Adapting to Climate Change

Objectives:
By the end of this activity, students will be able to:

1. Identify both natural and human-caused reasons for climate change.
2. Identify three key impacts climate change will have on wildlife.
3. Identify three ways in which wildlife managers are planning for climate change.
4. Identify potential climate change impacts on local species and create an action plan for helping protect these species.

Content areas:
Science, social studies

NC Essential Standards:
6.L.2.3, 7.E.1.1, 7.E.1.2, 7.E.1.6, 8.E.1.4, 8.L.3.1

Common core:
R1, R3, R8, S&L1, S&L4, W1

NGSS:
MS-ESS2.A, MS-ESS2C, ESS2.D, MS-ESS3.C, MS-ESS3.D, MS-LS2.A, MS-LS2.C, MS-ETS1.B.

Materials:

- ☐ Expert cards (one set per home group)
- ☐ Student sheets (one per student)
- ☐ Species cards (one species per home group)
- ☐ Chart paper

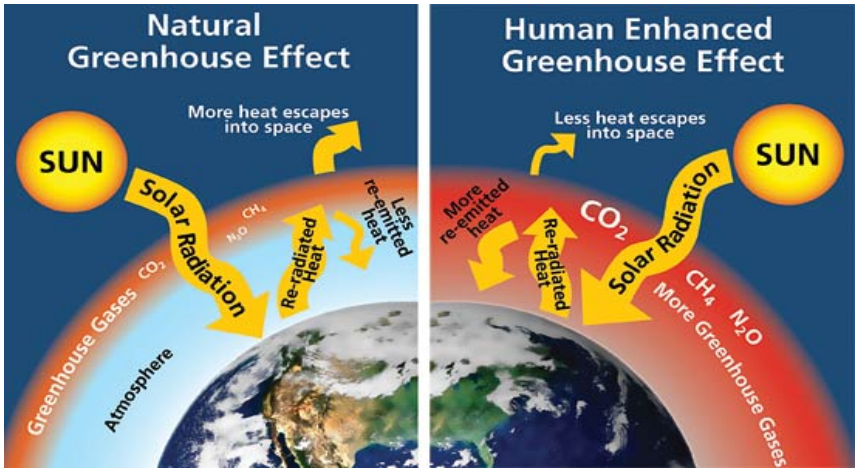
Activity Time:
One class period

Setting:
Classroom

Background:

The Earth's climate has changed for millions of years, fluctuating between ice ages and periods of warmer temperatures. Natural causes for climate change include changes in the tilt of the Earth's axis, changes in the reflectivity of the Earth's surface, changes in the sun's energy reaching Earth, volcanic activity, and natural changes in greenhouse gases. These changes occur over thousands of years.

These natural factors can contribute to both global warming and climate change, which are different things. **Global warming** refers to the average increase in temperature across the entire Earth's surface. There are other factors contributing to warming, but one of the main factors is changes in greenhouse gasses (see Natural Greenhouse Effect in the diagram below). Greenhouse gases act as a blanket over the Earth, trapping thermal radiation much like a blanket traps our body heat to keep us warm. We call this phenomenon the greenhouse effect because the atmosphere acts much like a greenhouse does, trapping the sun's radiation and keeping the planet warm. When the sun's radiation travels to Earth, most of it is absorbed by the Earth. Some of this radiation is released back into the atmosphere, and some of it is trapped by greenhouse gases, and then re-radiated in all directions further warming the planet. Without the greenhouse effect, the Earth would be much too cold for us and most other living organisms to survive. There are four main greenhouse gases – water vapor, carbon dioxide, methane, and nitrous oxide. Water vapor is the most abundant gas but only stays in the atmosphere for a short amount



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of time (a few days). Carbon dioxide is the next most abundant and stays in the atmosphere for the longest amount of time (30-100 years). Methane is about ten times better at trapping heat than carbon dioxide, but it dissipates faster (about ten years) and is less abundant. Nitrous oxide is the least abundant greenhouse gas and traps almost 300 times more heat than carbon dioxide and stays in the atmosphere for around 100 years.[1] Greenhouse gases are released into the atmosphere by natural processes. As these processes change over thousands of years, there are times when there are more greenhouse gasses in the atmosphere. When this happens, the heat trapping capacity of the atmosphere increases, and the average temperature across the Earth increases (global warming). Global warming is one of the factors that can cause **global climate change**. Climate change refers to any significant change in measures of climate for any given location lasting for an extended period of time. This includes major changes in temperatures, precipitation, or wind patterns, among others that occur over several decades or longer. The same changes can also be considered globally, and this is **global climate change**. Globally averaged increase in temperatures impacts many global processes. Increased temperatures impact global weather patterns, such as amounts and timing of precipitation and frequency and intensity of of severe weather such as thunderstorms, hurricanes, and winter storms. Warming can also melt glaciers and polar ice caps, which causes sea levels to rise and ocean currents to change.[2]

