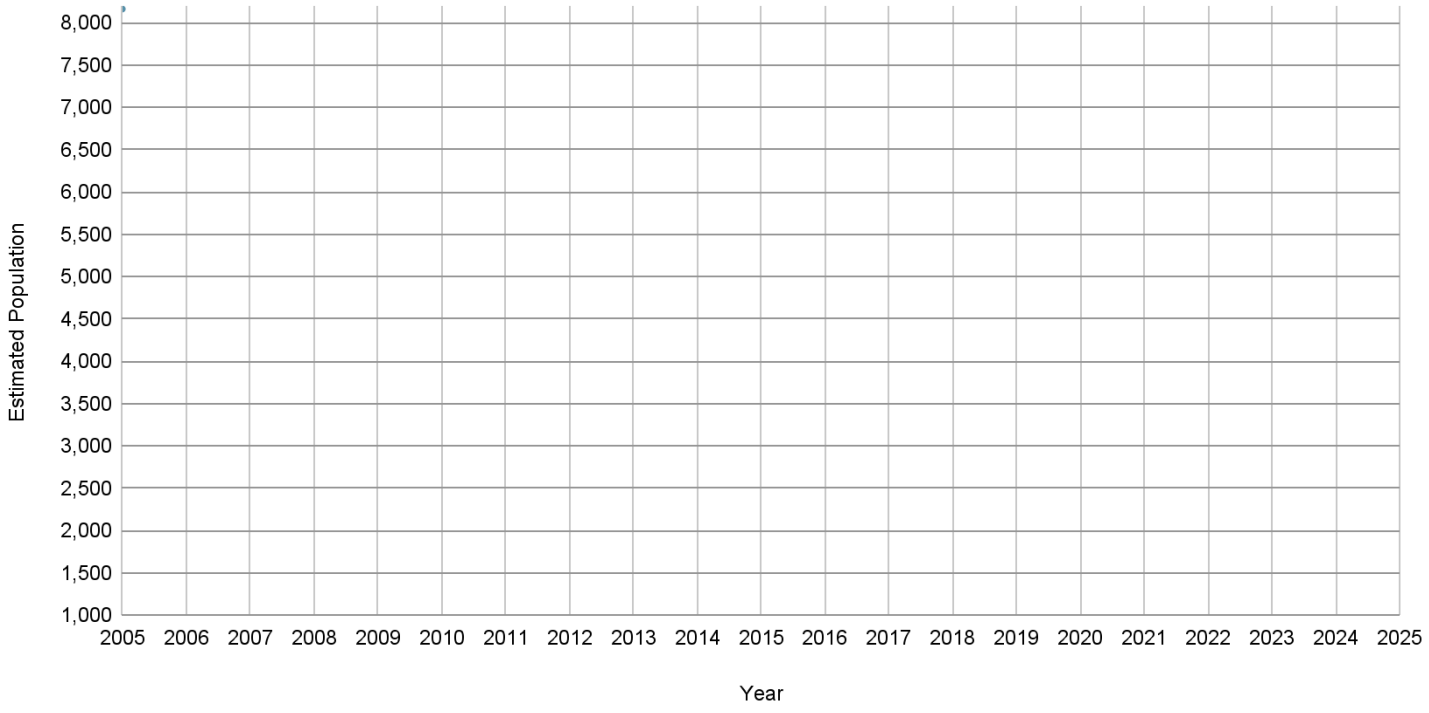
Adaptations (What special features help them survive)	
Predators (Who eats them?)	
Threats/Challenges	

Step 2: How is Minnesota's Moose population changing?
Directions: Use Evidence A and B to answer the questions below and make your predictions

1) Watch the video in Evidence A, then use the population data to create a line graph showing the change in moose population over time.

Estimated Moose Population 2005-2025

Source: DNR 2025 Aerial Moose Survey



2) How is the size of Minnesota's moose population changing? What patterns do you see in the aerial survey data?

3) Look at Evidence B: What patterns do you notice in the range of Minnesota's moose distribution? (How is it changing over time?)

4) Use your research and evidence A and B to predict some possible causes of moose population change. (We'll look at more data in the next step). *Feeling stuck? Think about what moose eat, predators, and their habitat.*

My Predictions	
Cause	Explanation

Evidence A: Moose Aerial Surveys

Each year the size of the moose population in northeastern Minnesota is estimated via an **aerial survey**. This survey is a collaboration between the Minnesota Department of Natural Resources (MN DNR), the Fond du Lac Band of Lake Superior Chippewa, and the 1854 Treaty Authority (and inter-tribal agency governed by the Bois Forte Band of Chippewa and Grand Portage Band of Lake Superior Chippewa).

CLICK HERE to see how aerial survey data is collected OR scan the QR Code on the right

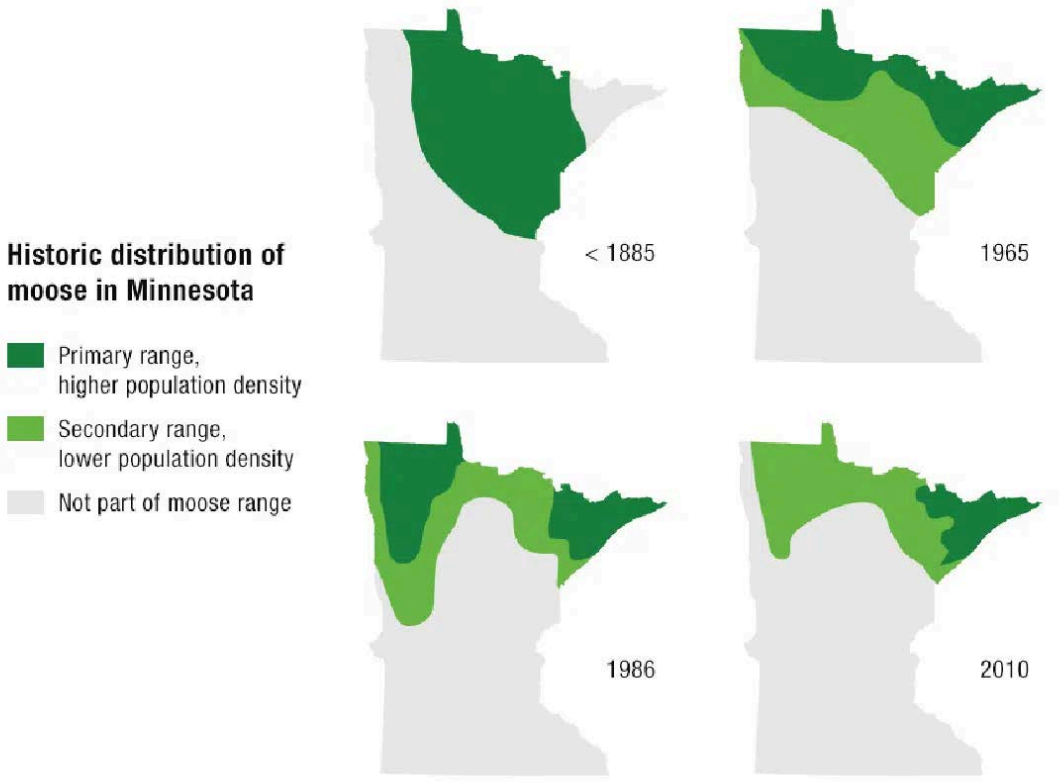
Aerial Moose Count Data 2005-2025

no data collected in 2021 due to covid-19

*Source: DNR 2025 Aerial Moose Survey

Year	*Population Estimate*
2005	8,160
2006	8,840
2007	6,860
2008	7,890
2009	7,840
2010	5,700
2011	4,900
2012	4,230
2013	2,760
2014	4,350
2015	3,450
2016	4,020
2017	3,710
2018	3,030
2019	4,180
2020	3,150
2022	4,700
2023	3,290
2024	3,470
2025	4,040

Evidence B: Historic Moose Distribution Maps



Source: https://queticosuperior.org/minnesota-dnr-survey-indicates-stable-moose-population/

FRIENDS OF THE BOUNDARY WATERS

MOOSE

mooz (Anishinabbemowin language)

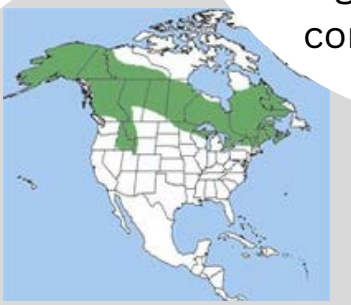
Alces alces (Scientific Name)

Moose in Decline?

Since the mid-2000s, moose populations in Minnesota have declined by ~60%. Habitat Loss, Parasites, and Climate Change have all been major contributors to this!

Fast Facts

- **Size:**
  - 6-7 feet tall
  - Average 950-1,000 pounds!
- **Lifespan:** 15-25 years
- **Diet**: Moose are herbivores that mostly eat the leaves and twigs of woody plants. Prefer willow, aspen, birch, maple, pin cherry, and mountain ash
- **Predators:** wolves are the main predator of moose, bears have been known to prey on moose.



Range and Habitat

Moose live in boreal (coniferous) forests. They prefer young forests where they can easily find food. Moose are often found on the shores of lakes and ponds especially in spring. Their thick fur limit them to colder climates, and they can experience heat stress at temperatures above 57F.

Moose are adapted for the Boreal Forest!

