

Unit	Human Impacts
Lesson	4.3 Understanding climate change
Essential question	How does climate change affect a stream ecosystem?
Objective	Students will be able to explain the mechanisms of climate change and how its effects can be minimized on stream ecosystems.
Key words	Greenhouse effect, enhanced greenhouse effect, climate change, climate change adaptation, thermal refuge, climate change mitigation
Related Standards	
NGSS standard	HS-ESS3-5
AP Env Sci topic	9.3, 9.4, 9.5
IB Biology topic	D4.3
IB ESS topic	6.2, 6.3
Suggested sequence of learning activities	<ol style="list-style-type: none"> 1. Starter quiz/prior knowledge check 2. Direct instruction (if traditional) or classroom discussion (if flipped). Slides here. 3. Students do hard copy carbon cycle activity. Sheet here. 4. Peers (or teacher) checks work 5. Students do on-line stream temperature data gathering and graphing. Instructions here.
Assessment	Exit ticket/comprehension check
Possible modifications	<ul style="list-style-type: none"> ● Give a keyword list (with or without definitions already included) to students before or during class ● Be intentional about student pairings (eg. heterogeneous skill levels) ● Lay out the boxes and arrows on the carbon cycle diagram and have the students label them only ● Choose fewer data points for the stream temperature data activity
Resources required	<p>Hard copies of the Carbon cycle student activity along with blank paper, scissors and glue sticks</p> <p>Internet access/computer for each student; hard copies or electronic access to student worksheet</p>

<p>Starter questions</p>	<ol style="list-style-type: none"> 1. What are two ways that climate change might affect a river ecosystem? 2. Why might fish be more vulnerable to climate change than mammals on land?
<p>Concepts covered in lesson</p>	<p>The greenhouse effect is a natural process by which certain gases in the atmosphere including carbon dioxide, methane, some nitrogen oxides and water vapor absorb infrared radiation (heat) that is emitted from the earth and sun, warming the atmosphere and surface of the planet. The enhanced greenhouse effect is a magnification of this process due to the anthropogenic (human-caused) increased emissions of greenhouse gases, primarily carbon dioxide and methane.</p> <p>Many human activities increase the amount of greenhouse gases in the atmosphere, but one of the most significant ones is the combustion of fossil fuels. Carbon is stored over the long term (hundreds of millions of years) inside of sedimentary rocks made of buried plant and animal material. This takes the form of coal, oil and natural gas. When humans mine and then combust fossil fuels for energy, carbon dioxide is released in the atmosphere at much greater rates than can be absorbed by natural processes such as photosynthesis. This increases the amount of carbon dioxide in the atmosphere, which absorbs more infrared radiation and causes climate change.</p> <p>This enhanced greenhouse effect is causing the climate to change, including:</p> <ul style="list-style-type: none"> ● Overall global air temperatures increase. ● Change in precipitation patterns including increased droughts in some areas and increased precipitation in others. ● More intense storms in terms of rainfall and wind speed. ● Overall ocean temperatures increase, causing thermal expansion and sea level rise. ● Ice caps melting. <p>Climate change can have a particularly detrimental effect on river habitats and trout in particular. Possible harms include:</p> <ul style="list-style-type: none"> ● Higher water temperatures can stress or kill cold water species like trout. ● Higher water temperatures can allow the introduction of invasive species that outcompete trout. ● Reduced precipitation can lead to drought and low water discharge rates. ● More intense storms can cause more frequent flooding events that can disrupt habitat. ● Some rivers are fed by glaciers which may disappear.

	<p>Steps taken to make habitats or people more resilient to climate change is called climate change adaptation. Many adaptations for more resilient river habitats are possible, including the following:</p> <ul style="list-style-type: none"> ● Connect rivers and headwaters so fish can move to find thermal refuges (places with cooler water temperatures during heat events). ● Increase riparian planting to maximize shade. ● Reduce the number of dams which can increase water temperatures and evaporation in reservoirs. ● Reduce the number of water diversions to keep the maximum amount of water in rivers for fish. <p>The most fundamental way to address climate change impacts is to attack the root cause by slowing the release of additional greenhouse gases into the atmosphere. This approach is called climate change mitigation.</p>
Slide presentation	Link here
Activities	<p>In class, students construct a hard copy carbon cycle, instruction here.</p> <p>In class, students gather and graph real-life on-line stream temperatures from the USGS website, instructions here.</p>
Exit ticket questions	<ol style="list-style-type: none"> 1. What are two common characteristics of an introduced species? 2. What is one common effect of an introduced species on an ecosystem? <p><u>Answers:</u></p> <ol style="list-style-type: none"> 1. <i>Fast growth/reproduction; lack of predators; can access a wide range of food</i> 2. <i>Outcompete native species resulting in a decrease in their population; alter habitat; can hybridize</i>
Extension questions/activities/resources	<p>Good climate change videos here (HHMI video 16 minutes) and here (Crash Course, 13 minutes).</p> <p>Have students define and find examples of positive and negative feedback loops as they relate to climate change.</p> <p>Have students research how scientists estimate temperatures in the past in order to build climate models.</p>