Although natural factors contribute to global warming and in turn, climate change, recent warming has occurred faster than ever recorded in the past. Changes over the last 100 years and those expected in the next 100 years can be attributed largely to human activities.[3] Since the industrial revolution, we have used fossil fuels like oil, coal, and natural gas to power our homes and businesses, fuel our cars and other transportation systems for food and commerce, and support life as we know it. We now understand with a 95% confidence level that the release of greenhouse gases by human activities in this short time period is the main cause of the recent warming trends we are seeing and expect to see continue into the future.[2] When we burn fossil fuels, they release greenhouse gases, enhancing the greenhouse effect.[4] Ice core data demonstrates that CO_2 levels varied between 180 and 270 parts per million over the million years preceding the industrial revolution, and then rapidly climbed to 400 parts per million by 2013.[5] Although other activities like raising livestock and energy production (e.g., natural gas leaks when producing and refining oil) can release methane and nitrous oxide which have more heat trapping potential, carbon dioxide makes up 82% of greenhouse gas emissions and remains in the atmosphere for up to a century. The high concentration of carbon dioxide paired with its long atmospheric lifetime makes it a target for many efforts to reduce our contributions to global warming. International treaties and meetings like the Koyoto Protocol and UN Summit on Climate Change have begun to help countries work together to reduce carbon emissions. Technological advances like more fuel-efficient cars, Energy Star appliances, and alternative energy sources are also helping reduce our emissions. These efforts by individuals, communities, and countries are encouraging. As mentioned above, sea level rise and increased occurrence of floods and droughts have been observed.[6] Because we are seeing some climate change impacts already, it is also important that we focus on **resiliency,** or ensuring our ability to thrive in a changing climate.

Climate change is also affecting wildlife, and we expect to see even more impacts in the future. Learning about these impacts helps wildlife managers make sure that wildlife is also resilient – able to survive and thrive in a changing climate. Three main effects that will have big impacts on wildlife are changing habitats, sea level rise, and shifts in the timing of seasons.[7] In the Appalachian Mountains, warmer regional temperatures are threatening the spruce-fir forest systems. These forests generally occur above 4,500 feet in elevation because they need cool temperatures to survive. These forest systems occur in Northern states, but as temperatures rise, they may disappear from North Carolina. Several species of wildlife depend on these habitats, so if the spruce-fir forests cannot survive in North Carolina, neither can the wildlife that lives there.[8] Sea level rise directly threatens beach and marsh habitats, as they may be flooded by sea water or eroded by storm surges.[9] As we start to experience warmer and shorter winters, the timing of events such as flower and leaf emergence and migration patterns are shifting. Since not all plants and animals are shifting their patterns

in sync, this can cause problems. One example is the relationship between winter moths and oak bud burst timing. Winter moths emerge in early winter and lay their eggs in tree canopies. The eggs get their cues from the lengthening spring days and emerge as the oak bud burst begins. If they hatch before the oak bud burst, they starve. If they hatch after bud burst, the caterpillars will have to eat less-digestible leaves. Since oak leaves take their cues from warming temperatures, warmer springs mean that oak trees are leafing earlier in the year. Because moths take their cues from lengthening days and oaks take their cues from temperature, a warmer spring can mean caterpillars hatch after oak bud burst, making it harder for them to get enough to eat.[10]

Wildlife managers are working hard to protect wildlife from these impacts. Wildlife managers can reduce risks to wildlife and protect the ability of wildlife to follow their habitat as climate change makes it move (e.g., up a mountain or inland from the ocean). Habitat destruction, fragmentation and degradation, disease, invasive species, and others threats also put wildlife populations at risk. By working to diminish the effects of these other threats and ensuring healthy habitat does exist, managers can help wildlife populations be more resilient to climate change. Adaptive management is a strategy in which managers continually gather data on wildlife and habitats. They use data to see if actions they take make positive changes for wildlife like improving survival or reproduction rates. Because they continuously collect data, they can test out new actions if old ones are not making wildlife populations more resilient to climate change. Wildlife managers need help, and often work with other groups using collaboration, citizen science and education efforts. Education and public outreach not only help wildlife managers do their jobs; they help ensure we are all prepared with the knowledge and awareness to do our part protecting wildlife.

Getting ready:

1. Prepare grouping assignments. Students should be assigned to a "home" group. Each home group should have at least six students. Each student in a home group should be assigned a letter A-F, which will be used to place students in "expert" groups during the activity.
2. Make enough copies of expert cards (A-F) so each student in an expert group has a copy of their topic.
3. Make enough copies of the "Adapting to Climate Change" student sheet for each group to have one.
4. Make enough copies of Species Cards (Appendix A) so that each student in a home group has a copy of their assigned species.

Procedure:

1. Review with the class key topics from previous lessons:
    a. Weather and climate both affect wildlife.
    b. Regional climate determines the amount and timing of precipitation and temperature, which affects the vegetation and wildlife that can live in an area.

2. Discuss with students that the climate is changing. Discuss how the climate changes due to both natural causes (e.g., volcanic activity, tilting of the Earth) and human activities (emissions of greenhouse gases). Briefly explain the concept of greenhouse gases. There are four main gases (water vapor, carbon dioxide, methane, and nitrous oxide) that act as a blanket in our atmosphere. Each of these has a different heat trapping potential and lifetime in the atmosphere. Without any greenhouse gases, it would be too cold for life to survive on Earth. However, if we have too much greenhouse gases in the atmosphere, the Earth warms. One of the most common sources of greenhouse gases is burning fossil fuels (gasoline for our cars, coal for our power plants, etc.). This releases carbon dioxide, which has one of the lower heat trapping potentials. However, carbon dioxide stays in the atmosphere for a long time and makes up 82% of greenhouse gas emissions, which is why it is most often targeted as a way to reduce our impact on global warming. Rising global temperatures are causing changes to

regional climates worldwide.