Climate Change and BWCA
Lesson 4: Climate Change and Moose Data Dig
This is the 4th lesson in the Climate Change and Moose Series, this lesson is intended to be teacher-led in the classroom

Lesson Outline

Objectives:

- SWBAT describe relationships between environmental change and species distribution in the BWCA

Materials:

- Lesson Slides
- Student Handouts (print one for each student)
- Evidence Sheets (print one set for each student group)

Lesson Flow

1) *Complete this lesson after the "Moose and Boreal Forest" module*
2) *Lesson Introduction and Set-up*
    a) Review BWCA basics with students: remind them of where the Boundary Waters are, as well as what the major biome is.
    b) Ask students to share what they remember from the last lesson. Use the following guiding questions:
        i) What type of animals live in the BWCA?
        ii) What animal did we investigate in the last class (moose)? What do you remember about moose?
        iii) How are moose populations changing in the BWCA?
    c) Show students a graph of moose population decline, discuss as a class: what could be causing these declines? Consider:
        i) What do moose need to survive?
        ii) What are possible threats to moose populations?
3) *Student Investigation:*
    a) Introduce students to their investigation question: WHY have moose populations in the BWCA been declining?

    b) Pass out student handouts and evidence sheets: students will look at a series of "puzzles." Each puzzle provides a different piece of evidence that students will use to answer questions. After reviewing all of the evidence, students will write a final claim explaining why we are seeing moose decline. Students justify their claim with evidence from the puzzles. Each puzzle includes a guiding question to help direct student investigation. Puzzles are summarized in the table below

Puzzle #	***Guiding Question***	***Evidence Sheets***	***Description of Student Tasks***
1	How is Minnesota's moose population changing?	A, B, C	Students examine historical moose range data. They draw the conclusion that the moose range and population size in Minnesota is decreasing. They brainstorm possible causes of this decline using information about Minnesota's biomes.
2	What is causing Minnesota's moose population to decrease?	D, E	Students look at moose mortality rate data from the DNR. They notice that parasites account for a large portion of moose deaths, before learning more about brainworm (P. Tenuis), a parasite that represents a disproportionate number of moose deaths.
3	What is causing the increase of P. tenuis (brainworm) in moose?	C, F, G	Students look at historical data to understand how deer populations in Minnesota have shifted. They notice that white tailed deer have been moving north before learning that deer carry the parasite P.tenuis. Students should make the connection that as deer migrate north they bring the parasite with them into moose territory.
4	Why are moose and deer ranges shifting? How is this related to climate change?	C, H	Students create a scatter plot showing predicted future average temperatures in the Boundary Waters under two different emission scenarios. They then use their graph along with biome data to draw the conclusion that shifting climate is connected to a change in Minnesota's biomes. As biomes change, deer are better able to survive in moose territory.
5: *Extension Puzzle*	How do rising temperatures affect moose health?	I, J, K	Students look at climate projection data to draw conclusions about changes in the maximum number of high-temperature days in the Boundary Waters. They then look at data on the effect of high temperatures on moose health in order to determine how increasing temperatures might affect the overall health of Minnesota's moose population.

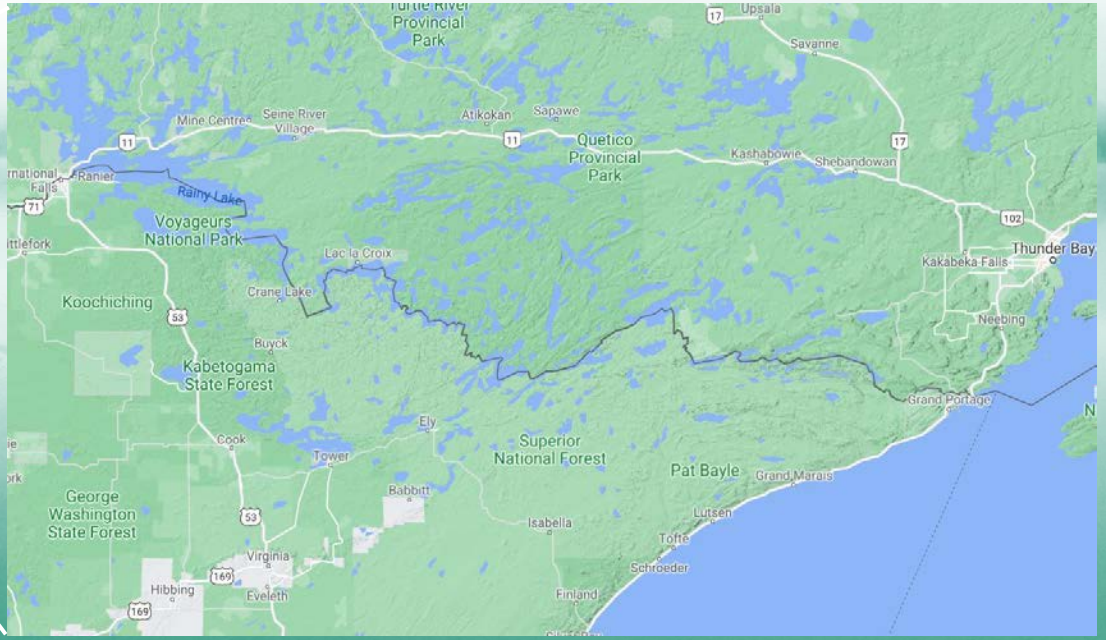
c) Final Claim: Students use the evidence sheets to write a claim that answers the questions: Why are moose populations in BWCA declining? How is climate change connected to this population decline?

d) Go over results as a full class: be sure to reinforce the big takeaway: Warmer temperatures (from climate change) are changing white-tailed deer distribution, as deer move north they are bringing brain worm which is causing decline in moose populations.


FRIENDS OF THE
BOUNDARY
WATERS

The Boundary Waters is the region of wilderness separating Canada from the US between Ontario and Minnesota, west of Lake Superior.

The BWCA is 1.2 million acres, and 20% of it is water!



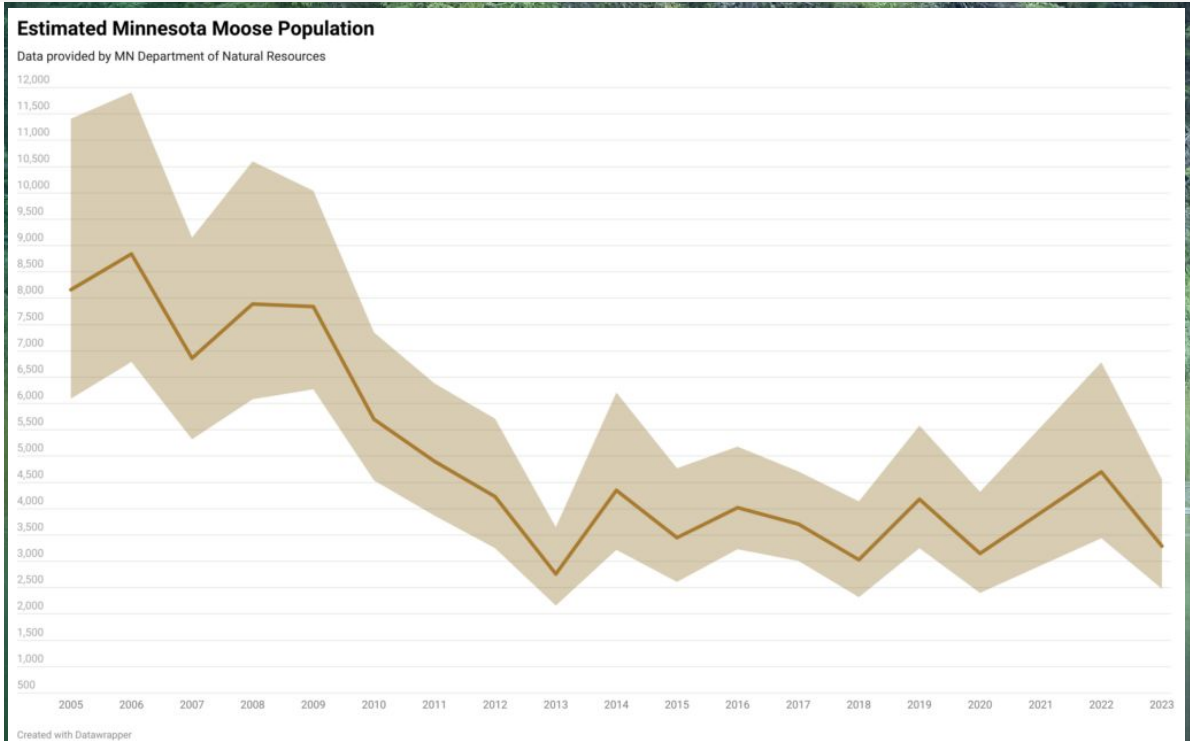
The BWCA is primarily **Boreal (Coniferous) Forest** biome

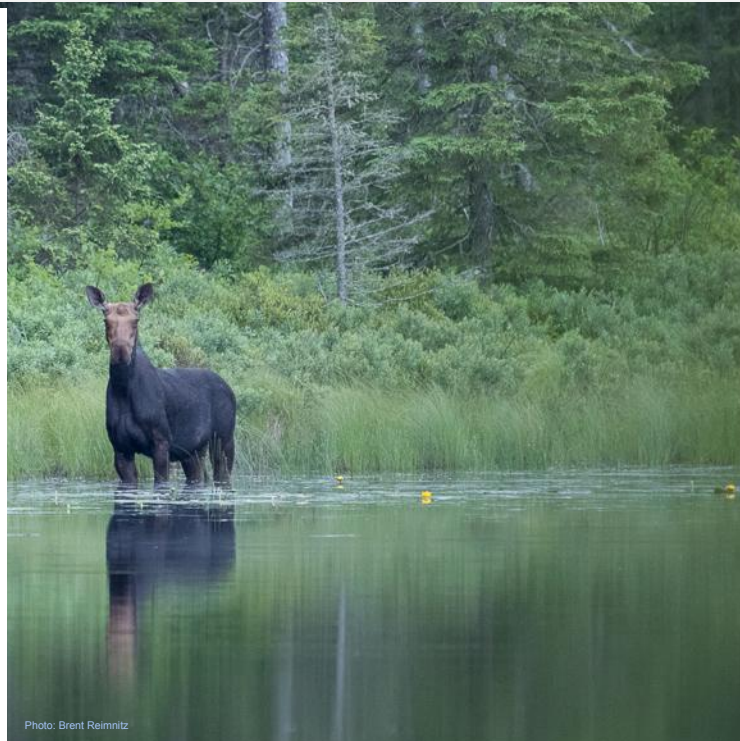
- Short, moist summers, long dry winters
- Temperature Range: -65 - 86F
- Thin, Acidic Soils (nutrient poor)
- Dominated by coniferous trees (spruce, fir, pine, and larch)

