STREAMS AND STEAM

Effects of Climate Change on the Water Cycle

DESCRIPTION

Students play a Chutes-and-Ladders-style board game to understand the effects of climate change on the water cycle.

PHENOMENON

How is climate change impacting the cycling of water through Earth's reservoirs?

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Predict how increasing temperatures on Earth will affect the water cycle
- Synthesize information about the effects of climate change on the water cycle
- Explain how changes in the water cycle affect humans

TIME
50 MINUTES – 1 HOUR

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8

CCSS.ELA-LITERACY.RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts. [Extension Activity]

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

CCSS.ELA-LITERACY.RST.6-8.7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10

CCSS.ELA-LITERACY.RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. [Extension Activity]

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12

CCSS.ELA-LITERACY.RST.11-12.1. Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. [Extension Activity]

CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

NEXT GENERATION SCIENCE STANDARDS

High School Performance Expectation

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions (MS, HS)	ESS2.A Earth Materials and Systems (MS, HS) ESS3.A Natural Resources (MS, HS) ESS3.C Human Impacts on Earth Systems (MS, HS)	Cause and Effect (MS, HS)

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BACKGROUND

The availability of water resources for humans, our crops, and our livestock is changing because of the enhanced greenhouse effect and resulting global warming and climate change.

The greenhouse effect ensures that Earth is warm enough to sustain life. Electromagnetic radiation from the sun, mostly at short wavelengths in the form of light, is able to pass through the atmosphere and is absorbed by Earth. Earth re-radiates some of this energy back toward space as heat, more of which was able to pass through the atmosphere and escape into space historically. We are currently experiencing the enhanced greenhouse effect, however, which is caused by increased greenhouse gases in our atmosphere. As higher levels of greenhouse gases are released into the atmosphere, more of the re-radiated heat from Earth is re-emitted back to Earth instead of escaping to space. This is causing the average global temperature to increase. The increasing temperature of Earth is called **global warming**.

Global warming is leading to additional changes to our climate, such as increased frequency of extreme weather events and changing precipitation patterns, wind patterns, and length of seasons. These long-term changes in measures of climate are called **climate change**.

The **water cycle** is the movement of water on, in, and above Earth, and it is largely driven by energy from short-wave electromagnetic radiation (sunlight) absorbed by Earth's surface. The effects of climate change on the water cycle are numerous because of how warmer temperatures affect water cycle processes. Warmer water evaporates more readily, and warmer air has the capacity to hold more water vapor. As a result, in some areas, the frequency of intense precipitation events will increase, and other areas will experience more drought. Also, because of higher temperatures, more precipitation is falling as rain instead of snow. In parts of the Northern Hemisphere, early arrival of warm spring season temperatures results in earlier snowmelt and altered streamflows.

MATERIALS

- *What Is Happening to Our Water? handout* [1 per student]
- *Streams and Steam handout* [1 per student]
- *Streams and Steam game board*, [1 per every 4 students]
- Optional: *Water Cycle diagram*, [1 per every 1-4 students]
- *PowerPoint presentation*
- Computer and projector
- Four unique coins, e.g. penny, nickel, dime, and quarter [1 set per every four students]
- Die [1 per every four students]
- Optional: Extension Activity handout [1 per student]

PREPARATION

1. Plan to divide students into groups of four. If necessary, smaller groups are also acceptable.
2. Make the *Streams and Steam* game boards. Trim the bottom edge of the top half of the *Streams and Steam* game board, cutting away the white and blue/grey edges. Trim the top edge of the bottom half of the Streams and Steam game board, cutting away the white and blue/grey edges. Place the two halves together, align the game squares at the border, and tape the halves together.
3. Set up a computer and projector and display the PowerPoint presentation.

PROCEDURES

1. Pass out a *What is Happening to Our Water?* handout to each student.
2. Instruct students to read the excerpt at the top of the handout.
3. Once most students have had enough time to read the excerpt, introduce the activity with the PowerPoint presentation.
   a. **Slide 2**: Earth is getting warmer because of the enhanced greenhouse effect. Increased greenhouse gases in the atmosphere have resulted in global warming, which includes higher global surface temperatures and also higher air and water temperatures. (Review the greenhouse effect and global warming if needed.)
   b. Optional: pass out copies of the *Water Cycle* diagram.
   c. Ask students to draw on their understanding of the water cycle to predict the effects of warmer air and water temperatures on the processes of the water cycle; direct them to write their predictions on the handout. Students can use the *Water Cycle* diagram (if they have a copy) and the excerpt at the top of the handout.
4. Divide students into groups of four.
5. Pass out a *Streams and Steam* handout to each student.
6. Pass out a completed *Streams and Steam* game board to each group.
7. Use the PowerPoint presentation to explain the game.

