

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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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 greenhouse gas emissions
- C) Risk Management Planning: follow procedures to avert or reduce the negative impacts of climate change

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

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

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.

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

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

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.

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.