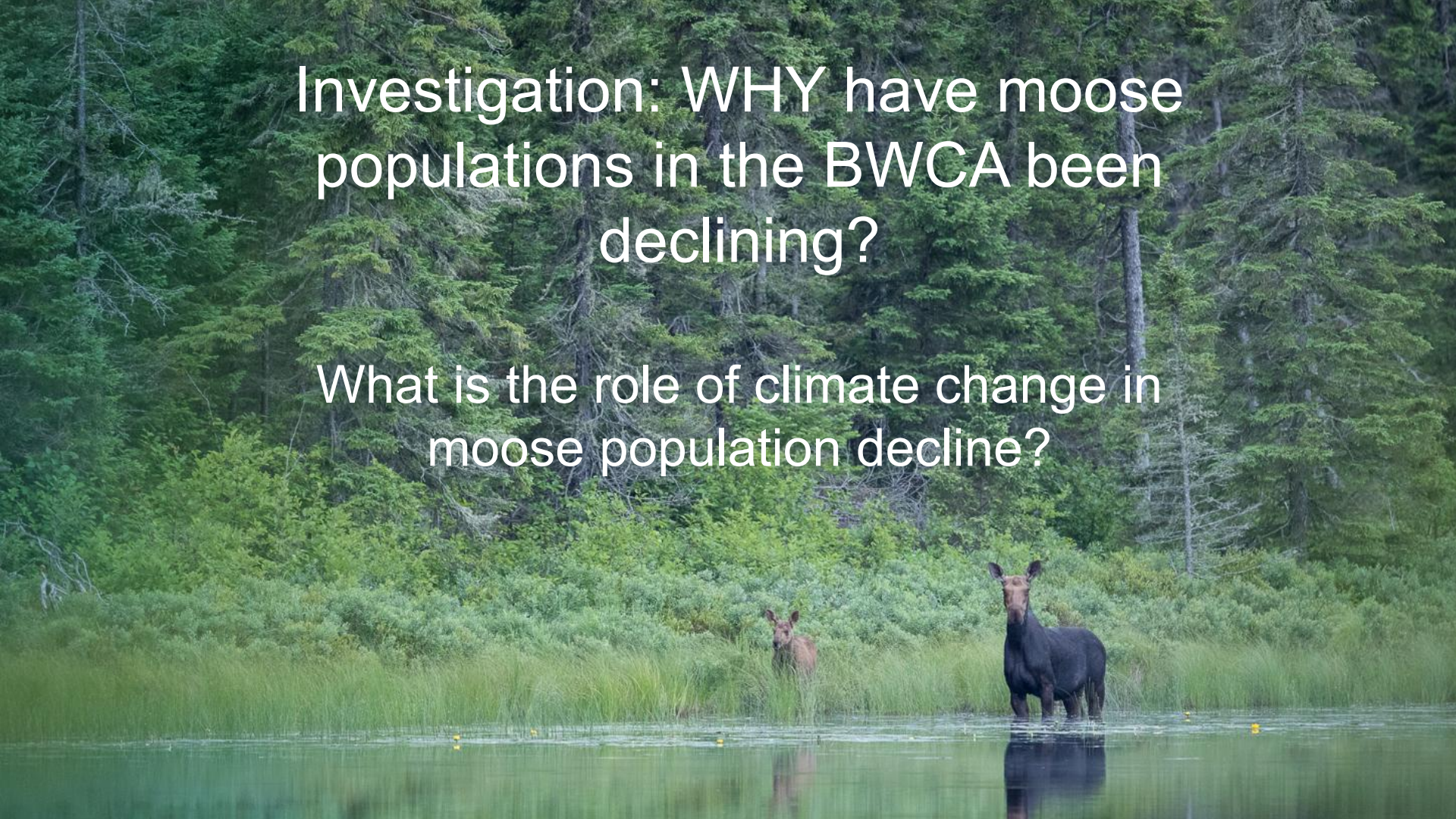
Photo: Thomas Spence

This biome is ideal for megafauna like Moose!

- Largest members of the deer family, weigh up to 1800 pounds
- Between 5-6.5 feet tall
- Herbivores: primarily eat woody plants
- Adapted to cold climates (can experience heat stress at temps above 57 degrees F)



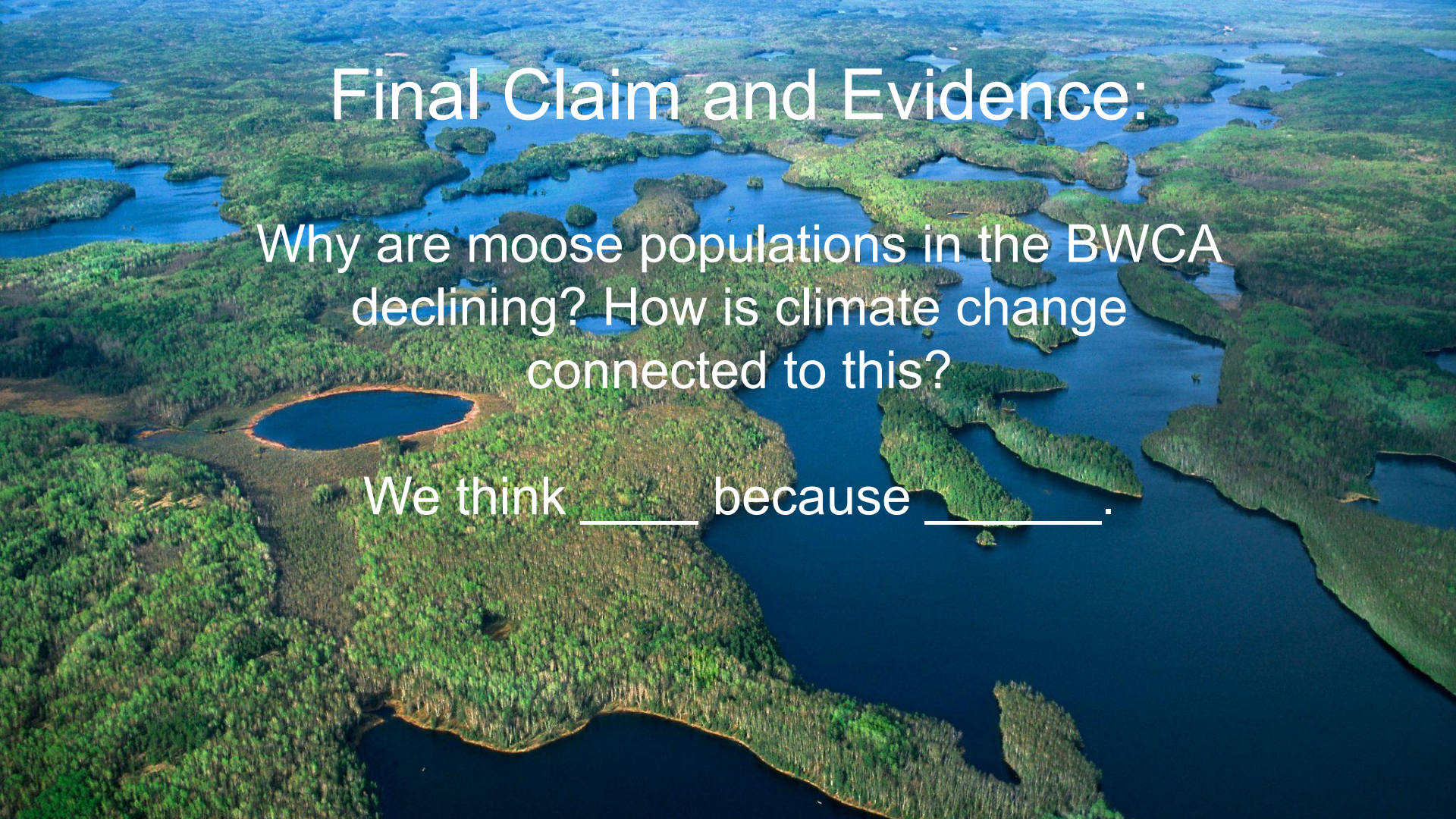



Investigation: WHY have moose populations in the BWCA been declining?
What is the role of climate change in moose population decline?

It’s time to investigate!

Directions:

1) Look at each of the pieces of evidence
2) Answer the questions on the evidence puzzles as you go
3) Use your findings to write a **claim** that answers the question: **Why are moose populations in the BWCA decreasing? How is this related to climate change?**



Final Claim and Evidence:

Why are moose populations in the BWCA declining? How is climate change connected to this?

We think _____ because _____.

Climate Change and BWCA

Lesson 4: Climate Change and Moose Data Dig

The Problem: Moose populations in the BWCA have been rapidly declining. Researchers across Minnesota have been collecting data to help figure out why, but they need your help! You need to evaluate the evidence and determine: What is causing the moose population to decline? What is driving these changes?

Puzzle 1:

Guiding Question: How is Minnesota's moose population changing?

Directions:Use Evidence A, B, and C to answer the questions below:

1) What part of Minnesota are Moose mostly located in?

2) What biome are the moose mostly found in? What do you know about that biome? (What is the climate like? What type of plants are found there?)

3) How has the moose population changed over time? Brainstorm: Why do you think we might be seeing these changes?

Puzzle 2:
Guiding Question: What is causing Minnesota's moose population to decrease?
Directions: Use Evidence D and E to answer the questions below:

1) What are the highest causes of moose mortality (death)?

2) What parasite is responsible for most of the moose deaths?

3) Where does P. tenuis (brainworm) come from? (How is it infecting moose?)

Puzzle 3:
Guiding Question: What is causing the increase of P.tenuis (brainworm) in moose?
Directions: Use Evidence C, F, and G to answer the questions below:

1) What biome are the deer mostly found in? What do you know about that biome? (What is the climate like? What type of plants are found there?)

2) How has deer distribution (where they are) in Minnesota changed over time?

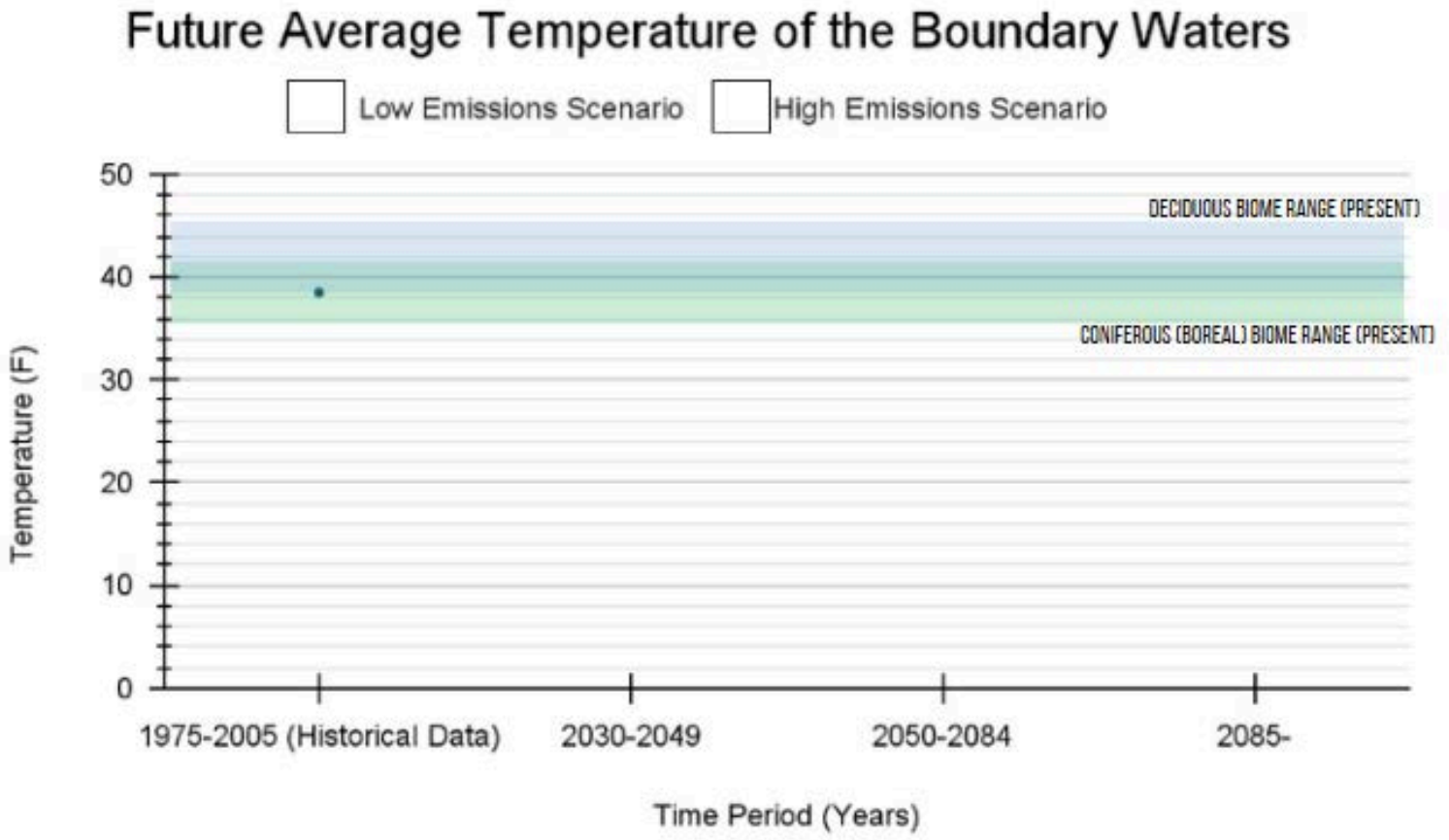
3) How is deer migration affecting moose populations?

