CLIMATE CHANGE
Hudson River Impacts

Be sure to administer the pre-survey before facilitating the lesson.

Objectives and Standards		
Objectives • Describe the relationship between greenhouse gases and climate change. • Draw connections between the greenhouse gas effect and climate change impacts in the Hudson Valley. • Examine the climate change effects in the Hudson Valley by analyzing informational text.	***NYS P-12 Science and Engineering Practices*** • Asking questions and defining problems • Obtaining, evaluating, and communicating information	***NYS Next Generation ELA Anchor Standards*** • Writing Standard 5: Draw evidence from literary or informational texts to support analysis, reflection, and research.

Materials

- [ ] **Powerpoint - Climate Change: Hudson River Impacts**
- [ ] Pre-survey (1 copy per student)
- [ ] KWL Chart (optional)
- [ ] Fish Images (1 class set)
- [ ] **Online Hudson River Fish key**
- [ ] Modified excerpt from "Review of Climate Change Effects on Water Quality and Estuarine Biota of the NY & NJ Harbor & Estuary" (1 copy per student)
- [ ] Hudson River Fish and Climate Change worksheet (1 copy per student)

Engage (5 mins)

Show a photo of climate change impact in the Hudson Valley (slide 2 in PowerPoint) for the students to make observations. Possible ways to use this photo to begin the lesson are:

- Ask the students to Think, Pair, and Share with these prompts: I notice, I wonder, it reminds me of.
- Ask students to share the first word that comes to mind in response to seeing the photo.
- Use the attached chart, KWL (Know, Want to Know, Learned) chart and ask students to fill out the first 2 columns. You can also do this as a class.

Explore (10 mins)

We will explore some foundational climate change topics by watching a video.

If this is your students' first introduction to climate change use this **CO_2 + climate change video.**

Encourage the students to examine the different concepts raised in the video as you watch. Below are some recommendations for "check for understanding" questions that you can ask prior to each pause point:

- (0:43min) What are 3 greenhouse gases listed in the video?
- (1:30min) Can you think of things in your life that are similar to the greenhouse effect (i.e. cars heating up in the sun, garden greenhouse, blankets on a cold night, etc.)? Is the greenhouse effect *all* bad?
- (2:15min) How do scientists know what CO_2 concentrations in the atmosphere were like in the past?
- (2:35min) Why do you think we measure CO_2 in parts per million vs. percentage? 1ppm is 10,000 times smaller than 1 percent. Therefore, when discussing small amounts of something, like the relatively small amount of CO_2 in the atmosphere, it is easier to list it as 380ppm rather than 0.038%.
- (4:55min) Does climate change affect all people equally? Use this as an opportunity to bring up environmental and climate justice issues: the communities most at risk are located near the source of fossil fuel production and power generation, and tend to be lower income and/or minority communities.

For higher level students **this video** examines climate change through an environmental chemistry perspective.

Below are some recommendations for "check for understanding" questions that you can ask prior to each pause point:

- (1:20min) Do gases have mass? What is the force that keeps atmospheric gases from drifting out into space?
- (2:33min) In what form is most of the earth's energy received from the sun? Does infrared light heat up the atmosphere?
- (3:27min) As the earth warms up, it gives off heat radiation, in what form of radiation? What gases in the atmosphere trap this heat?
- (4:31) Before humans began burning fossil fuels, what was the amount of CO_2 in the atmosphere? (0.0028% CO_2 vs 21% O2)

Explain (5 mins)

Use the PowerPoint to reinforce the following points:

Greenhouse effect

- The atmosphere was created by the heat of the sun, the interchange of gases between plants and animals, and gravity.
- Most energy from the sun that reaches earth comes in the form of visible light. This light travels through the atmosphere and warms the earth's surface. The surface then radiates infrared heat radiation that is trapped by the greenhouse gases like CO_2, water vapor, and methane. This natural effect, which allows for life on the planet to exist, is exacerbated by the increase of greenhouse gases from burning fossil fuels, making the Earth too hot, causing climate change.