3. Explain that today's activity will explore some of the impacts that climate change will have on wildlife and some of the ways managers and citizens can help protect these wildlife.

4. Organize the students into groups of six. This will be students' home groups. Assign each group member a letter A-F. Now ask students to reorganize into groups based on their letters. This will be students' expert groups. Each expert group will learn about one of the following topics.
    A. Sea level rise
    B. Transforming habitats
    C. Changing seasonal cues
    D. Adaptive management
    E. Collaboration
    F. Habitat conservation and restoration

5. Give each expert group copies of the information sheet of their topic (one for each student).

6. Give each expert group 10 minutes to read over the sheet, ask questions of one another, discuss the key questions, and prepare to report out to other students.

7. Now have students return to their home groups. There should be at least one expert for each topic present in each home group.

8. Have each expert report out on their findings to their home group members.

9. Assign each home group one species (from Appendix A). Each group member should have a copy of the species card for the species assigned to their group.

10. Have group members work through the student sheet "Adapting to Climate Change" to brainstorm ways in which climate change may impact their species as well as strategies that wildlife managers and communities may use to help protect this species.

11. Ask students to record their plan on chart paper to present to the class.

Discussion and assessment

1. At the end of class, have students present the risks to their species as well as a plan for action. If time permits, have students create a poster or other visual presentation.
2. Consider having students create formal presentations and invite community members to the presentation.

Extensions

1. Invite a representative from your state's wildlife agency to come speak with your class about what he or she does, the role the agency plays in caring for wildlife, and discussions around how to plan for climate change.
2. Check with your wildlife agency for classes, workshops, and other resources.
3. Have students write an argument defending their action plan choice.

Sources and other resources

[1] US EPA. (2014). Nitrous Oxide Emissions. Retrieved December 03, 2014, from http://www.epa.gov/climatechange/ghgemissions/gases/n2o.html

[2] National Aeronautics and Space Administration. (2014). Climate Change: Vital Signs of the Planet: How do we know? *Global Climate Change: Vital Signs of the Planet*. Retrieved October 27, 2014, from http://climate.nasa.gov/evidence/

[3] IPCC. (2014). Summary for Policy Makers. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadne, K. Seyboth, … J. C. Minx (Eds.), *Climate Change 2014, Mitigation of Climate Change*. Cambraige, U.K. and N.Y., USA: Cambridge University Press. *(also see this video summarizing the report: https://www.youtube.com/watch?v=XnUXqhMS2bo)*

[4] US EPA Climate Change Division. (2014). Greenhouse Gas Emissions: Greenhouse Gases Overview. Retrieved from http://www.epa.gov/climatechange/ghgemissions/gases.html

[5] National Oceanic and Atmospheric Administration. (2014). Ice Core | National Climatic Data Center (NCDC). Retrieved November 03, 2014, from http://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/ice-core

[6] National Climate Assessment. (2014). Retrieved November 21, 2014, from http://nca2014.globalchange.gov/

[7] National Fish, Wildlife and Plants Adaptation Partnership. (2012). *National Fish, Wildlife and Plants Climate Adaptation Strategy*. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, DC. Retrieved from http://www.wildlifeadaptationstrategy.gov/pdf/NFWPCAS-Final.pdf

[8] North Carolina Wildlife Resources Comission. (2014). Spruce-Firt Forest in Southern Blue Ridge Mountains. Retrieved from http://www.southernhighlandsreserve.org/LiteratureRetrieve.aspx?ID=125485&A=SearchResult&SearchID=387429&ObjectID=125485&ObjectType=6

[9] National Wildlife Federation. (2014). Global Warming Impacts on Estuaries and Coastal Wetlands. Retrieved October 27, 2014, from http://www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Effects-on-Wildlife-and-Habitat/Estuaries-and-Coastal-Wetlands.aspx

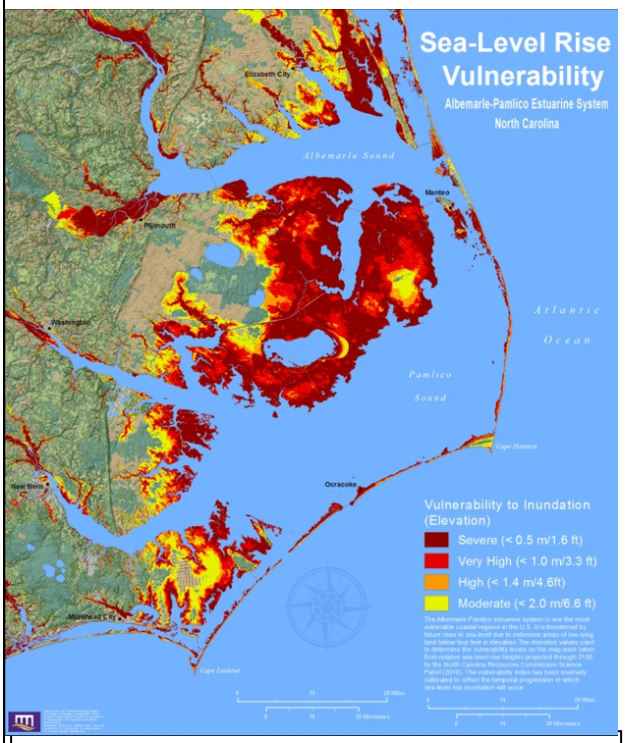
[10] Visser, M. E., & Holleman, L. J. (2001). Warmer springs disrupt the synchrony of oak and winter moth phenology. *Proceedings B of the Royal Society*, *268*(1464), 289–94. doi:10.1098/rspb.2000.1363