Puzzle 4:

Guiding Question: Why are moose and deer populations shifting? How is this related to climate change?

Directions: Use Evidence C and H to answer the questions below:

1) Look at Evidence H: Future Average Temperature Data for the Boundary Waters. Use the data table to complete the scatter-plot below. The green and blue bars show you the temperature range for coniferous (boreal) biomes and deciduous biomes.



Use your graph to answer the questions below.

2) How is temperature expected to change in the BWCA?

3) How do the high and low emission scenarios differ? How are they similar?

4) As temperature changes, what do you expect to happen to the biomes in the BWCA? How will this affect moose populations?

Puzzle 5: (HS Only)
Guiding Question: How do rising temperatures affect moose health?
Directions: Use Evidence I, J, and K to answer the questions below:

1) How is the number of days over 90 degrees in the Boundary Waters expected to change by the mid and late centuries? How is this different in a high versus low emissions scenario?

2) At what temperatures do moose begin to experience heat stress? What are the effects of heat stress on moose?

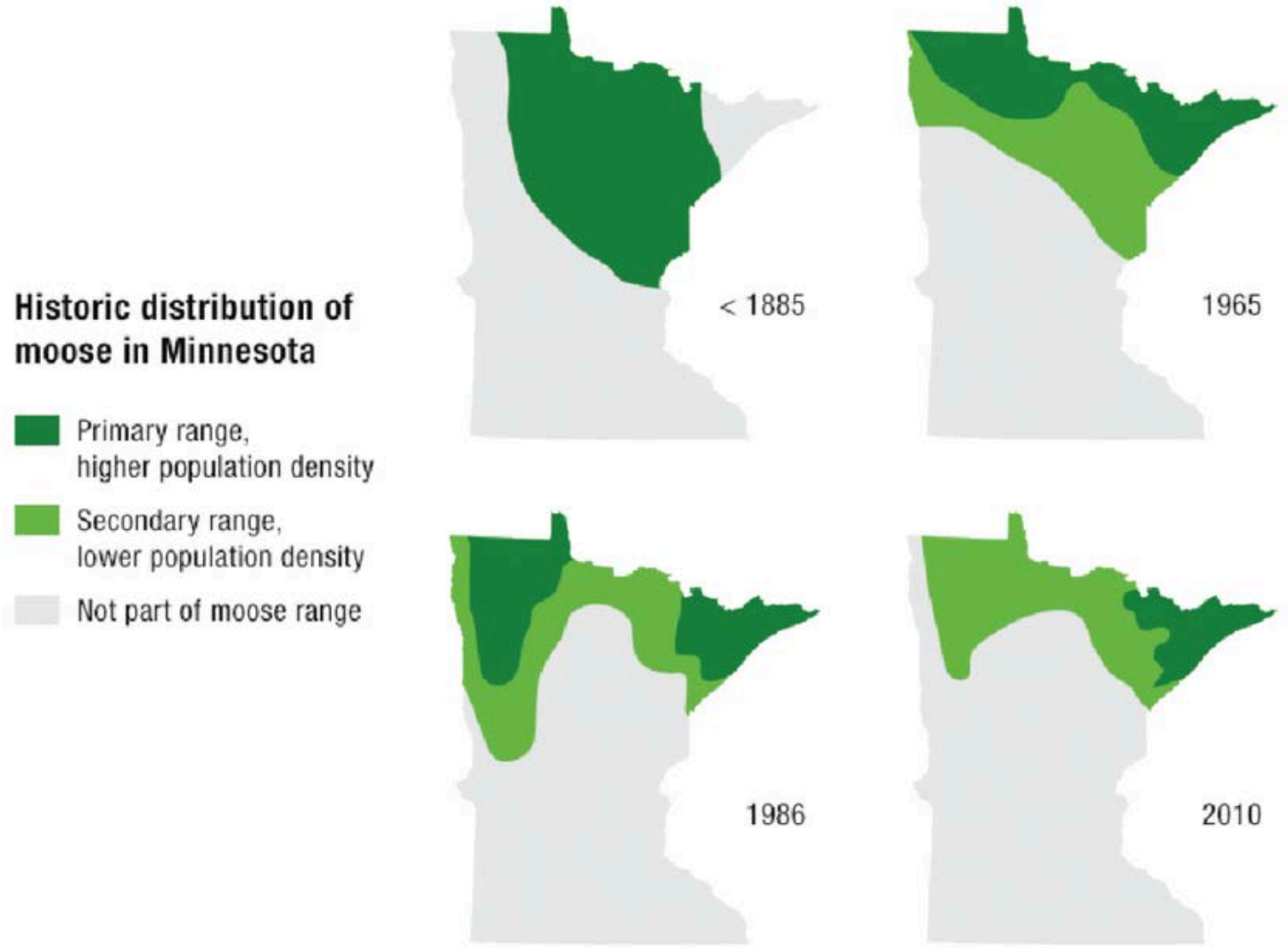
3) How do you expect the overall health of Minnesota's moose population to change as the number of high-temperature days increases? Explain your thinking.

Final Claim: Use all of your evidence to write a final claim (answer to our question). Be sure to use evidence to support your claim.

Why are moose populations in the BWCA declining? How is climate change connected to this?

EVIDENCE A

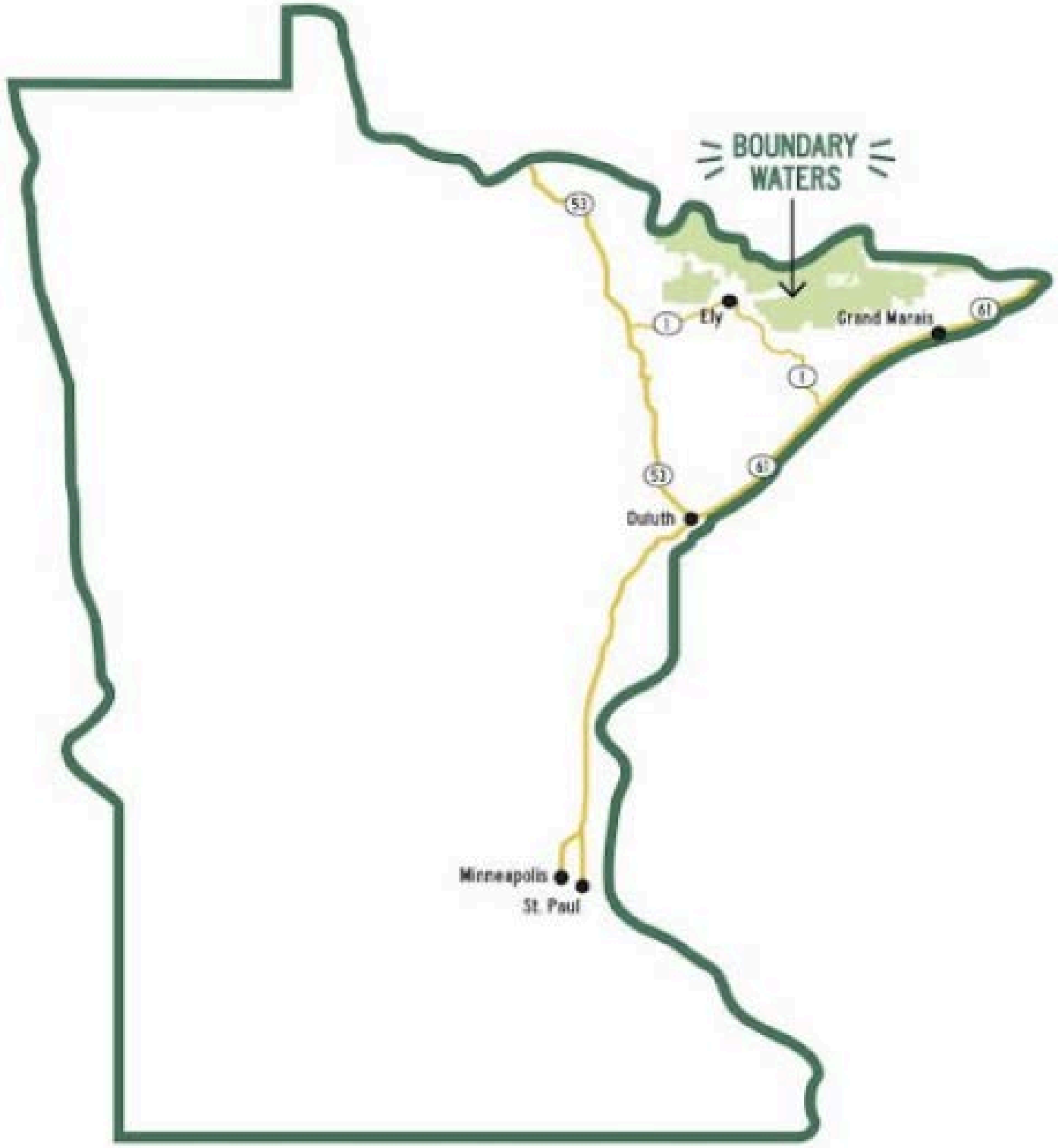
MINNESOTA MOOSE RANGE 1885-PRESENT



FRIENDS OF THE BOUNDARY WATERS

EVIDENCE B

BWCA LOCATION



FRIENDS OF THE BOUNDARY WATERS

EVIDENCE C

MINNESOTA BIOME DISTRIBUTION AND FACTS

"Biome" is a term used to describe a biological community. Usually biomes, occur over large areas and include many similar plant communities and the animals that live in them. The map below shows the major biomes found in Minnesota and their distribution.