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a. **Slide 3**: This is the Streams and Steam game board. The game is played like Chutes and Ladders.
b. **Slide 4**: Rules of the game:
   i. Every player rolls the die. The highest number goes first.
   ii. Players follow from left to right.
   iii. All players begin with their coin on the start space.
   iv. Roll the die and move the coin the number of spaces indicated.
b. **Slide 5**: Rules of the game (continued):
   i. When a player lands on a space at the top of a stream, they "raft" down the stream (in the direction of the arrows) by moving their coin to the square at the bottom of the stream.
   ii. When a player lands on a space at the bottom of a column of steam, they rise up the column of steam by moving their coin up to the square at the top of the steam column (in the direction of the arrows).
b. **Slide 6**: Rules of the game (continued):
   i. The squares without pictures do not require any further action. Rest there until your next turn.
   ii. Two or more players may stop at the same square.
   iii. The first player to cross into the Finish space wins the game. An exact roll of the die is not required.

8. In the table in question #1 on the handout, instruct students to list all of the causes and effects that each student from their group lands on during the game. On the game board, causes are written in the beginning stream or steam square, and effects are listed in the square where the stream or steam ends. Example, cause: increased evaporation; effect: more water in the atmosphere.
   a. Instruct students to only write each pair of causes and effects **once** if they are landed on multiple times.
   b. Slide 7: Instruct students to use the Key of Possible Action Types on page 1 to write in the third column possible action types that can be taken to mitigate or adapt to the cause and effect listed.
   c. Instruct students to look at the example that has been done on their handout.
   d. Keep this slide up as students play the game for their reference as they complete the third column of their table.
      i. Water Conservation: use methods to decrease water use.
      ii. Mitigating Climate Change: use methods to reduce greenhouse gas emissions.
      iii. Risk Management Planning: follow procedures to avoid or minimize the impact of climate change.

9. Pass out a set of four unique coins and a die to each group. Ask students to give each player one coin and begin playing.
10. Play as many rounds of the game as time permits. One round of the game takes approximately 10 – 15 minutes.
11. **Slide 8**: Ask students to volunteer to summarize the effects of climate change on the water cycle that they learned from playing *Streams and Steam*. Return to the PowerPoint presentation to review the effects summarized by students and to wrap up the activity.
    a. Review some of the important effects of climate change on the water cycle.
       i. Because surface, air, and water temperatures on Earth are increasing, there is a higher rate of evaporation of water into the atmosphere. Warmer air holds more water, which changes precipitation patterns. Also, water vapor is a greenhouse gas, so more water in the atmosphere further enhances the greenhouse effect and changes the climate.
       ii. We will experience more severe drought in some areas. As climate change intensifies, climate scientists predict less rainfall in the Mediterranean, southwest North America, and southern Africa.
       iii. Earth will receive increased precipitation in some areas. More precipitation is predicted in Alaska and other high latitudes of the Northern Hemisphere and near the equator.
       iv. As global surface temperatures continue to increase, most areas on Earth will have warmer winter temperatures.
          1. Warmer winter temperatures mean that more precipitation falls as rain instead of snow. Snowpack will be reduced, and there will be less water stored in snow to supply watersheds.
          2. With warmer winters and spring-like temperatures coming earlier, snow is melting earlier, altering the timing of streamflow. The increased temperature in springtime increases evaporation from surface water bodies, reducing overall streamflow. This generally means that less water is available during late spring and summer months when demand is highest for crops, livestock, and general public use.
12. To answer question 1 on page 2 of the handout, ask students to explain how these changes to the water cycle will affect humans [possible answers: less water available for crops, livestock, and general public use; less food available because of decreased water supply for crops and livestock and increased water temperatures in fisheries; loss of

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life and property due to flooding and more extreme weather events; increased soil erosion due to flooding and drought; less snow for recreation; changes in ability to produce hydroelectric power because of changes in streamflow].

13. **Slide 9**: Instruct students to think in more detail about mitigation and adaptations to the effects of climate change on the water cycle. Guide them to fill in the table in question 2 on page 2 of the handout. Ask them to choose three effects from the game table and give an example of an action that could be taken to respond to each effect. Students may need guidance on this table. Refer to the Answer Key for example solutions to the effects modeled in the board game. Possibly facilitate a whole-class discussion surrounding these solution-based actions.

EXTENSIONS

1. Students read the National Public Radio (NPR) article from "All Things Considered" and by Christopher Joyce, "There's a Big Leak in America's Water Tower," and answer the associated questions.
2. Have students take action to conserve water by developing and implementing a water education campaign for their community, a water conservation plan for their home or school, or a similar action project of their choice.

ADDITIONAL RESOURCES

1. Websites with background information about the effects of climate change on the water cycle:

Environmental Protection Agency (EPA), Water Resources. Climate Impacts on Water Resources. Updated 21 Dec. 2025. Web. Accessed 14 Jul. 2026. <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources_.html>.