The relationship between CO_2 and temperature

- Scientists can examine ice core samples and other proxies to determine the levels of carbon dioxide in the atmosphere from 400,000 years ago. The level of CO_2 in the atmosphere is higher now at 380ppm than it has ever been.
- We can observe the direct relationship between temperature and CO_2: the more CO_2 there is in the atmosphere, the higher the temperature gets. Therefore, the more CO_2 and other greenhouse gases we emit through human activity, the higher the Earth's temperature becomes.

Phenology

- Phenology refers to the timing of plant and animal life cycle stages, such as when flowers bloom, birds migrate or when offspring are born. Many of these events are sensitive to changes in the climate and are indicators of changing climate.
- The next activity will look at the phenology of some fish in the Hudson River.

Expand/Elaborate (20 mins)

Let's take a look at how climate change is affecting the Hudson River right now. This activity will look at different fish species and how they are being impacted by climate change.

Divide students into groups of 3-5 students. Give each group a photo of a fish (see Fish Images). In their groups, students will use the **online Hudson River Fish key** to identify the species of fish from their photo. Students will then explore the impacts that climate change has on their species of fish by reading about their fish in the modified excerpt from "Review of Climate Change Effects on Water Quality and Estuarine Biota of the NY & NJ Harbor & Estuary." (**full report link here**) They will complete the accompanying worksheet, Hudson River Fish and Climate Change. Time-permitting, students can present their findings to the class.

Before the "Evaluate" portion of the lesson, be sure to summarize the climate change impacts students have explored, and to remind them that climate change impacts people in the Hudson Valley, as well. Increasingly severe weather (e.g. storms, heat) cause damage to lives and property. Loss of tidal wetlands not only means a loss in biodiversity, but also less protection for us against storm surge. Warmer temperatures facilitate the spread of disease like Lyme disease and the Zika virus. Most importantly, climate change, much like other environmental problems, affects people of color and of lower income first and worst. It is then critical to involve these communities in climate solutions.

Evaluate (5 mins)

Possible ways to conclude the lesson are:

- Complete "Learned" part of the KWL chart.
- Use the presentations about the impacts of climate change on fish as an evaluation.
- Have students respond to the following question: Based on what you learned today, what are two ways in which climate change impacts you now/will impact you in the future?

Preview of Field Trip

If you're going on a field trip with Clearwater, give them a preview of what to expect! Activities on the upcoming field trip will allow students to explore ways in which we can collect data to monitor changes in the river environment due to climate change.

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MATERIALS

Climate Change Pre-Survey

Date: ______________________________

School: ______________________________

Grade: ______________________________

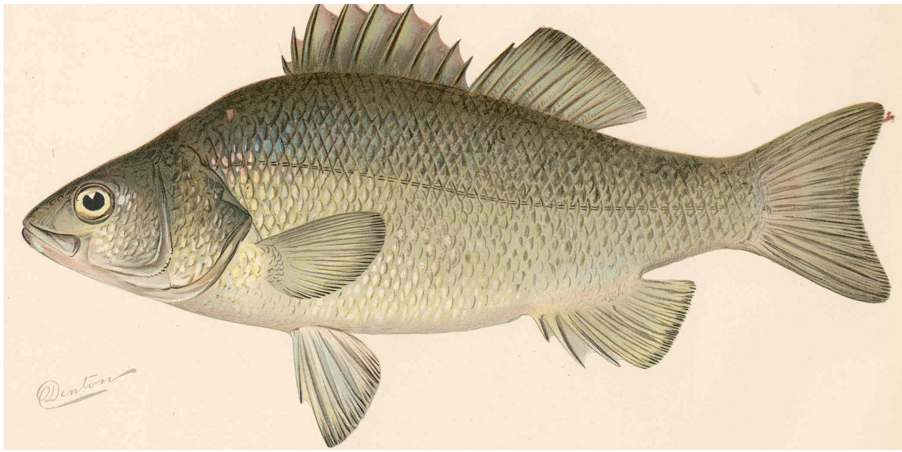
	1 = Not at All	*2 = A little*	*3 = Somewhat*	*4 = Yes*	*5 = Absolutely*
I am knowledgeable about environmental issues.					
I understand the causes of climate change.					
I know how climate change will affect my community and the Hudson River.					
I know what I personally can do to help address the causes of climate change.					
I feel prepared to talk with others about climate change and what we can do to address it.					