FRIENDS OF THE BOUNDARY WATERS

EVIDENCE C

MINNESOTA BIOME DISTRIBUTION AND FACTS

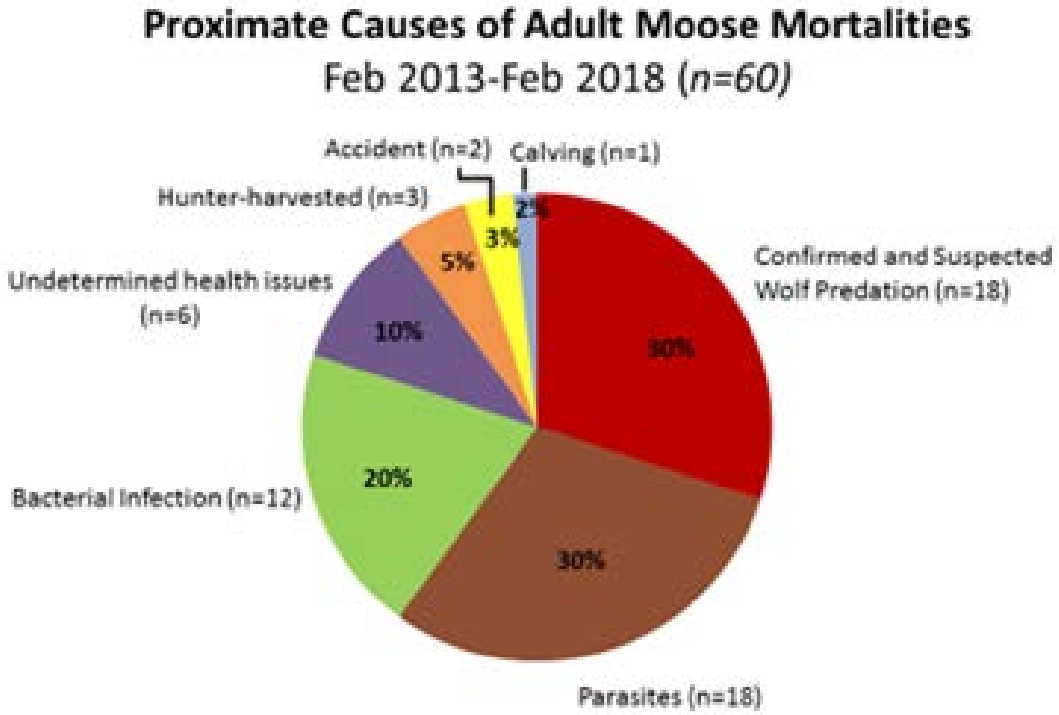
"Biome" is a term used to describe a biological community. Usually biomes, occur over large areas and include many similar plant communities and the animals that live in them. The table below shows samples of conditions within Minnesota's biomes.

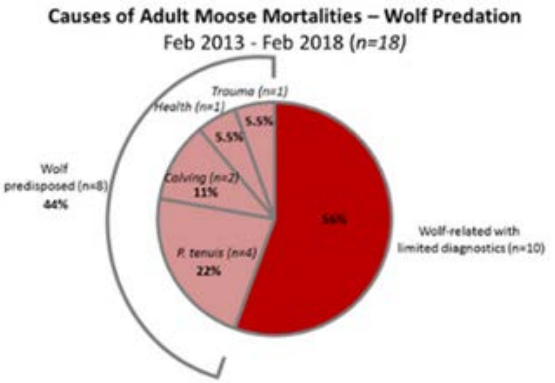
	AVERAGE ANNUAL PRECIPITATION	AVERAGE ANNUAL TEMPERATURE	VEGETATION EXAMPLES	ANIMAL EXAMPLES	AVERAGE GROWING SEASON LENGTH
TALLGRASS ASPEN PARKLAND BIOME	20"-22"	35°-44°F	• ASPEN • HEART-LEAVED WILLOW • WIREGRASS SEDGE • SMALL WHITE LADY'S SLIPPER • LITTLE BLUESTEM	• SHARP-TAILED GROUSE • SANDHILL CRANE • AMERICAN BITTERN • CANADIAN TOAD • AMERICAN ELK	90-100 DAYS
CONIFEROUS FOREST BIOME	21"-32'	36°-41°F	• BLACK SPRUCE • NORTHERN WHITE CEDAR • BALSAM FIR • RED PINE • FLY HONEYSUCKLE	• WOOD FROG • BOREAL CHICKADEE • COMPTON'S TORTOISESHELL BUTTERFLY • GRAY WOLF • MOOSE	90-100 DAYS
DECIDUOUS FOREST BIOME	24"-35"	39°-45°F	• NORTHERN RED OAK • AMERICAN BASSWOOD • SUGAR MAPLE • PRICKLY GOOSEBERRY • RUE ANEMONE	• EASTERN HOGNOSE SNAKE • CERULEAN WARBLER • EASTERN PIPISTRELLE BAT • GRAY FOX • EASTERN SPOTTED SKUNK • WHITE-TAILED DEER	100-130 DAYS
PRAIRIE GRASSLAND BIOME	18"-33"	37°-45°F	• BIG BLUESTEM • BLAZING STAR • PURPLE PRAIRIE CLOVER • PRAIRIE DROPSEED • LEADPLANT	• GREAT PLAINS TOAD • GREATER PRAIRIE CHICKEN • UPLAND SANDPIPER • POCKET GOPHER • BADGER	130-180 DAYS

EVIDENCE D

CAUSE OF MORTALITY AMONG MOOSE

A 2018 study from the DNR found parasites, in particular P. Parelaphostrongylus tenuis (p. tenuis, also known as brainworm) was a leading cause of death among moose in Minnesota.





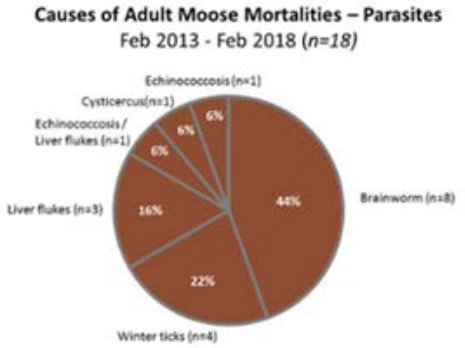


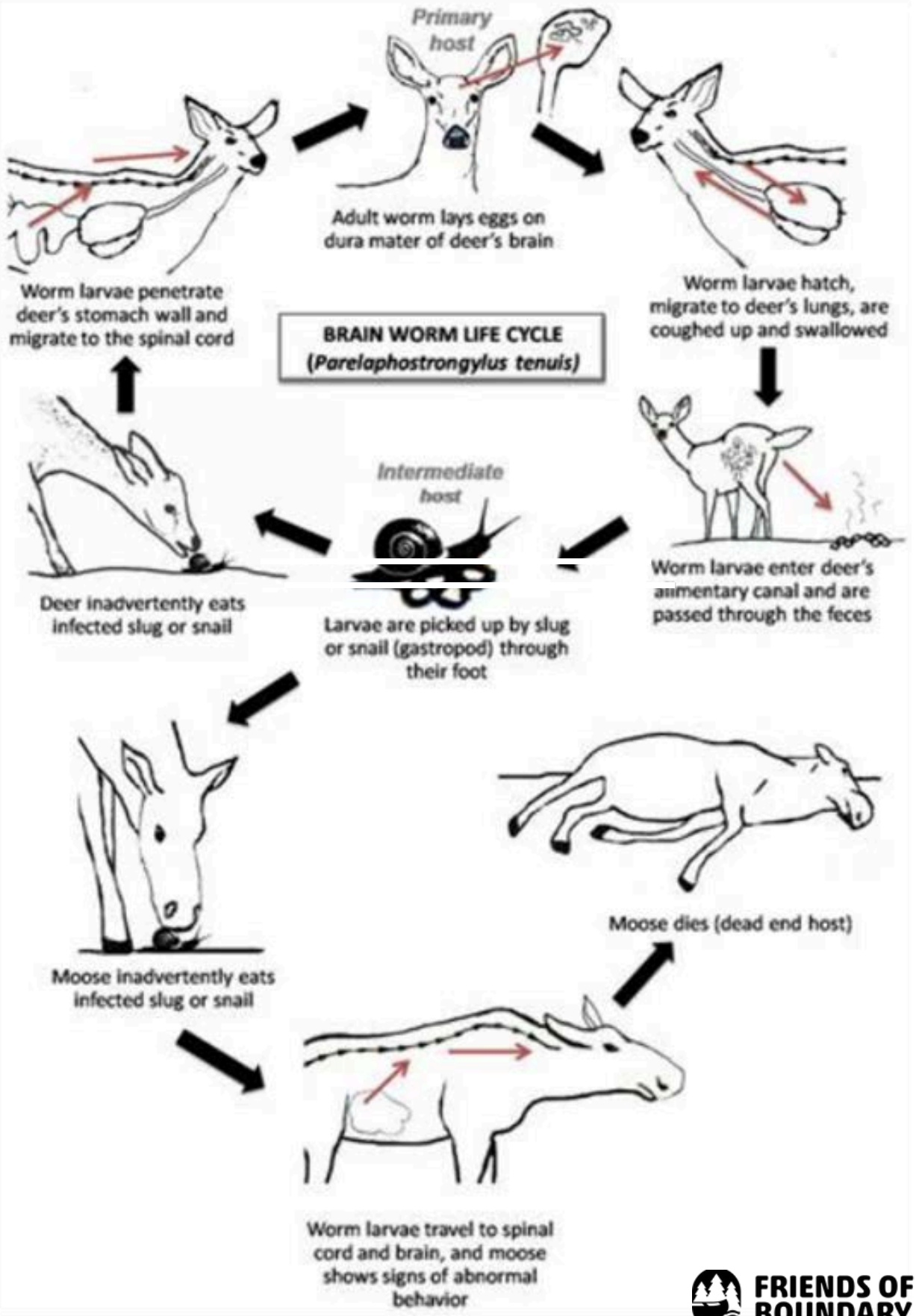
Figure 3. Cause-specific mortality of collared, adult moose (*n*=60) from 2013–2017, northeast Minnesota.