National Aeronautics and Space Administration (NASA), Earth Observatory. The Water Cycle and Climate Change. Web. Accessed 14 Jul. 2026. <http://earthobservatory.nasa.gov/Features/Water/page3.php>.

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Name _____ Date _____

Effects of Climate Change on the Water Cycle

DIRECTIONS

Please read the excerpt below and use your knowledge of the water cycle to make predictions about the effects of climate change on the water cycle.

The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.

Increased evaporation may dry out some areas and fall as excess precipitation on other areas. Over the past 50 years, the amount of rain falling during the most intense 1% of storms increased by almost 20%.

Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas.

Excerpted from: EPA - Climate Impacts on Water Resources
www.epa.gov/climatechange/impacts-adaptation/water.html#watercycles

PREDICTIONS

Using the excerpt above and your knowledge of the water cycle and processes like evaporation, what do you think some of the effects of climate change are on the water cycle?

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Name _____ Date _____

Effects of Climate Change on the Water Cycle

DIRECTIONS

Please follow the rules below to play a round of Streams and Steam with your group, and answer the questions.

RULES OF PLAY

1. Roll the die to determine who starts the game.
2. Player who rolls the highest number plays first.
3. Players follow in turn from left to right.
4. All players begin with their coin on the start space.
5. Roll die and move the coin the number of spaces indicated.
6. When a player lands on a square at the TOP of a stream, the player will "raft" down the stream by moving their coin down to the square at the bottom of the stream.
7. When a player lands on a square at the BOTTOM of a column of steam, the player will rise up the steam column by moving their coin up to the square at the top of the steam column.
8. The squares without pictures are regular squares and do not require any further action.
9. Two or more players may stop at the same square together.
10. The first player to cross into the finish space wins the game; an exact roll of the die is not required to win.

QUESTIONS

1. List all of the causes and effects that you and your group members land on when you go down a stream and/or up a column of steam while playing Streams and Steam. Only write each pair of causes and effects **once** if it is landed on multiple times. For each cause and effect pair, choose one or more action types (from the Key of Action Types) that could be taken in response.

   Write the corresponding letter for your chosen action type(s).You may choose more than one action type.

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Key of Action Types

A) Water Conservation: use methods to decrease water use
B) Mitigating Climate Change: use methods to reduce greenhouse gas emissions
C) Risk Management Planning: follow procedures to avoid or minimize the impact of climate change

Cause	Effect	Action Type(s)
Example: Increased evaporation	More severe drought in some areas	A, B, C

2. Choose one of the effects from the table above. Explain how this change to the water cycle affects humans.

3. Choose three of the effects and actions from the game table. Fill out the table below and explain, more specifically, what actions could be taken to respond to each effect.

	Effect	Action Type	Example Action
	Example: More severe drought in some areas	A) Water Conservation	Xeriscaping (landscaping to minimize water use)
1			
2			
3			