Expert Cards

A: Sea level rise

As average global temperatures rise, glaciers and polar ice caps are melting. The water that was previously trapped on land flows into the ocean raising ocean levels. Also, as water warms, it expands. This expansion is too small for us to observe with our eyes, but when you consider all the water in all the oceans, even a little expansion can lead to a big change. Both increases in water in the ocean from melting glaciers and the expanding volume of all water in the ocean contribute to the rising sea levels we are experiencing. Because of the topography of the shorelines, not all areas are experiencing sea level rise at the same rate. In North Carolina, we have experienced about one foot in sea level rise since 1930, and we expect about two to three additional feet in the next 100 years.

Piping plovers nest in sandy dunes and beaches.
Photo by U.S. Fish & Wildlife Service



http://www.ecu.edu/renci/focus/SeaLevelRise.html

Along coastlines, sea level rise can have big impacts on wildlife. As the ocean rises, it can erode beaches and flood salt water marshes. Also, higher water levels mean that storm surges from hurricanes or other strong storms can create more flooding. Higher water level and more flooding can damage nesting sites for wildlife like the piping plover, sea turtle, or diamondback terrapin. The rising salt water can also increase the salinity in areas that contain brackish water (a mix of salt and fresh water). The changing salinity can change which types of vegetation can survive and grow in the new saltier marshes. Normally, as sea levels rise, marshes would simply move further inland. However, this may not happen in some places because agricultural lands, housing, and businesses will form barriers to the natural inland movement. This may mean these habitats and the wildlife that live there have nowhere to go.

Key Questions:

Discuss these questions with your group members:

1. Wildlife use coastal wetlands as shelter, nesting sites, and places to find food. Many coastal wetlands are brackish, meaning they are part salt water and part fresh water. This medium salinity supports specific plants that grow in these wetlands. How might sea level rise affect coastal wetland habitats and the wildlife that live there?
2. When sea levels rise, how might that change what happens during hurricanes? How will that affect barrier islands and coastal habitats?

Defenders of Wildlife. (2010). *Understanding the impacts of climate change on fish and wildlife in North Carolina*. Washington, DC. Retrieved from http://www.defenders.org/sites/default/files/publications/executive_summary_understanding_the_impacts_of_climate_change_on_fish

B: Transforming habitats

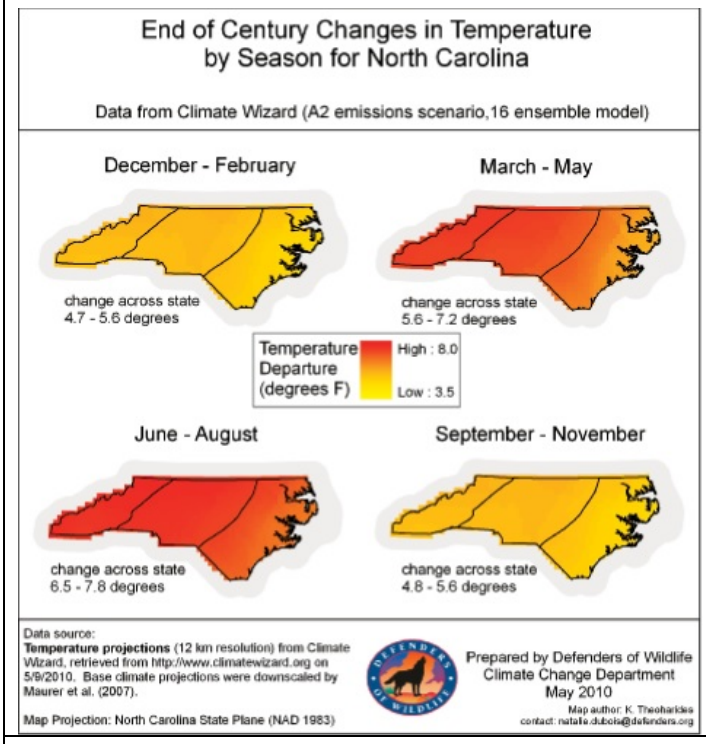
Regional climate includes the average rainfall and temperatures in an area. With climate change, precipitation patterns and temperature norms may change. Part of this means that wet areas may become wetter (more rainfall) and drier areas may become drier. Extreme weather may also increase, meaning more floods and droughts. Overall, we expect temperatures to rise, which will mean higher air and water temperatures.