FRIENDS OF THE BOUNDARY WATERS

EVIDENCE E

BRAINWORM (P.TENUIS) LIFE CYCLE

Illustration by Natalie Sacco, NYSDEC
https://www.dec.ny.gov/animals/72211.html



FRIENDS OF THE BOUNDARY WATERS

EVIDENCE F

DISTRIBUTION (RANGE) OF WHITE TAILED DEER PRE-EUROPEAN SETTLEMENT TO TODAY

Figure 1. Range map of cervids (deer, elk, moose, and caribou) in Minnesota prior to European settlement.

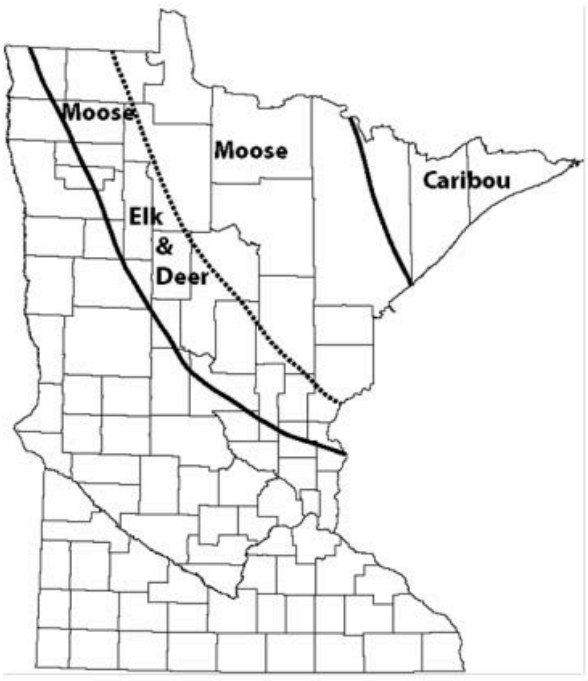


Figure 2. Range map of deer family members in Minnesota around 1880.

Figure 3. Range map of deer family members in Minnesota around 1920.

Source: https://files.dnr.state.mn.us/wildlife/deer/deer_backgrounder.pdf

FRIENDS OF THE BOUNDARY WATERS

EVIDENCE G

COMMENTARY FROM AN ECOLOGIST ON MOOSE-DEER INTERACTION

LISTEN

So why are we seeing this collapse of the moose population in Minnesota and replacement by white tailed deer? White tailed deer aren't very well adapted to cold and snow. But one of the things that's happened with climate change is we've tended to get warmer winters which means we have less snowpack and temperatures are more mild and so that allows deer to wander further northward. When I was working in the Boundary Waters in 2011 and 2012. I remember talking to long term residents at the end of the Gunflint Trail, who, at the time reported seeing the first ever white tailed deer that far north in Minnesota, they had cabins on lakes up there for 50-60 years, and they never seen a white tailed deer in that area. But there was a particularly mild winter in 2011-2012 where we basically had almost no snow and temperatures were really mild and so whitetail deer were able to move north during that really mild winter, and areas where they weren't historically.

And one of the bad things about deer migration north is that White Tail Deer carry this parasite called Brain worm, which will affect the brains of moose, but has less of an impact on white tailed deer. And the way this parasite works is that it'll be carried in a white tailed deer and they'll either die or defecate and the brain worms will then attack a snail and be in a snail. And moose will eat that vegetation that contains that snail, it'll ingest the brain worm then the brain worm will work through the spinal column of the moose and go up to the brain of the moose. And basically what the brain worm does is it causes the moose to go crazy and kind of walk around aimlessly in circles and become really susceptible to predation. So brain worm is basically always fatal for moose, but really doesn't cause any mortality on white tailed deer. So anytime there are deer and moose in an area, there's a decline in Moose because of brain worm that's introduced in those areas. So that's one of the effects that we're seeing is that milder winters are allowing deer to migrate northward, which is having an asymmetric impact on moose.

Eli Anosko, Resident Ecologist at Treehaven, University of WI Steven's Point
Presentation on Climate Change in the Boundary Waters
Used with permission.

EVIDENCE H

FUTURE AVERAGE TEMPERATURE DATA FOR THE BOUNDARY WATERS

Climate models show two different possible temperature-futures for the boundary waters depending on the number of carbon emissions created by humans. High emission scenarios where more carbon emissions are released result in more warming. Lower emission scenarios where less carbon emissions are released result in less warming.

	LOW EMISSION SCENARIO AVERAGE ANNUAL TEMPERATURE (°F)	HIGH EMISSION SCENARIO AVERAGE ANNUAL TEMPERATURE (°F)
1975-2005 (HISTORICAL DATA)	38.5°F	
2030-2049	41°F	42°F
2050-2084	43°F	44°F
2085-	44°F	49°F

DATA FROM 2030 ON IS BASED ON CLIMATE MODELS

U.S. Climate Resilience Toolkit
Source: Census Bureau, CEQ, Esri, FEMA, MRLC, NOAA, UCSD

FRIENDS OF THE BOUNDARY WATERS

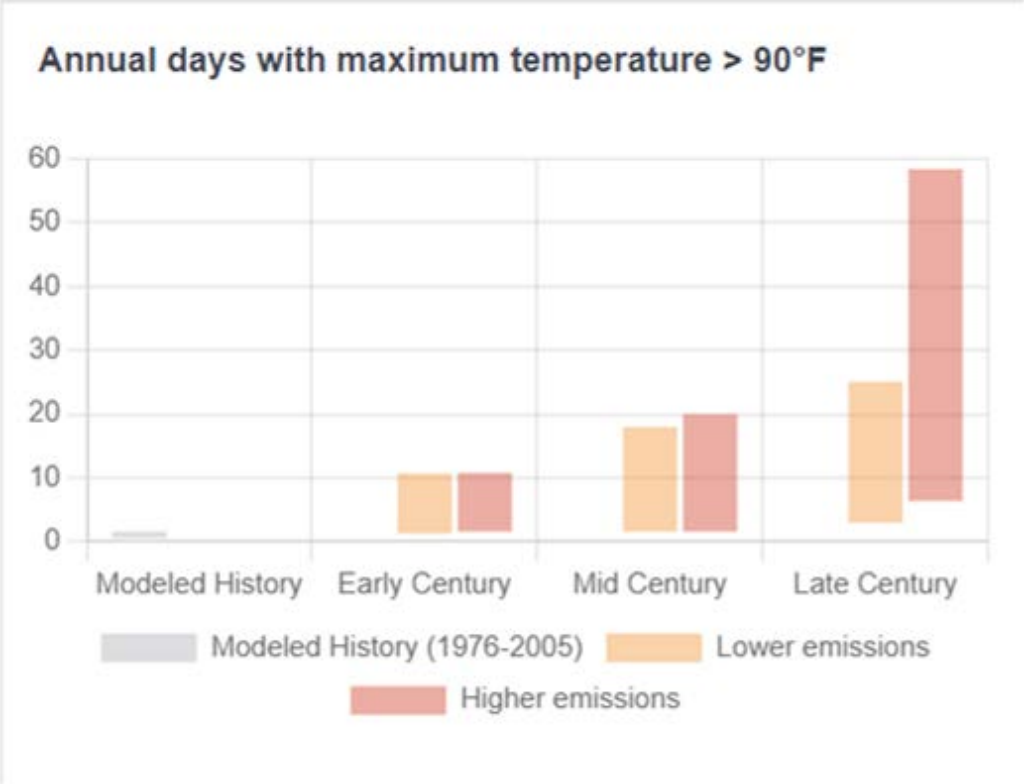
EVIDENCE I

Climate Projections for the Boundary Waters

Predicted future high-Temperature days in the Boundary Waters under low and high emission scenarios

Future Climate Indicators

Indicator	Modeled History (1976 - 2005)	Early Century (2015 - 2044)		Mid Century (2035 - 2064)		Late Century (2070 - 2099)	
		Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions	Lower Emissions	Higher Emissions
	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max	Min - Max
Temperature thresholds:							
Annual days with maximum temperature > 90°F	1 days 1 - 2	4 days 1 - 11	5 days 2 - 11	7 days 2 - 18	11 days 2 - 20	11 days 3 - 25	29 days 6 - 58
Annual days with maximum temperature > 95°F	0 days 0 - 0	1 days 0 - 3	1 days 0 - 3	2 days 0 - 5	3 days 0 - 7	3 days 0 - 10	13 days 2 - 34
Annual days with maximum temperature > 100°F	0 days 0 - 0	0 days 0 - 0	0 days 0 - 1	0 days 0 - 1	0 days 0 - 2	1 days 0 - 1	4 days 0 - 16
Annual days with maximum temperature > 105°F	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	0 days 0 - 0	1 days 0 - 4



U.S. Climate Resilience Toolkit
Source: Census Bureau, CEQ, Esri, FEMA, MRLC, NOAA, UCSD

FRIENDS OF THE BOUNDARY WATERS

EVIDENCE J

Moose Temperature Threshold for Heat

Temperature (C)	Temperature (F)	Moose Response
15	57	Respiratory system increases, start of heat stress.
20	68	Moose begins to pant ,
Above 20	Above 68	Continually increased heart rate and energy expenditure.

RENECKER L. A., AND R. J.HUDSON. 1986. SEASONAL ENERGY EXPENDITURES AND THERMOREGULATORY RESPONSES OF MOOSE. CANADIAN JOURNAL OF ZOOLOGY 64:322–327.

EVIDENCE K

Commentary from an Ecologist on High Temperature Effects on Moose

“There's also some direct effects that warmer temperatures are really hard on moose. They're a species that's adapted to cold climates. So if we get temperatures like we had the summer where it's 90 degrees up in Ely, that's enough to cause heat stress and a moose and so during those really warm On periods of time, they have to kind of find cooler habitat. So they may lay down in a bog or like stand in a lake instead of feeding. And so that affects their survival as well, because they're not able to forage as efficiently because of those warmer temperatures. “

LISTEN

Eli Anosko, Resident Ecologist at Treehaven, University of WI Steven’s Point
Presentation on Climate Change in the Boundary Waters
Used with permission.

FRIENDS OF THE BOUNDARY WATERS

Climate Change and BWCA
Lesson 5: Addressing Climate Change in the BWCA
This is the 5th and final lesson in the Climate Change and Moose Series, this lesson is intended to be teacher-led in the classroom

Lesson Outline

Objectives:

- SWBAT describe one effect of climate change on the BWCA
- SWBAT compare and contrast different strategies for addressing climate change
- SWBAT write a climate action plan and defend their choice with evidence.