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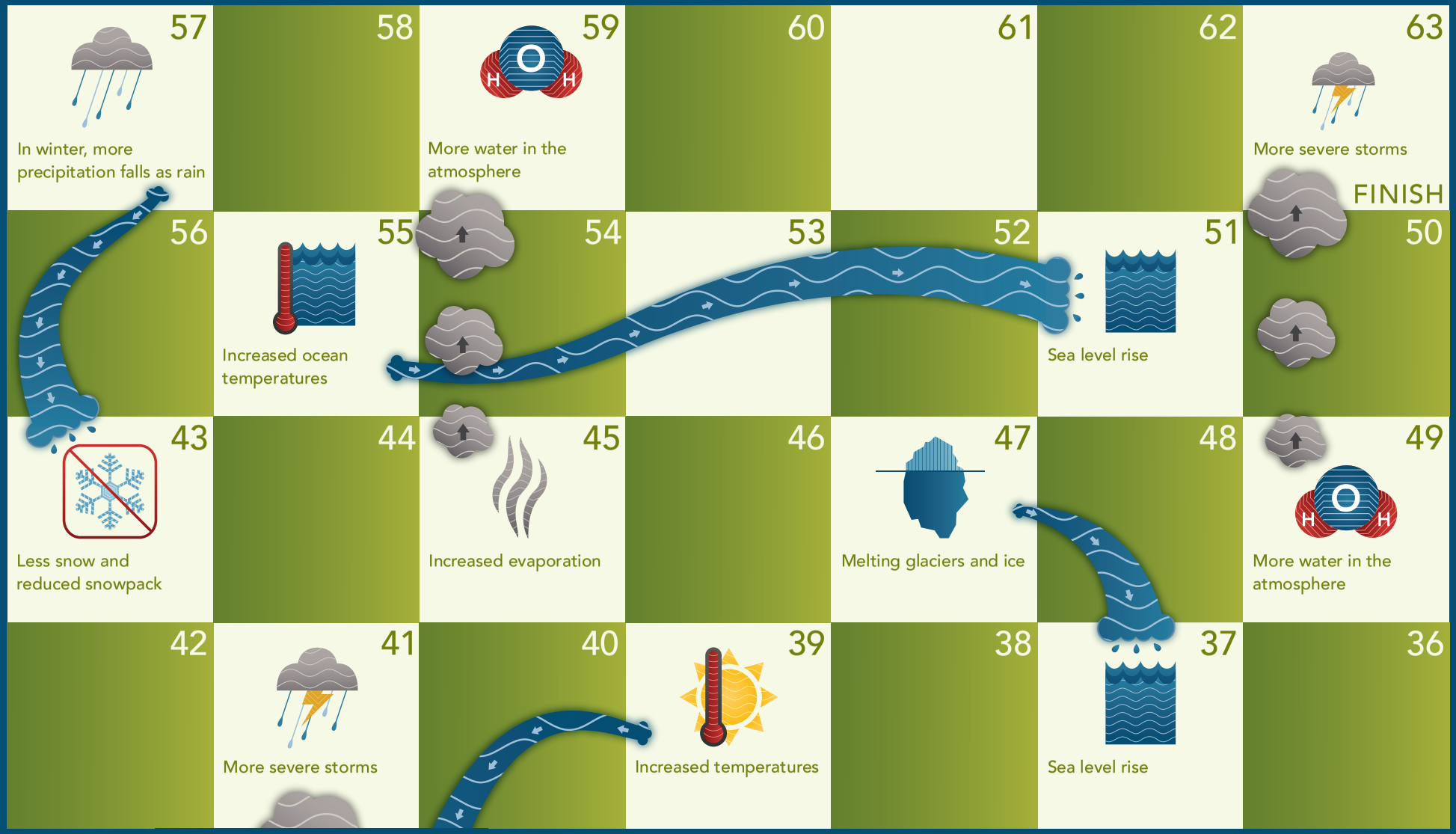
STREAMS AND STEAM

EFFECTS OF CLIMATE CHANGE ON THE WATER CYCLE



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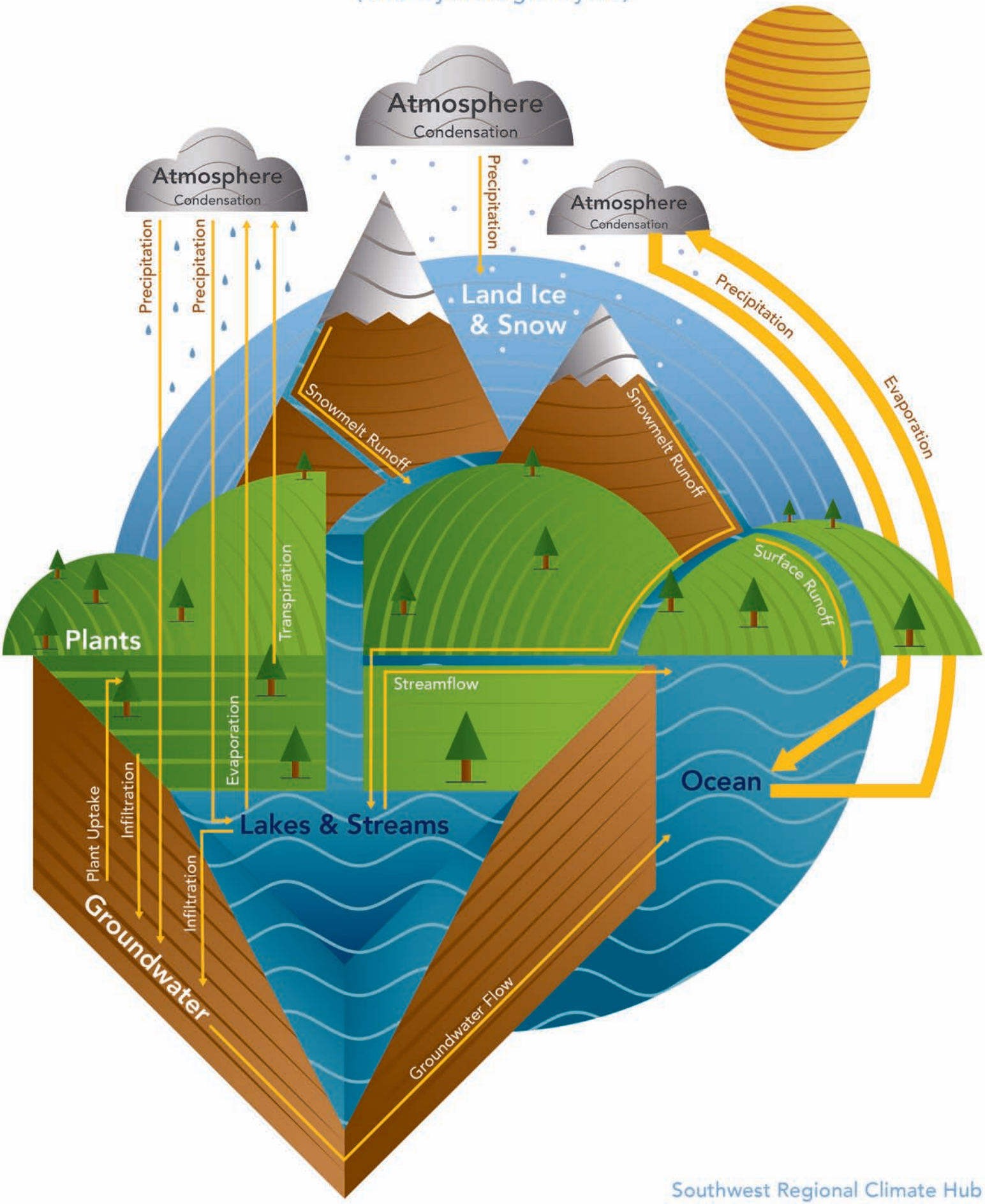
THE WATER CYCLE
(The Hydrologic Cycle)