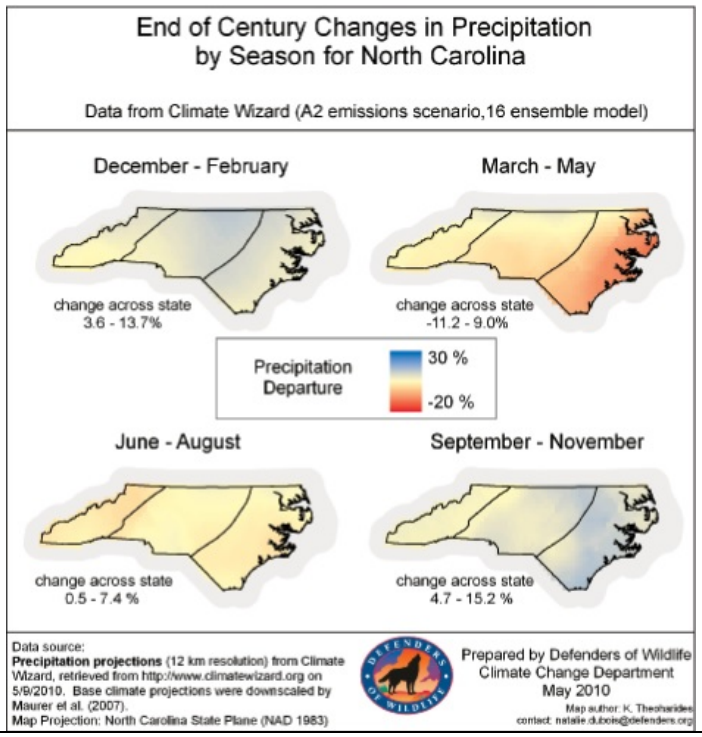
Spruce-fir forest on Clingmans Dome in North Carolina
Photo by Brian Stansberry
Appvoices.org

In the Appalachian mountains, these changing climate conditions can mean changes to some ecosystems. In the mountains, higher temperatures may mean warmer stream waters and higher levels of rainfall may cause flooding and erosion which can clog up streams. Warmer water holds less oxygen, which means our streams cannot support as much life. Streams with too much sediment can become clogged, fill in gravel bottoms with mud, and change the habitat available to fish and other aquatic life to lay eggs and find food. Higher temperatures may push certain vegetation species further north, such as the spruce-fir forests of North Carolina. Wildlife such as the Northern flying squirrel depend on these specific types of forests. As spruce-fir forests disappear from North Carolina, the wildlife that lives there may be able to follow them as they shift northward. However, barriers such as highways or urban areas may make it difficult for wildlife to follow these habitats as they shift northward.

In other areas of the country, such as the American West and Midwest, we expect higher temperatures and lower precipitation levels. These warmer, drier conditions could mean lower stream levels for Western salmon and trout, disappearance of Midwestern wetlands that waterfowl use for nesting sites.

Below, you'll find maps that project the changes in temperature and precipitation we expect over the next 100 years in North Carolina. As you can see, the changes in temperature and precipitation are broken down by season. Winter and fall are expected to be around 4-6 degrees warmer and summer is expected to be about 5.5-8 degrees warmer. Precipitation may rise across all seasons, but more so in the winter. In the spring, the coast may see less rainfall.





Key Questions:

Discuss these questions with your group members:

1. Think back to previous activities. How do you think changing precipitation and temperature patterns might affect vegetation? How might this affect wildlife?
2. What kinds of wildlife live in NC rivers? How might they be affected by floods or droughts? Warmer temperatures?

Defenders of Wildlife. (2010). *Understanding the impacts of climate change on fish and wildlife in North Carolina*. Washington, DC. Retrieved from http://www.defenders.org/sites/default/files/publications/executive_summary_understanding_the_impacts_of_climate_change_on_fish_and_wildlife_in_north_carolina.pdf

C: Changing seasonal cues

Because many plants and wildlife take cues from changes in the seasons, warming temperatures may mean shifts in when wildlife do things like lay eggs and hibernate. Problems arise when not all species change at the same rate, creating a mismatch of wildlife needs and resources available.

Snowshoe hares are masters of camouflage. Their coats are white in the winter to blend in with the snow, and in the summer, their coat darkens to match the forest vegetation. They get their cues for the coat change by the lengthening days of spring. Lately, however, spring has been coming earlier. Temperatures rise and melt the snow before the days lengthen enough to give the snowshoe hare its cue to change coats. As a result, the white winter coats stick out against the brown brush revealed by the melting snow. The loss of camouflage makes the hares much easier to spot by predators.

Snowshoe hares are brown in the summer to blend in with the surrounding vegetation and their white coats let them blend in with the snow in the winter. If snows melt before the hares change colors, the white hares are easy to spot.
Photo by L.S. Mills research team.
http://www.npr.org/

Warmer temperatures also trigger birds to migrate. Birds spend the winter gathering energy and time their migration north so they can reach their summer range and lay eggs when the most food is available for feeding chicks. Some birds have already begun to respond to earlier arrival of spring by migrating earlier. This is not the case for all birds, however. Those that are not shifting their migration patterns in sync with earlier spring arrivals seem to be reaching their Northern breeding grounds a little too late to time the hatching of their young with peak food availability. This seasonal mismatch has been documented in several bird species in Europe such as the pied flycatcher.