KWL Chart

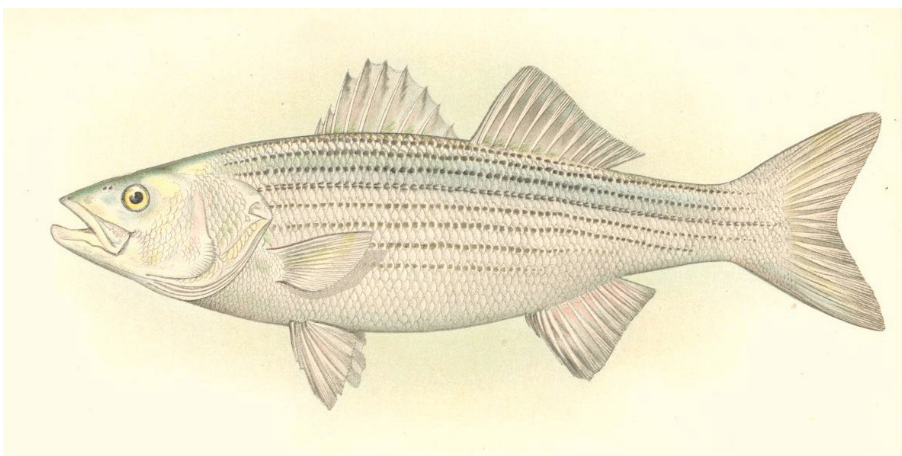
An example of how to set up a KWL chart. Students can fill this out independently or in small groups. This can be done as a class on a whiteboard or SmartBoard, as well.