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THERE'S A BIG LEAK IN AMERICA'S WATER TOWER

by **CHRISTOPHER JOYCE**, NPR, All Things Considered

Source: www.npr.org/2014/08/27/341372550/theres-a-big-leak-in-americas-water-tower

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An earlier spring in Montana's Glacier National Park means full waterfalls at first – but much drier summers. *Robert Glusic/Corbis*

The northern arm of the Rocky Mountains is sometimes called "the crown of the continent," and its jewels are glaciers and snowfields that irrigate large parts of North America during spring thaw.

But the region is getting warmer, even faster than the rest of the world. Scientists now say warming is scrambling the complex relationship between water and nature and could threaten some species with extinction as well as bring hardship to ranchers and farmers already suffering from prolonged drought.

To see how this vast natural irrigation system works, it's best to fly over it. Seated next to Richard Hauer in a Cessna he calls "Montana Rose," I can see snowcapped mountains and wide valleys spread out below. Hauer, an ecologist at the University of Montana, calls this place a giant sponge.

Moist air from the Pacific hits the mountains and falls as snow and ice. The mountains hold that water until spring. Then it melts and runs through the gravel valleys and across big parts of North America.

It's worked that way for millennia. But lately, Hauer says, Montana is warmer, and spring's melt starts earlier. "When that happens, all that storage of snow and water in the high country will go through the system [the mountains and valleys] much faster," he explains. "It's a change that's taking place because the snowmelt is occurring earlier. ... Basically, if you turn the spigot on earlier, it runs out of water sooner."

Running out of water sooner means drier summers – just when plants, animals and people need it most.

Ecologists like Hauer say there are other changes happening as well – retreating glaciers, and more flash floods. "One of the expectations with climate change is that we're going to see a decrease in the permanent streams, particularly in the high alpine, and an increase in the temporary, ephemeral streams," Hauer says.

Already, scientists have noted the shrinking of the more than two dozen glaciers in Glacier National Park, as well as the disappearance of some snowfields that once lasted through summer.

Now they're trying to find out how this affects wildlife – wildlife that's important for holding together the complex food web here.

I join three scientists from the U.S. Geological Survey on a mountainside a couple of thousand feet below Hauer's flight path. We're hiking up into a snowfield in the park, toward a stream flowing down from the snow. "It's a great place to be if you are an obscure, high-alpine-stream insect," says aquatic entomologist Joe Giersch. Obscure insects are Giersch's life. Several species of very rare but important insects live here, in 40-degree meltwater.

Joe Giersch, an ecologist with the U.S. Geological Survey, studies stoneflies that live only in the melt from glaciers and snowpack in the northern Rockies. *Clint Muhlfeld/USGS*

Giersch bends over the stream – it's only a few inches deep – and turns over a few rocks. In 10 minutes, he finds what he wants: a tiny, brown, wet smudge of a fly. "All right! This is *Lednia tumana*." It's smaller than the head of a match and, to my eye, is just a brown blob. Giersch assures me that's what it is. "I've looked at a lot of these," he says. He calls the fly "charismatic microfauna."

Charismatic may be a stretch, but micro for sure. *Lednia tumana* is a stonefly. It spends part of its life in streams, but only icy streams in these mountains. It eats algae and other tiny organisms in the streams, and other insects and fish eat it. Stoneflies are part of a larger food web. Pull out one string, says our hiking companion, Daniel Fagre, and the web starts to come apart.