Key Questions:

Discuss these questions with your group members:

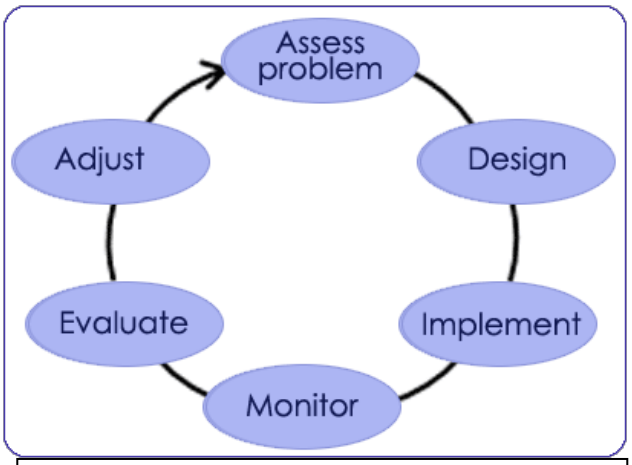
1. Wildlife depend on seasonal cues for lots of things. The changing of the seasons cues birds to migrate, some species to come out of hibernation, and many animals to begin breeding. What other species depend on seasonal cues for part of their life cycle?
2. How might these species be affected by changing seasonal cues?

Saino, Nicola, et al. "Climate warming, ecological mismatch at arrival and population decline in migratory birds." *Proceedings of the Royal Society B: Biological Sciences* 278.1707 (2011): 835-842.

Stenseth, N. C., & Mysterud, A. (2002). Climate, changing phenology, and other life history traits: nonlinearity and match-mismatch to the environment. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(21), 13379–81. doi:10.1073/pnas.212519399

D: Adaptive Management

The adaptive management process of assessing a problem, designing a plan, implementing a plan, monitoring impacts, evaluating results, and adjusting the plan forms a circular pattern in which the management plan is adaptable (see figure). This approach is important when in complex systems that are difficult to predict perfectly. The climate system is incredibly complex, making it hard to predict exactly what will happen or how wildlife will respond. Scientists are becoming more confident in their predictions, but we do not know exactly how climate change will affect wildlife. This uncertainty can make it hard for wildlife managers to plan for the future.



Adaptive management process
www.doi.gov

One important strategy for making sure we are able to protect wildlife in an uncertain future is a practice called adaptive management. Using adaptive management, managers test the plans they implement and change them when objectives are not being met. After implementing a plan, they collect data to see if it is working. One example is the Platt River Recovery Implementation Program in Wyoming, Colorado and Nebraska. The goal of the program is to increase populations of interior least terns, piping plovers, whooping cranes and pallid sturgeons. Managers have developed two strategies to restore river habitat. One involves altering the river pathways to restore historic flow patterns and one does not. Managers do not know which strategy will work best. By using adaptive management, managers can try each strategy in different areas, collect data on the four species, and adjust the plan to include more of the strategy that is working better. If the plan is not helping address objectives (here, increasing populations of the four target species), they change their plans and try again. Adaptive management requires gathering large amounts of data and spending lots of time deciding what to do. It can be expensive and time consuming, but it will likely be an important strategy to protecting wildlife as we start to see the impacts of climate change increase. Wildlife agencies are beginning to reach out to other partners like citizen science groups (see information in Expert group E) to help maintain up-to-date data on the health of our wildlife. These networks of both citizens and scientists can help spread out the big job of understanding how wildlife are responding to climate change.

Key Questions:

Discuss these questions with your group members:

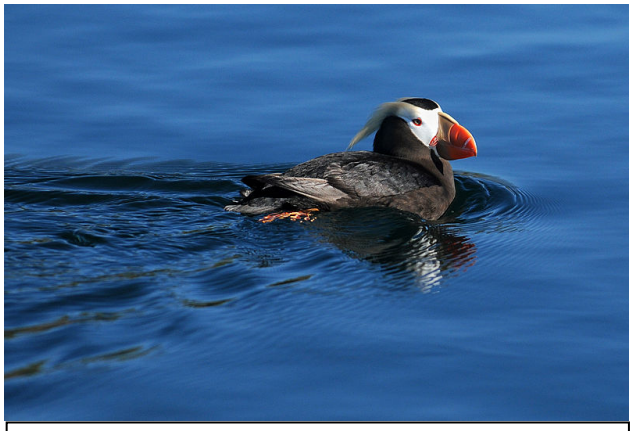
1. Why might adaptive management be better than making a single decision?
2. Why might adaptive management be more challenging than making a single decision?
3. How might managers use adaptive management to help protect species from climate change impacts?

Defenders of Wildlife. (2010). *Understanding the impacts of climate change on fish and wildlife in North Carolina*. Washington, DC. Retrieved from http://www.defenders.org/sites/default/files/publications/executive_summary_understanding_the_impacts_of_climate_change_on_fish_and_wildlife_in_north_carolina.pdf

Runge, M. C. (2011). An Introduction to Adaptive Management for Threatened and Endangered Species. *Journal of Fish and Wildlife Management*, *2*(2), 220–233. doi:10.3996/082011-JFWM-045

E: Collaboration and Education

Conserving wildlife in the face of climate change is a big job, and wildlife managers cannot do it on their own. Conserving wildlife will be easier if managers reach out to partners like researchers and conservation organizations and work to ensure local, state, and federal agencies work together. Researchers can help provide managers with the data they need to make decisions. Conservation organizations like land trusts and wildlife non-profit organizations also work to conserve habitat and wildlife and can likely help with monitoring efforts. Making sure local, state, and federal agencies work together will help managers "divide and conquer." For instance, biologists across the Northeast are working together to track shorebird habitat. Because shorebirds like the Tufted Puffin have ranges that are bigger than individual agencies or refuges, biologists can get a more complete picture of how shorebirds are responding to climate change and make the best conservation plans possible.