Know	***Want to Know***	***Learned***

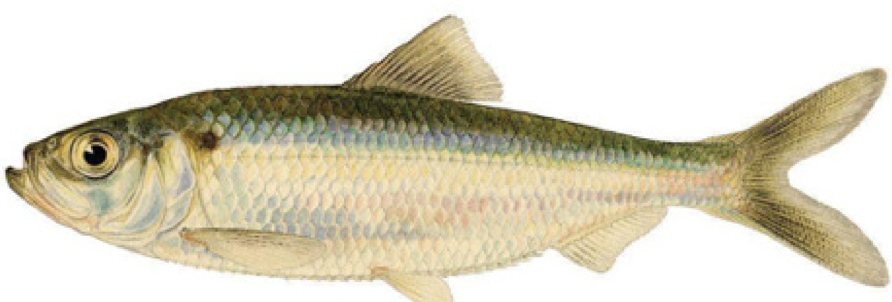
Fish Images



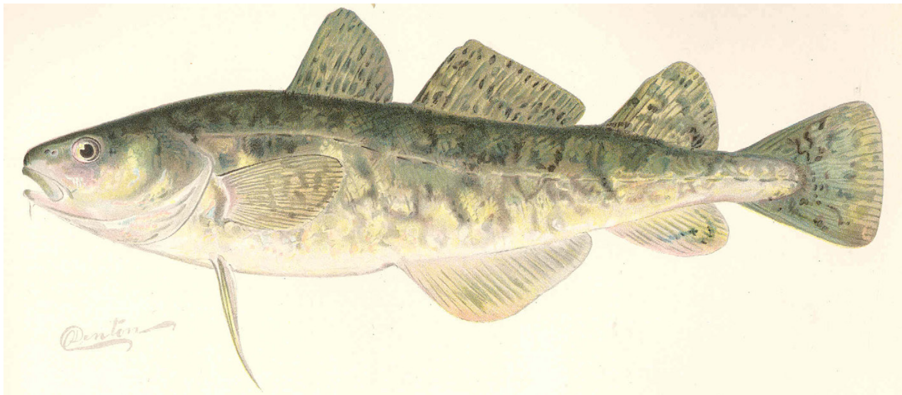
A



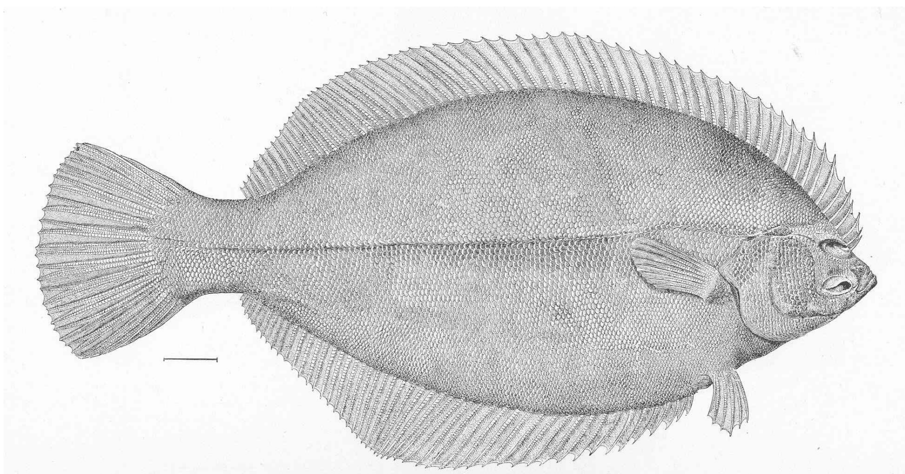
B



C



D



E

Key
A: White Perch
B: Striped Bass
C: River Herring
D: Atlantic Tomcod
E: Winter Flounder

Modified excerpt from "Review of Climate Change Effects on Water Quality and Estuarine Biota of the NY & NJ Harbor & Estuary"

Some notable patterns and observations of characteristic fish species in response to climate change in the Hudson Estuary include:

White perch *(Morone americana)* — A common resident species in the Harbor Estuary, white perch has shown particular resilience to climate change. This species can adjust how far it migrates and its distribution patterns **(where it lives)** because they can tolerate a variety of environmental conditions (Secor and Gallagher 2017). In recent years, climate change has altered the timing and extent of river flow **(the amount of freshwater from the watershed).** A zebra mussel (Dreissenia polymorpha) invasion of the upper (freshwater) portion of the tidal Hudson River in the early 1990s, while not climate change-related, reduced food availability for white perch, as well. These changes have altered the age/size structure **(how big they are compared to their age)** and distribution of the Harbor Estuary's white perch population. Overall, however, the white perch population remains stable, while several other species have declined over the same time period, and in response to similar climate change impacts and ecological changes.

Striped bass *(Morone saxatilis)* — Over the past several decades, striped bass movements and distribution **(where it lives)** in the Hudson River Estuary and New York Bight have been highly variable, depending on weather patterns, prey availability, river discharge **(how much freshwater is moving down the river at a time),** and population size/age structure **(how big they are compared to their age).** Climate change is likely to affect the amount of larval fish that reach adulthood of this species in future years (Waldman 2006, 2014). One climate-related change in striped bass ecology to date is that the beginning of striped bass spawning **(laying eggs)** has been observed to occur at an earlier period in the spring in the Hudson River Estuary and other mid-Atlantic estuaries because temperatures in these areas are getting warmer earlier (Kennedy et al. 2002). While the Hudson River striped bass stock is anticipated to remain stable overall, it is expected that spawning will continue to occur earlier as temperatures rise. It is also expected that striped bass populations will move north in future years, towards cooler water temperatures (Waldman 2014).