Lednia tumana is fish food that's long thrived in the glacier-fed streams of Montana's Glacier National Park. But as the glaciers are disappearing, so is the fly. *Joe Giersch/USGS*

"In only a few decades, we're going to lose all the glaciers here," says Fagre, a research ecologist with the USGS at the West Glacier Field Station. "And they've been persistent on the landscape here for 7,000 years – so suddenly you are having a profound change in just a few decades, and that's very difficult for many organisms to adapt to."

What's happening is that as the average temperature increases here, the snow and ice, in effect, retreat up the mountain to colder air. Ecologist Clint Muhlfeld, who also studies this fly, says eventually the ice and the insects will run out of mountain. "You know, there's nowhere to go," he says. "They're at the top of the continent – the water tower of the continent – and it's a squeeze play." Muhlfeld notes that the federal government is considering listing *Lednia* as an endangered species because of the effects of climate change.

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Moving farther down the mountain, you can see more signs of this disruption in the way water works here – in places like Montana's Flathead Lake, for example, one of the biggest lakes in the country.

Jack Stanford, who runs the Flathead Lake Biological Station, has spent decades studying the complex interactions of plants, animals and water. "The way in which water is deposited first and then transported by the rivers is fundamental to the distribution and abundance of organisms," he says.

SAVING ONE SPECIES AT THE EXPENSE OF ANOTHER

Some of those organisms – for instance, salmon – are important, not only to nature but to people too.
If you get a warmer spring, you get flash floods, because the rain comes in before the snow has melted. It's called a "rain on snow event," and it can be trouble for salmon, which lay eggs in the gravel of stream beds. Rain on snow is like rain falling on pavement – it creates floods that wash the young salmon away, decimating the population.

"The way it plays out is that the food web gets a shakeup," Stanford says. "And ... the bottom line is, some players in that complex food web will be winners, and some will be losers."

Stanford says humans have already changed the natural world in ways we couldn't predict. Climate change is like putting another pair of dice in play.

QUESTIONS

1. Explain in your own words what ecologist Richard Hauer means when he says, "if you turn the spigot on earlier, it runs out of water sooner."

2. What is happening to stoneflies in the northern Rockies? Why?

3. How will changes to stonefly populations affect insects and fish that eat stoneflies?

4. Explain how the loss of 7,000-year-old glaciers over the course of a few decades may cause difficulties for organisms in the northern Rockies.

5. How are flash floods detrimental to salmon populations?

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ANSWER KEY

Effects of Climate Change

on the Water Cycle

DIRECTIONS

Please read the excerpt below and use your knowledge of the water cycle to make predictions about the effects of climate change on the water cycle.

> The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between. Warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.
>
> Increased evaporation may dry out some areas and fall as excess precipitation on other areas. Over the past 50 years, the amount of rain falling during the most intense 1% of storms increased by almost 20%.
>
> Warming winter temperatures cause more precipitation to fall as rain rather than snow. Furthermore, rising temperatures cause snow to begin melting earlier in the year. This alters the timing of streamflow in rivers that have their sources in mountainous areas.
>
> Excerpted from: EPA - Climate Impacts on Water Resources
> *www.epa.gov/climatechange/impacts-adaptation/water.html#watercycles*

PREDICTIONS

Using the excerpt above and your knowledge of the water cycle and processes like evaporation, what do you think some of the effects of climate change are on the water cycle?

Student answers will vary but may include some of the following:

- *Higher rate of evaporation of water into the atmosphere because of warmer surface, air, and water temperatures*
- *Changing precipitation patterns – more precipitation in some areas and less in others, more severe storms*
- *More precipitation falls as rain instead of snow because of warmer winter temperatures*
- *Snow is melting earlier, which alters the timing of streamflow and reduces the availability of water during the late spring and summer months when demand is highest*
- *Sea level rise because of increased water temperatures and melting glaciers and ice*

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ANSWER KEY

Effects of Climate Change *on the Water Cycle*

DIRECTIONS

Please follow the rules below to play a round of Streams and Steam with your group, and answer the questions.

RULES OF PLAY

1. Roll the die to determine who starts the game.
2. Player who rolls the highest number plays first.
3. Players follow in turn from left to right.
4. All players begin with their coin on the start space.
5. Roll die and move the coin the number of spaces indicated.
6. When a player lands on a square at the TOP of a stream, the player will "raft" down the stream by moving their coin down to the square at the bottom of the stream.
7. When a player lands on a square at the BOTTOM of a column of steam, the player will rise up the steam column by moving their coin up to the square at the top of the steam column.
8. The squares without pictures are regular squares and do not require any further action.
9. Two or more players may stop at the same square together.
10. The first player to cross into the finish space wins the game; an exact roll of the die is not required to win.

QUESTIONS

1. List all of the causes and effects that you and your group members land on when you go down a stream and/or up a column of steam while playing Streams and Steam. Only write each pair of causes and effects **once** if it is landed on multiple times. For each cause and effect pair, choose one or more action types (from the Key of Action Types) that could be taken in response. Write the corresponding letter for your chosen action type(s).You may choose more than one action type.