Warmer temperatures can negatively affect nesting sites for Tufted puffins. By working together, managers across the Northeast can keep an eye on the puffin and use insights for conservation planning.
http://www.eopugetsound.org/

Another key partner for wildlife managers are citizens. In recent decades, **citizen science** projects have become more common, in which ordinary citizens collect data that scientists use. These projects allow scientists to collect much more data than they would be able to on their own as well as involve citizens in ongoing research. For example, the Christmas bird count run by the Audubon Society from mid-December through early January provides a huge dataset on migratory bird patterns, from which scientists can better understand which birds are moving where and when. Tens of thousands of participants log in to the Audubon Society website from mid-December to early January to report names and locations of the migratory birds spotted in their area. This project provides ornithologists valuable data on where migratory birds are traveling and when. Projects like these not only help collect data but they also engage the public in conservation efforts. Engagement is an important step to ensure everyone is working together towards climate change solutions and making wildlife more resilient. Resiliency refers to the ability for wildlife to thrive in spite of climate change-related impacts. There are lots of ways we can all help wildlife, and through education and outreach, wildlife managers can help us understand how.

Key Questions:

Discuss these questions with your group members:

1. Why would wildlife managers want to partner with researchers and neighboring agencies to monitor how climate change may be affecting wildlife? What kinds of research do you think would be most helpful in your area?
2. What are some ways that you could help learn about climate change impacts on wildlife?

Defenders of Wildlife. (2010). *Understanding the impacts of climate change on fish and wildlife in North Carolina*. Washington, DC. Retrieved from http://www.defenders.org/sites/default/files/publications/executive_summary_understanding_the_impacts_of_climate_change_on_fish_and_wildlife_in_north_carolina.pdf

F: Habitat conservation and restoration

Climate change is not the only thing threatening wildlife. Urbanization, deforestation, invasive species, pollution, and disease are also posing a risk to wildlife and their habitats. Protecting wildlife from these other threats will help make them more resilient to risks from climate change. Resiliency refers to the ability for wildlife to thrive in spite of climate change-related impacts. For instance, healthy wetlands support a variety of wildlife, but they also help cool water, reduce sediment from run-off, and control flooding. Restoring one hectare of wetland can translate to as much as $33,000 in savings preventing storm damage. When Hurricane Katrina hit the Gulf Coast in 2005, areas with the most robust wetlands experienced less flooding, and unprotected areas like New Orleans were decimated by unprecedented floods. Although it is difficult to point to climate change as the cause of any one storm event, scientists expect to see an increase in the frequency and severity of storms in association with global warming. Protecting and restoring wetland habitats can protect the wildlife that lives there and make those areas more resilient to climate change impacts.

Volunteers working to restore wetland habitats
www.carolinasalt.com

Another key strategy is preserving wildlife corridors, or areas that connect different areas of wildlife habitat. As temperatures rise, we expect for wildlife habitats and populations to shift towards the poles and to higher elevations. If wildlife try to move from current ranges and find barriers created by urban areas, highways, or dams, they may not be able to shift their ranges in response to warming temperatures. By protecting wildlife corridors, these shifts are more possible.

Besides protecting wildlife and habitats, efforts to improve and restore existing habitats can also help wildlife. Continuing with the example from the gulf coast, several restorations efforts are well underway to restore wetland and mangrove ecosystems that will reduce the type of damage caused by Hurricane Katrina. One of the most famous examples is on Avery Island, where the Tabasco Sauce plant is located. After Katrina, Tabasco orchestrated a massive restoration of the entire island, which now supports a host of wetland wildlife and is the site of a park for visitors to enjoy. Not only is the park serving an important ecological and cultural role now, but this restoration may help protect the factory from future flooding events.

Key Questions:

Discuss these questions with your group members:

1. Why are conservation and restoration efforts especially important in the face of climate change?
2. What kinds of habitat restoration projects would benefit your state as climate changes?

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., & Mulder, K. (2008). The value of coastal wetlands for hurricane protection. *AMBIO: A Journal of the Human Environment*, *37*(4), 241-248.

Adapting to Climate Change
Student Sheet

Name: _____

Species your group is working with: _____

1. What are three major climate change impacts that will likely affect wildlife?

2. Which of these impacts will most likely affect your species? Give at least three specific ways climate change may impact your species.

3. What are three major strategies to help wildlife adapt to climate change impacts?

4. Which strategies do you think will be most important to your species?

At the end of class, your group will assume the role of wildlife managers. Be prepared to present to the rest of the group the specific threats your species might experience and why. Then, propose a plan of action to protect this species.

Climate Impacts and Adaptation strategies Teachers notes

Possible answers to Key Questions on the back of the expert cards:

Transforming Habitats:

1. Shifting temperature and precipitation norms can change the types of vegetation that are in an area. Even though NC is expected to have more precipitation overall, it is projected to fall in concentrated times (floods, followed by drier periods). Warmer temperatures paired with dry spells can mean some plant species cannot survive. This becomes a problem for wildlife if they depend on those species for food or cover.
2. Examples of species: hellbender, trout, Northern alligator. Flooding or drought can affect aquatic species (flooding can wash away eggs and food, drought can leave waters too low to support life), Warmer temperatures can affect oxygen levels in water, affecting the wildlife that lives there (e.g., trout, hellbender). Warming water temperatures can also be good for some species, like the American alligators. They may be able to grow larger and expand their range as water warms.