Materials:

- Lesson Slides
- Student Handouts (print one for each student)
- Climate Change Solution Sheets (print one set per student group)
- Species Risk Assessment Project (print one for each student)

Lesson Flow

1) *Complete this lesson after the "Climate Change and Moose Data Dig"*
2) *Lesson Introduction*
    a) Review big ideas from this unit with students: Boundary Waters is a protected wilderness area in northern Minnesota.
    b) BWCA is primarily a boreal (coniferous) forest, these ecosystems are vulnerable to climate change because many of their species are reliant on cool temperatures.
    c) We are already seeing the effects of climate change in the BWCA. One example is with moose.
    d) Review moose decline data, and show video clip reviewing why moose populations are declining (warmer temperatures bringing white tailed deer, who bring brain worm)
        i) For more clarification watch: https://www.youtube.com/watch?v=QMEuvef7Lkw
3) *Investigation: Solutions Jigsaw Activity*
    a) Students explore 1 of 3 different approaches to addressing moose population decline:
        i) Reducing Emissions
        ii) Wildlife Management (Reducing Deer Population)
        iii) Rewilding and planting heat resilient spruce seeds
    b) Students fill out a graphic organizer describing their solution before sharing out in small groups.
    c) Students share their results in small groups and use the findings from others to complete their graphic organizer.

d) Students use their research to write a proposal for what they think they think the first step for mitigating climate change should be
e) Students share their ideas in small groups, before revising their ideas, and completing final reflection.

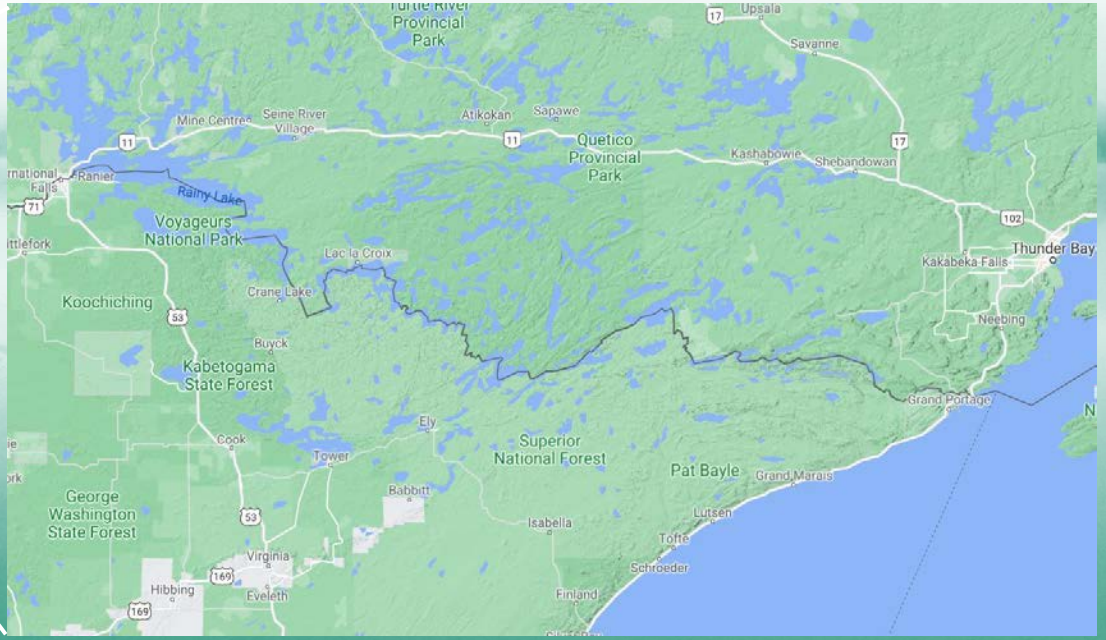
4) Species Risk Assessment Project

a) Students choose a Boundary Waters species to research using recommended resources on the student sheet.
b) Students use their research to fill out a graphic organizer summarizing the results of their findings
c) Students use their research to write a proposal for what strategies they think would best support their chosen species in a changing climate.
d) Students share their ideas in small groups.
e) Optional Extension: To use this activity as a summative assessment, have students create a poster to display their findings. Posters could then be displayed and shared in a gallery walk.


FRIENDS OF THE
BOUNDARY
WATERS

The region of wilderness separating Canada from the US between Ontario and Minnesota, west of Lake Superior.

The BWCA is 1.2 million acres, and 20% of it is water!



The BWCA is primarily **Boreal (Coniferous) Forest** biome

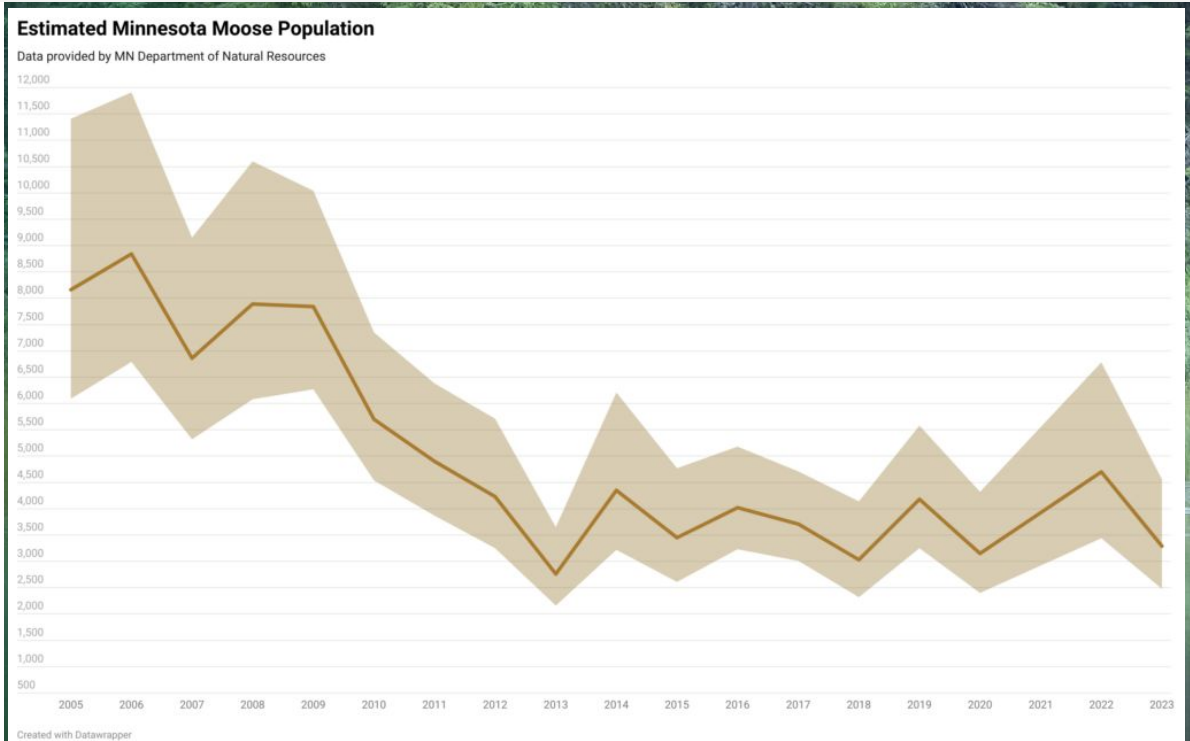
- Short, moist summers, long dry winters
- Temperature Range: -65 - 86F
- Thin, Acidic Soils (nutrient poor)
- Dominated by coniferous trees (spruce, fir, pine, and larch)

Photo: Thomas Spence

Due to Climate Change the forest composition and seasons of the BWCA are changing!

We're already seeing the effects of climate change in the BWCA

- Shorter and warmer winters
- Warmer waters
- Increase in wildfires
- Decrease in different species populations such as the **moose**



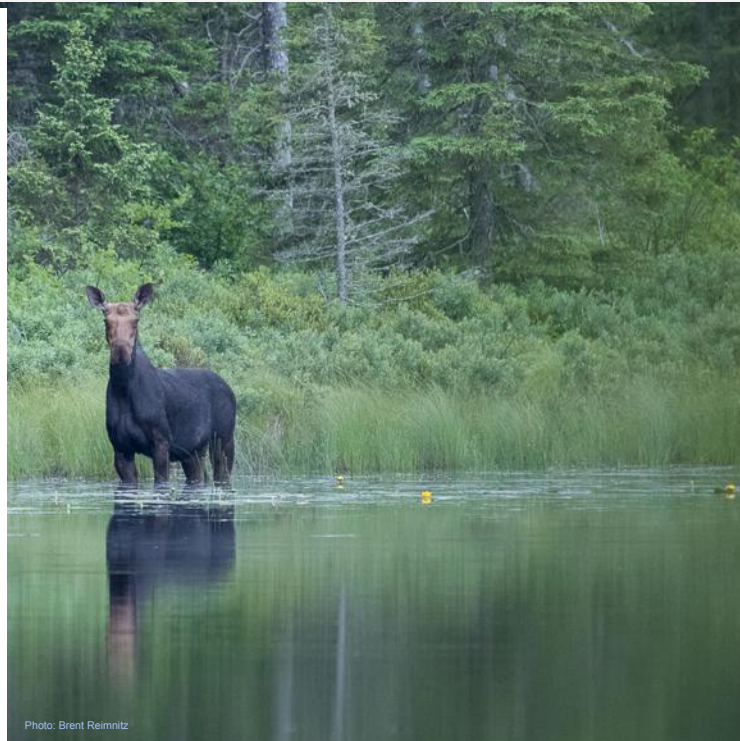


Photo: Brent Reimnitz

Check-in: What is causing moose decline in the BWCA?

Last class you looked at different evidence for the moose decline in the BWCA: What do you remember?