Key of Action Types

A) Water Conservation: use methods to decrease water use
B) Mitigating Climate Change: use methods to reduce
C) Risk Management Planning: follow procedures to a
of climate change

Student answers will vary but may include any or all of these answers

CAUSE	EFFECT	ACTION TYPES
Example: Increased evaporation	*More severe drought in some areas*	*A, B, C*
Increased evapotranspiration	*More water in the atmosphere*	*A, B*
Increased ocean temperatures	*More severe storms*	*B, C*
Reduced precipitation and decreased soil moisture in some areas	*Reduced groundwater availability*	*A, B, C*
More intense precipitation in some areas	*Flooding in some areas*	*B, C*
Decreased precipitation in spring	*More severe drought in some areas*	*A, B, C*
Increased temperatures	*Decreased soil moisture because of evaporation*	*A, B*
Increased evaporation	*More water in the atmosphere*	*B*
Melting glaciers and ice	*Sea level rise*	*B, C*
More water in the atmosphere	*More severe storms*	*B, C*
Increased ocean temperatures	*Sea level rise*	*B, C*
In winter, more precipitation falls as rain	*Less snow and reduced snowpack*	*A, B, C*

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2. Choose one of the effects from question #1. Explain how this change to the water cycle affects humans.

- *More severe drought in some areas: less water available for crops, livestock, and general public use*
- *More water in the atmosphere: will lead to increased precipitation and flooding in some areas, which could result in property damage and human health effects; also, water vapor is a greenhouse gas, so more water in the atmosphere further enhances the greenhouse effect and changes the climate*
- *More severe storms: property damage, human health effects, loss of life*
- *Reduced groundwater availability: less water available for crops, livestock, and general public use*
- *Flooding in some areas: property damage, human health effects, loss of life*
- *Decreased soil moisture because of evaporation: less water available for crops, increased soil erosion, which could result in fewer nutrients available for crops*
- *Sea level rise: erosion of beach sand and reduction of recreation opportunities and impact to the tourism economy, property damage, displacement of waterfront and island property owners, loss of life*
- *Less snow and reduced snowpack: less water stored in snow to supply watersheds (so less water available for crops, livestock, and general public use), reduction of recreational opportunities and impact to the tourism economy*

3. Choose three of the effects and actions from the game table. Fill out the table below and explain, more specifically, what actions could be taken to respond to each effect.

Student answers will vary but may include any or all of these answers

	Effect	Action Type	Example Action
	Example: More severe drought in some areas	*A) Water Conservation*	*Keriscaping (landscaping to minimize water use)*
1	*More severe storms*	*C*	*Outline emergency plans for response in vulnerable areas*
2	*Flooding in some areas*	*B*	*Install energy efficient appliances to reduce greenhouse gas emissions and reduce likelihood of future flooding*
3	*Reduced groundwater availability*	*A*	*Install water efficient appliances at home*

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ANSWER KEY

THERE'S A BIG LEAK IN AMERICA'S WATER TOWER

by **CHRISTOPHER JOYCE**, NPR, All Things Considered

Source: www.npr.org/2014/08/27/341372550/theres-a-big-leak-in-americas-water-tower

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An earlier spring in Montana's Glacier National Park means full waterfalls at first – but much drier summers. *Robert Glusic/Corbis*

The northern arm of the Rocky Mountains is sometimes called "the crown of the continent," and its jewels are glaciers and snowfields that irrigate large parts of North America during spring thaw.

But the region is getting warmer, even faster than the rest of the world. Scientists now say warming is scrambling the complex relationship between water and nature and could threaten some species with extinction as well as bring hardship to ranchers and farmers already suffering from prolonged drought.

To see how this vast natural irrigation system works, it's best to fly over it. Seated next to Richard Hauer in a Cessna he calls "Montana Rose," I can see snowcapped mountains and wide valleys spread out below. Hauer, an ecologist at the University of Montana, calls this place a giant sponge.

Moist air from the Pacific hits the mountains and falls as snow and ice. The mountains hold that water until spring. Then it melts and runs through the gravel valleys and across big parts of North America.

It's worked that way for millennia. But lately, Hauer says, Montana is warmer, and spring's melt starts earlier. "When that happens, all that storage of snow and water in the high country will go through the system [the mountains and valleys] much faster," he explains. "It's a change that's taking place because the snowmelt is occurring earlier. ... Basically, if you turn the spigot on earlier, it runs out of water sooner."

Running out of water sooner means drier summers – just when plants, animals and people need it most.

Ecologists like Hauer say there are other changes happening as well – retreating glaciers, and more flash floods. "One of the expectations with climate change is that we're going to see a decrease in the permanent streams, particularly in the high alpine, and an increase in the temporary, ephemeral streams," Hauer says.