River herring – Alewife *(Alosa pseudoharengus)* and blueback herring *(Alosa aestivalis)*—collectively termed "river herring" populations in mid-Atlantic estuaries, including the NY/NJ Harbor Estuary are susceptible to warming water temperatures—adults may start to make their homes further out in the sea where it is cooler, resulting in longer migration periods for the fish to return to their spawning **(egg laying)** waters in coastal areas. The amount of larval river herring that reach adulthood is also strongly affected by spawning stream temperatures and river flow: the warmer the stream temperatures, the fewer larvae survive (O'Connor et al. 2012). Spawning times are also changing with rising water temperatures. Evidence of this in the NY region is provided by recent observations of unusually early (February) alewife spawning on the south shore of Long Island that correspond to warmer temperatures (Waldman 2014).

Atlantic tomcod *(Microgadus tomcod)* — Occupying a similar geographic range as smelt, tomcod tend to remain in estuaries rather than migrate offshore. Historically, tomcod were very abundant throughout the Harbor Estuary, and were reported as far south as the lower Chesapeake Bay (Virginia); however, there are no recent reports of spawning in any of the Atlantic coast areas south of the NY/NJ Harbor Estuary (Daniels et al. 2005). The Hudson river tomcod population is currently exhibiting a sharp decline; a contributing factor may be the rising water temperature of the river, particularly at the extreme southern portion of their distributional range **(where they live).** As with rainbow smelt, tomcod populations are also declining in nearby estuaries and coastal areas, including Long Island sound, where temperatures are also rising. It is expected that the Hudson River population will further diminish, and perhaps become extirpated **(no longer found in a particular area)** entirely in the coming decades (Daniels et al. 2005).

Winter flounder *(Pseudopleuronectes americanus)* — Prior to the late 1970s, winter flounder was one of the most abundant species sought after by inshore anglers throughout the Harbor Estuary and adjacent coastal waters. Within the past few decades, winter flounder have declined sharply throughout the southern portion of their range, from New Jersey to Rhode Island (Jefferies et al. 2011, Waldman 2014). Winter flounder spawn (lay eggs) in estuaries at temperatures ranging from 1-10°C, with optimal spawning conditions at 2-5°C... Brrr! The evolution of cold water spawning in winter flounder is considered to be a mechanism for avoiding predation on new larvae by sand shrimp *(Crangonidae)*, which actively feed during warmer seasons. Thus, as winter water temperatures become warmer, sand shrimp will be able to feed on winter flounder larvae - no more cold temperatures means no more protection for winter flounder larvae from predation. An increase in winter water temperatures in estuaries supporting winter flounder populations is potentially a critical threat to the amount of larval fish that reach adulthood because of increased susceptibility to this predation.

Warmer waters are also associated with greater egg mortality **(death)** rates in winter flounder and reduced larval growth rates (Keller and Klein-McPhee 2000). Winter flounder have historically exhibited long-term cyclical abundance patterns with periods of high and low abundance; however, periods of low abundance are now of longer duration and abundance peaks have diminished in recent decades.

Hudson River Fish and Climate Change

Your fish species: ____

What are some of the climate change impacts that will affect your species of fish (circle all that apply)

Food sources - prey availability

Increased susceptibility to predation

Changes in river flow (timing, how much it flows, etc.)

Increased temperature of spawning waters

Increased temperature of home waters

What are some of the responses to climate change that we can expect in your species of fish? (circle all that apply)

Changes in age/size

Changes in seasonal range/where it lives

Changes in spawning dates

Moving to colder water

Changes in migration patterns

Reduced larval growth rates and/or survival

Reduced survival

Overall, how will climate change affect your species population in the Hudson River?

Increase Decrease Stable

Would you say your fish species is/will be resilient to climate change? Why or why not?

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