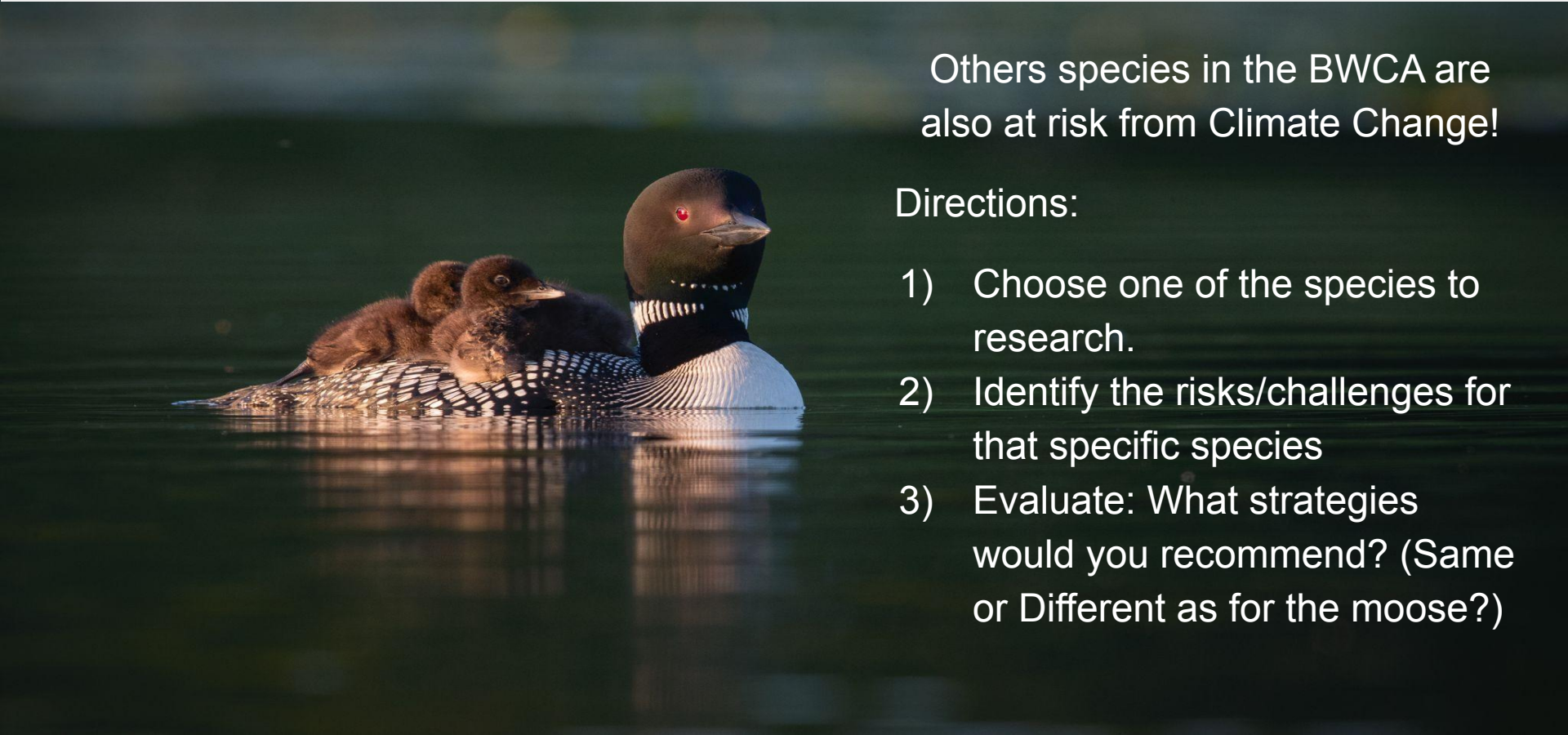
Dig-in: What are some solutions?

Climate change is having a significant impact on moose and the Minnesota's boreal forests as a whole. Your task is to evaluate some different solutions and come up with an action plan.

Directions:

1) Collect a copy of the handout
2) Read/Listen to the **one** of the three different management ideas
3) Use the information to fill out the graphic organizer
4) Share out your findings with your small group
5) Make a choice; What plan or combo of plans seems like the best option? Defend your choice with evidence
6) Discuss: Share out in small groups
7) Revise: Look back at your ideas, have they changed? What are some possible challenges to dealing with a crisis like moose decline?

Extend your thinking: Species Risk Assessment



Others species in the BWCA are also at risk from Climate Change!

Directions:

1) Choose one of the species to research.
2) Identify the risks/challenges for that specific species
3) Evaluate: What strategies would you recommend? (Same or Different as for the moose?)

Climate Change and BWCA

Lesson 5: Addressing Climate Change Student Guide

The Problem: Climate change is causing a change in the composition of Northern Minnesota's forests. Forests in the boundary waters are shifting from boreal species (aspens, spruce, pines, and firs) to more temperate and deciduous species (oak, maples, elms, and cottonwoods). Changes in the composition of the forest mean changes to the animals that can live there as well. Moose populations are already feeling this effect. White tail-deer are becoming more abundant in the BWCA. These deer bring brain worms. Brainworms are fatal to moose and have been linked to decreasing population size.

Your Task: Evaluate the possible solutions below. Compare the benefits and drawbacks of each, then come up with an action plan!

Proposed Solution	Big Idea	Learn More
Solution 1: Reducing Global Carbon Emissions	In order to slow the rate of warming, we need to reduce fossil fuel emissions globally. This can be done by: ● Switching to renewable energy ● Instituting a carbon tax ● Improving energy efficiency	
Solution 2: Wildlife Management	Moose populations are decreasing as a direct result of brain worms brought to the region by white tailed deer. By reducing the number of white tailed deer in Northern Minnesota we can help increase moose populations. This could be done by: ● Increasing deer management funding ● Increasing length of hunting season and number of permits issued, specifically in moose range ● Monitoring deer populations for disease (specifically brainworm)	
Solution 3: Forest Management	Boreal forests that have higher diversity have been shown to be more resilient to climate change. This means that in warmer climates they stay more stable, and can support more boreal species (such as moose). Forest diversity could be promoted by: ● Planting more heat resistant trees such as white oak, red oak, spruce, and firs. ● Increasing protection for mixed secondary forests	

Summarize your Findings: Use the information from the table above to fill in the graphic organizer below

Solution	Summary What is it? How does it Work?	Advantages	Disadvantages/ Challenges

Reflect: Use your graphic organizer to answer the reflection questions

1) What solution (or combination of solutions) seems the most realistic and effective? Explain your thinking

2) What resources would be needed for this solution to work? (consider people and physical materials)

3) What do you see as some of the biggest challenges/barriers to these solutions?

Check-in: Share out your ideas with at least 2 other classmates, then answer the reflection questions below

1) After discussing with classmates, look back at your initial ideas about what solution would work best. Did you and your classmates agree/disagree? How have your ideas changed after discussion?

2) What do you think is the most important first step in addressing the moose decline problem? What are some possible challenges you foresee in dealing with this problem?

STRATEGIES FOR ADDRESSING CLIMATE CHANGE IN THE BWCA

Forest Management

Climate change is increasing temperatures in Minnesota. As this happens, Boreal Forests are shifting. Scientists at the B4Warmed project are working to model these changes and plant more resilient forests! Forests that can adapt to climate change provide more habitat and heat protection for moose!

Image of B4Warmed Project Experimental Plots: these model forests are helping scientists determine what trees to plant to help protect Boreal Forests! Learn more about the project here

Read more about B4Warmed and other forest management strategies here

https://tinyurl.com/36mrrr9dt

https://www.youtube.com/watch?v=XjCtmK3YhcIt

FRIENDS OF THE BOUNDARY WATERS

STRATEGIES FOR ADDRESSING CLIMATE CHANGE IN THE BWCA

Wildlife Management

As Boreal Forests warm, new species are moving north -including white tailed deer. Deer bring parasites like brain worm that are linked to moose decline. One possible way to address moose loss is to rethink wildlife management. Researchers are looking at ways to manage deer populations, and looking to species like wolves to help support moose!

https://tinyurl.com/yeyrvkvs

One way to help boost moose populations is to regulate deer populations. The DNR creates new management plans every 10 years, with a 5 year review. You can learn more about how they manage deer populations here:

Read more about how increasing wolf populations could support Minnesota Moose!

https://tinyurl.com/2nz25hy2

Researchers have been looking at where moose and deer overlap. They've found that targeting mineral licks could help reduce rates of brainworm! **Learn more here**

https://tinyurl.com/5n8wn4r7

FRIENDS OF THE BOUNDARY WATERS

STRATEGIES FOR ADDRESSING CLIMATE CHANGE IN THE BWCA

Reducing Carbon Emissions

Climate change is driven by the increase in greenhouse gasses in the atmosphere. Burning fossil fuels such as coal, oil, and gas is one of the main drivers of greenhouse gasses. In order to slow warming we need to reduce our carbon emissions. Slowing warming will help to protect our boreal forests and moose populations!

Learn about increasing energy efficiency here

https://tinyurl.com/yc49jhz2

Learn about Carbon Taxes Here

https://www.youtube.com/watch?v=fUGYW9xTFas

Learn about switching to renewable energy here

https://tinyurl.com/4zsd6f4vt

FRIENDS OF THE BOUNDARY WATERS

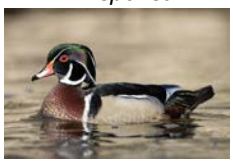
Climate Change and BWCA

Lesson 5: Addressing Climate Change Species Risk Assessment Project

The Problem: Climate change is causing a change in the composition of Northern Minnesota's forests. Forests in the Boundary Waters are shifting from boreal species (aspens, spruce, pines, and firs) to more temperate and deciduous species (oak, maples, elms, and cottonwoods). Changes in the composition of the forest mean changes to the animals that can live there as well. Moose populations are already feeling this effect, but many other species have been affected too!

Your Task: Choose one of the species below to investigate further. Use the recommended resources to research the effects of climate change on your chosen species. Identify the specific risks and challenges of climate change to your species, then evaluate what strategies can best support your chosen species in a changing climate.

Step 1: Choose one of the species below to investigate

Snowshoe Hare ***Waabooz*** *Lepus americanus* 	**Fisher** ***Ojiig*** *Pekania pennanti* 	**Common Muskrat** ***Wazhashk*** *Ondatra zibethicus* 	**Wood Turtle** ***Mitigwaakiing dizi mishiikenzh*** *Glyptemys insculpta* 
American Marten ***Waabizheshi*** *Martes americana* 	**Spring Peeper** ***Agoozimakakii*** *Pseudacris crucifer* 	**Painted Turtle** ***Miskwaadesi*** *Chrysemys picta* 	**Common Loon** ***Maang*** *Gavia immer* 
Wood Duck ***Mitigoningwiishib*** *Aix sponsa* 	**Smallmouth Bass** ***Noosa'owesi*** *Micropterus dolomieu* 	**Lake Whitefish** ***Adikameg*** *Coregonus clupeaformis* 	**Walleye** ***Ogaa*** *Sander vitreus* 

Step 2: Use the resources below and other internet resources to research your species. Fill out the graphic organizer with your findings

- Climate Vulnerability Assessment, Great Lakes Indian Fish and Wildlife Commission: contains individual species risk assessments for each of the species listed above.
- DNR Impacts of Climate Change Testimonials: includes interviews from DNR employees and Minnesota residents on the impacts of climate change they are currently seeing
- State of the Boundary Waters (2018 Friends of the BWCA Report): Discusses impact of climate change on BWCA species.

Common Name: _____

Anishinaabe Name: _____

Scientific Name: _____

Distribution and Habitat	General Description	Vulnerability Status

Climate Threats (How is Climate Change Expected to Effect this species)

Resources/Actions that Could Help Support this Species	Sources

Step 3: Make a recommendation:

1) Based on your research what strategies would you suggest to best support your species in a changing climate. Explain your thinking.

2) What resources would be needed for this solution to work? (consider people and physical materials)

3) What barriers do you expect to encounter with these solutions? What are the limitations to this method?

4) How are these strategies similar/different to those that support moose?