Already, scientists have noted the shrinking of the more than two dozen glaciers in Glacier National Park, as well as the disappearance of some snowfields that once lasted through summer.

Now they're trying to find out how this affects wildlife – wildlife that's important for holding together the complex food web here.

I join three scientists from the U.S. Geological Survey on a mountainside a couple of thousand feet below Hauer's flight path. We're hiking up into a snowfield in the park, toward a stream flowing down from the snow. "It's a great place to be if you are an obscure, high-alpine-stream insect," says aquatic entomologist Joe Giersch. Obscure insects are Giersch's life. Several species of very rare but important insects live here, in 40-degree meltwater.

Joe Giersch, an ecologist with the U.S. Geological Survey, studies stoneflies that live only in the melt from glaciers and snowpack in the northern Rockies. *Clint Muhlfeld/USGS*

Giersch bends over the stream – it's only a few inches deep – and turns over a few rocks. In 10 minutes, he finds what he wants: a tiny, brown, wet smudge of a fly. "All right! This is *Lednia tumana*." It's smaller than the head of a match and, to my eye, is just a brown blob. Giersch assures me that's what it is. "I've looked at a lot of these," he says. He calls the fly "charismatic microfauna."

Charismatic may be a stretch, but micro for sure. *Lednia tumana* is a stonefly. It spends part of its life in streams, but only icy streams in these mountains. It eats algae and other tiny organisms in the streams, and other insects and fish eat it. Stoneflies are part of a larger food web. Pull out one string, says our hiking companion, Daniel Fagre, and the web starts to come apart.

Lednia tumana is fish food that's long thrived in the glacier-fed streams of Montana's Glacier National Park. But as the glaciers are disappearing, so is the fly. *Joe Giersch/USGS*

"In only a few decades, we're going to lose all the glaciers here," says Fagre, a research ecologist with the USGS at the West Glacier Field Station. "And they've been persistent on the landscape here for 7,000 years – so suddenly you are having a profound change in just a few decades, and that's very difficult for many organisms to adapt to."

What's happening is that as the average temperature increases here, the snow and ice, in effect, retreat up the mountain to colder air. Ecologist Clint Muhlfeld, who also studies this fly, says eventually the ice and the insects will run out of mountain. "You know, there's nowhere to go," he says. "They're at the top of the continent – the water tower of the continent – and it's a squeeze play." Muhlfeld notes that the federal government is considering listing *Lednia* as an endangered species because of the effects of climate change.

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Moving farther down the mountain, you can see more signs of this disruption in the way water works here – in places like Montana's Flathead Lake, for example, one of the biggest lakes in the country.

Jack Stanford, who runs the Flathead Lake Biological Station, has spent decades studying the complex interactions of plants, animals and water. "The way in which water is deposited first and then transported by the rivers is fundamental to the distribution and abundance of organisms," he says.

SAVING ONE SPECIES AT THE EXPENSE OF ANOTHER

Some of those organisms – for instance, salmon – are important, not only to nature but to people too.
If you get a warmer spring, you get flash floods, because the rain comes in before the snow has melted. It's called a "rain on snow event," and it can be trouble for salmon, which lay eggs in the gravel of stream beds. Rain on snow is like rain falling on pavement – it creates floods that wash the young salmon away, decimating the population.

"The way it plays out is that the food web gets a shakeup," Stanford says. "And ... the bottom line is, some players in that complex food web will be winners, and some will be losers."

Stanford says humans have already changed the natural world in ways we couldn't predict. Climate change is like putting another pair of dice in play.

QUESTIONS

1. Explain in your own words what ecologist Richard Hauer means when he says, "if you turn the spigot on earlier, it runs out of water sooner."

   Snowmelt is happening earlier because of warmer temperatures. Because streams are flowing sooner, there is no longer water available throughout the season. Summers are drier, and that is when humans, plants, and animals need water the most.

2. What is happening to stoneflies in the northern Rockies? Why?

   Their populations are declining, and they may be listed as an endangered species. Their habitat is disappearing with the melting snow and ice because of warmer temperatures.

3. How will changes to stonefly populations affect insects and fish that eat stoneflies?

   As populations of stoneflies decrease, populations of their predators may also decrease unless there are other prey items available.

4. Explain how the loss of 7,000-year-old glaciers over the course of a few decades may cause difficulties for organisms in the northern Rockies.

   Because local organisms are adapted to live in glacier ecosystems, they will have difficulties as the climate changes relatively quickly. Organisms that are able may attempt to move up mountains to higher elevations and cooler temperatures, but they will run out of space if warming continues. Some species are unable to move, and they could face decreasing population sizes and possible extinction.

5. How are flash floods detrimental to salmon populations?

   Flash floods carry away young salmon, which results in a lack of juveniles to grow into adults.

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