Sea Level Rise:

1. Changing salinity may affect the types of vegetation that can survive in the brackish water. If salinity changes enough, it may be detrimental to many wetland plant species, which could affect food, cover, and nesting sites for a host of marsh wildlife (marsh rabbits, diamondback terrapin, snowy egret).
2. Higher sea levels might mean that storm surges are stronger, exacerbating the erosion of beaches and the flooding of coastal wetlands. This may greatly affect the barrier islands (they may disappear), and then drastically change coastal wetland habitats. In theory, coastal wetland habitats could just move inland as sea levels rise. However, sea level rise may happen faster than these habitats can develop or urban or agricultural development may prevent coastal wetlands from moving any further inland.

Changing seasonal cues

1. Any migrating bird depends on seasonal cues to begin migration. Other animals featured in this module that depend on seasonal cues: Marbled salamander, Northern bobwhite quail, and Eastern wild turkey. Cooler fall temperatures and increased rains cue marbled salamanders to head to the vernal pools to lay their eggs. Lengthening spring days cue both quails and turkeys to start mating, nesting, and laying eggs.
2. Some birds seem to be adapting well to earlier springs, but others are not changing their patterns. Mismatches between when birds migrate and when food is available may affect survival or reproduction.

Adaptive Management

1. Adaptive management involves monitoring and part of the plan is looking for and responding to change. Single decisions make a recommendation without considering how things may change. Because climate change involves impacts that are complex and hard to predict, an adaptive approach may be more effective at responding to impacts on wildlife as they happen.
2. Adaptive management may be more challenging because it requires constant data collection and re-evaluation. It's requires more time and resources.
3. Especially when we don't know how species will respond to climate change, we can use adaptive management to make a plan for what we know and what we predict will happen. With monitoring, we can see if our plan seems to be working and readjust if we think we can make it better or if conditions change.

Collaboration and Education

1. Collaboration can help wildlife managers get the help they need. By working together, we can collect more data over a greater area. Because adaptive management require lots of data and a big picture perspective, collaboration is key to making sure managers have the information they need to make the best decisions possible.
2. Participating in citizen science projects, but also doing things like working to protect the habitats that do exist (touched on in the habitat conservation and restoration section).

Habitat conservation and restoration

1. Climate change will bring a host of impacts that we will have a hard time controlling. But, by investing in things we can control like habitat conservation and restoration, we increase the resiliency of wildlife that are at-risk.
2. In North Carolina, wetland conservation and restoration will be important to protect both wildlife and people against sea level rise and storm surges. Doing what we can to protect temperature sensitive communities like the spruce-fir forests and other key vegetation communities will also help make other ecosystems and wildlife resilient to climate change impacts. Additionally, preserving wildlife corridors will help ensure that wildlife are able to move freely as ranges begin to shift due to rising temperatures.

Student Sheet answers:

1. Three major risks:
    a. Changing habitats
    b. Sea level rise
    c. Changing season cues

2. Below are wildlife species that lend themselves well to this activity:

Wildlife Species	Potential impacts
Diamondback terrapin	The biggest threat is sea level rise, which could completely flood terrapin habitat. Especially as the terrapin are pinned between the ocean and substantial coastal development, they may have nowhere to go if sea levels rise. Sea level rise paired with more severe hurricanes may bring bigger storm surges, which besides destroying habitat, could wash terrapins from where they burrow in the mudflats or wash away food sources. They may also be affected by rising temperatures because the sex ratios in their egg clutches are determined by temperature.
Eastern hellbender	The biggest threat to the hellbender is the changing forest habitats of the mountains, including higher temperatures and increased rainfall in the form of flooding events. Higher air temperatures can increase water temperatures, which can decrease the amount of oxygen available for these giant salamanders. Paired with loss of shade from the dying hemlock trees, warming water is a real concern. Flooding events can also wash away hellbender eggs, making it more difficult for them to successfully reproduce.
American alligator	Climate change may benefit alligator populations in several ways. Alligators are ectothermic (cold-blooded), and warmer temperatures allow their metabolisms to work faster. Warmer air and water temperatures may allow alligators to convert their food to body mass more quickly, allowing them to grow more quickly. Also, alligators cannot survive if water gets too cold. As water temperatures increase,

	alligators may be able to move further inland and northward.
Northern flying squirrel	Rising temperatures and more frequent drought events threaten the spruce-fir forests in North Carolina. These types of forests exist farther northward, but if they disappear from North Carolina, so will the Northern flying squirrel which depends on them for food and raising their young. If this does happen, the squirrels will only be able to find suitable habitat farther north, if barriers like roads do not prevent them from moving.

3. Three major strategies for protection from impacts:
    a. Conservation and restoration of habitat
    b. Adaptive Management
    c. Collaboration

4. For this question, answers may vary greatly, and students may come up with creative answers. Any and all of these strategies could apply to the example species above. Coastal wetland restoration may be particularly important for the terrapin, hemlock restoration may help out the hellbender, monitoring of alligators can build understanding of where they may be expanding, and protection of the spruce-fir system will conserve Northern flying squirrel habitat in North Carolina. Other more creative strategies may be necessary. For instance, wildlife managers have attempted to help flying squirrels be able to move across highways by erecting tall poles that the squirrels can use as launching platforms for long glides needed to cross roadways.